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Biofuels: Growing Energy

UCLA February 2008

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Drivers Of Our Transportation Fuel Future…

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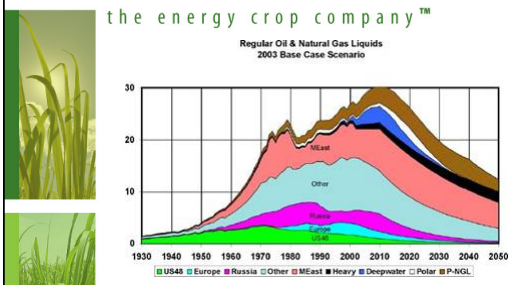

Fuel Supply

Fuel Demand

Fuels Emissions

Fuel Security

Are Biofuels The Answer?

Demand Trends
- Consumption outpacing discovery
- China & India

Supply Trends
- Nationalization of reserves
- High oil prices
- Peak production (?)

Energy Security
- Little domestic supply
- Unrest in producing regions

Environmental
- Carbon emissions
- Drilling/mining

Pressure to create a significant, renewable, domestic source of liquid fuels

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Survey Questions

1. Should we encourage the use of biofuels?
   a) Yes
   b) No

2. Do we have enough land for biofuels?
   a) Yes
   b) No

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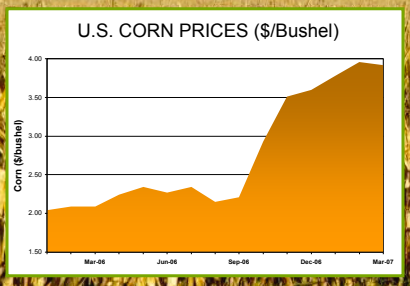
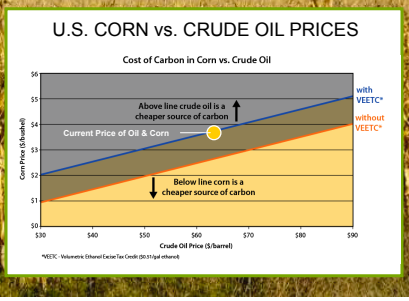
First Generation Biofuels
U.S. Ethanol Production – A Midwest Gold Rush?

CURRENT INSTALLED CAPACITY
113 facilities: 5.6 BGY

CAPACITY UNDER CONSTRUCTION
77 new plants; 7 expansions: 6.2 BGY





Source: Renewable Fuels Association

Survey Questions

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1. Is corn the United States' best choice for a biofuels feedstock?
   a) Yes
   b) No

2. Should we rely on Brazil or other countries for biofuel supplies?
   a) Yes
   b) No

Corn Is Not The Answer…

JANUARY 2006

"America is ***addicted to oil***, which is often imported from unstable parts of the world"…

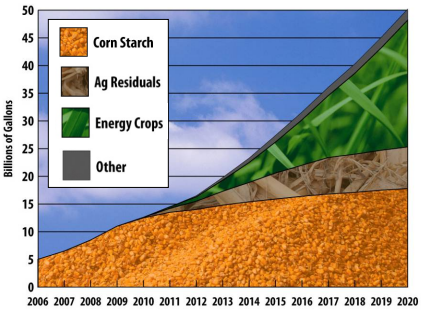
…"We will also fund additional research in cutting-edge ***methods of producing ethanol, not just from corn but from wood chips, stalks or switchgrass***"

…"Our goal is to make this new kind of ethanol practical and ***competitive within six years***"

JANUARY 2007

…"We must increase the supply of alternative fuels, by setting a mandatory fuels standard to require **35 billion gallons** of renewable and alternative fuels in 2017 -- and that is nearly five times the current target"

BIOFUELS



- 2006: 5 billion gal/yr of ethanol (U.S only)
- 23 billion gal/yr of biofuels from energy crops will require 11MM acres in 2020*
- Biotechnology enables scale, marginal land use, reduced inputs and lower cost processing

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It's the Cellulose, Stupid

"With plausible technology developments, biofuels could supply some *30% of global demand* in an environmentally responsible manner without affecting food production. To realize that goal, so-called advanced biofuels must be developed from *dedicated energy crops*, separately and distinctly from food."

Steven E. Koonin
Chief Scientist, British Petroleum

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Basic Carbohydrate Biochemistry

Sucrose (sugarcane)

Starch (corn grain)

Cellulose (cell walls)

Hemicellulose (cell walls)

amylase / glucoamylase

Cellulases | **Hemicellulases**

Hydrolysis / C_6 fermentation / distillation

C_6 fermentation/ distillation

C_5/C_6 fermentation/ distillation

Biofuels

Biofuels

Biofuels

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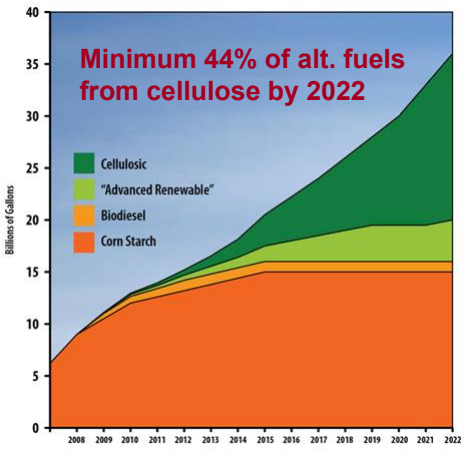
2007 ENERGY ACT: 36 Billion Gallons/Year

Alternative Fuel Mandates

Energy Independence and Security Act of 2007



Steel in the Ground

- **$385MM in direct DOE funding for cellulosic biorefineries**
- **$4B in loan guarantees**
- **More being developed with state assistance**

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Survey Questions

1. Should the government mandate the use of biofuels?
   a) Yes
   b) No

2. Should the government mandate which fuels? i.e. which feedstock, refining technology, end molecule
   a) Yes
   b) No

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How Much Fossil Fuel Energy is Required to Produce Ethanol?

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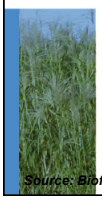

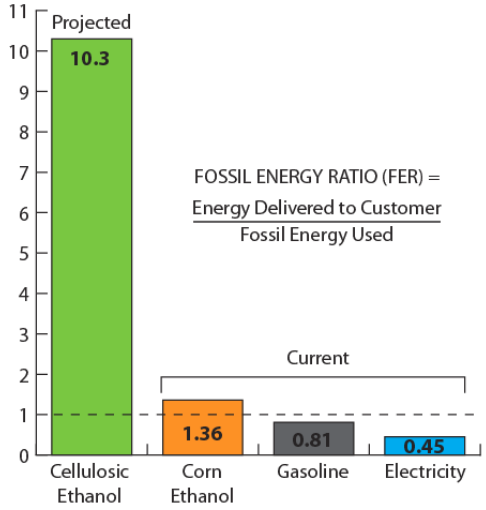

Source: Biofuels Joint Roadmap, June 2006, DOE; data derived from Brinkman et al. 2005

A Few Ethanol Myths…

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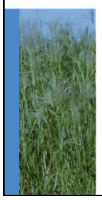

- 70% of energy = 70% of miles per gallon
- Flex-fuel vehicles – can run on 0-85% EtOH
  - $30 manufacturing cost
  - $250 conversion
  - 0-75% of Brazilian car market in 3 years
- We get ethanol in just about every gallon of gas in the US today. It can be moved.
  - Rail and dedicated pipes
- We might not make ethanol, e.g. butanol, mixed alkanes…

Cellulosic Ethanol Today

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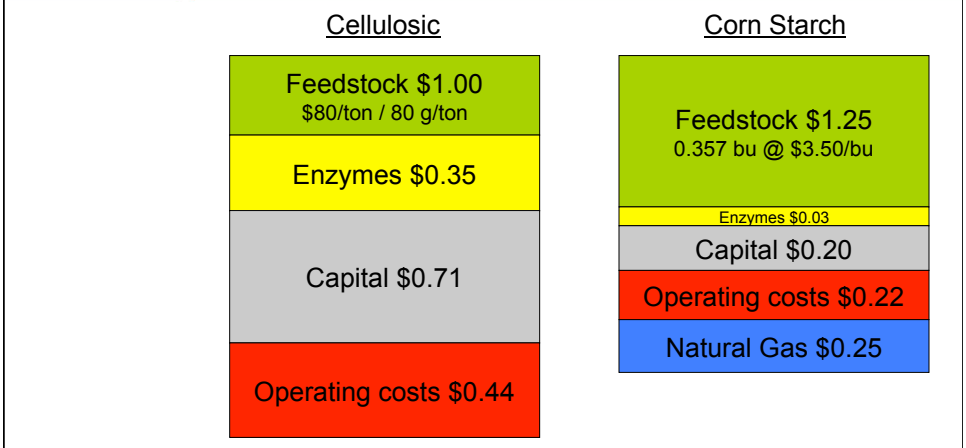

$/gallon (gross)	**$2.50**	**$1.95**
energy/feed credit	**(- $0.10) lignin**	**(- $0.26) DDG**
Net $/gallon	***$2.40***	***$1.69***

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What Will Drive Cellulosic Biofuels To Economic Viability?

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- Technology/capital cost curves
  - As seen for starch refining, sucrose refining, nuclear power, cell phones, flat screen TV, etc…
- Government policies – "tilting the playing field"
  - Feedstock – Ag policies
  - Biorefineries – Grants, loans, tax treatments
  - Refining technologies – R&D investments
  - Markets - Mandates: RFS, blending credits, CO2

Survey Questions

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1. Should the government subsidize farmers in the United States?
   a) Yes
   b) No
2. Should the government subsidize the biofuels industry in the United States?
   a) Yes
   b) No

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A Few Words on…

Agriculture

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A Brief History of Life…

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Event	Years Ago
Formation of Earth	4,600,000,000
Unicellular life	3,500,000,000
Photosynthesis	3,000,000,000
Multicellular life	1,000,000,000
Cambrian explosion	600,000,000
Land plants	400,000,000
Flowering plants	150,000,000
K/T extinction	65,000,000
Hominids	7,000,000
End of last Ice Age	18,000
Agriculture	10,000
Green Revolution	40

Agriculture is not "natural", it is a distinctly human activity

Why Have Agriculture?

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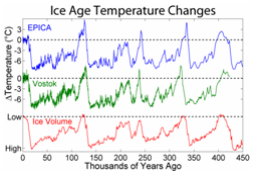
- Climate Change?
  - End of last Ice Age creates agronomic opportunity?



- Population Pressure?
  - Extinction of megafauna due to climate change or human predation?


Mastodon


Giant Sloth


N. American Camel


Giant Beaver

- Cultural Progress?
  - Optimized foraging and co-evolution of species leading to domestication?

Should We Have Agriculture?

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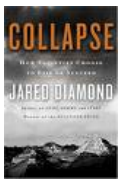
The Worst Mistake In The History of the Human Race
"a catastrophe from which we have never recovered"
-Jared Diamond



or

Agriculture—The Basis of Civilization
"The single, decisive factor that made it possible for mankind to settle in permanent communities was agriculture"
-Encyclopedia Britannica






Survey Questions

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1. Is it ethical to convert land to agriculture?
   a) Yes
   b) No

2. Should private land owners be able to convert their land to agri/silva culture?
   a) Yes
   b) No

Plants Did Not Evolve To Serve Man

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Figure 2. Modern corn hybrid (right), its wild relative teosinte (left), and their hybrid (cob in the center). (Photo kindly provided by John Doebley.)

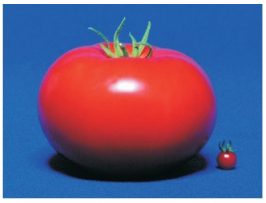

Figure 1. Cultivated tomato (left) and its wild relative *Lycopersicon pimpinellifolium* (right; approximate diameter of smaller tomato = 1 cm). (Photo kindly provided by Steve Tanksley.)

Genetic manipulation or "breeding" has been instrumental

Plant Physiology, May 2001, Vol. 126, pp. 8–15, www.plantphysiol.org © 2001 American Society of Plant Physiologists

Most Crops Are "Non-indigenous Species"

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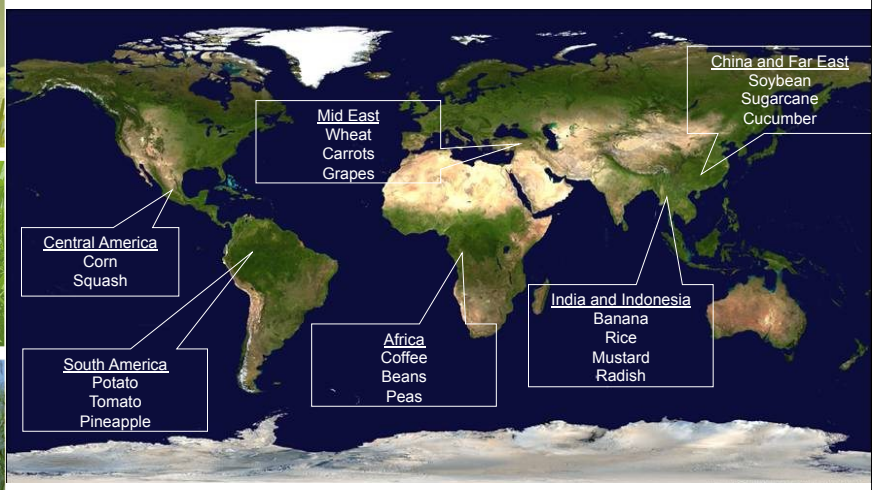

Is this "natural" or is it "bio-pollution"?

What Limits Crop Yields?

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- Germplasm
  (genetics)
- Biotic stress
  - Weeds
  - Insects
  - Fungi
- Abiotic stress
  - Drought
  - Nitrogen
  - Temperature

Technology Is Game Changing…

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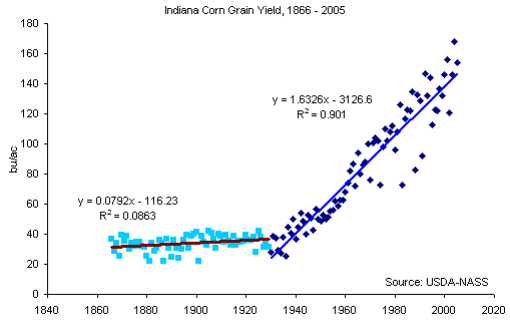

Adoption of hybrid genetics has tripled US corn yield since 1940!!

A Few Words About Biotechnology…

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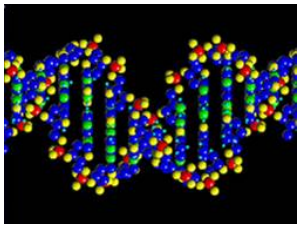

- Plants first transformed in 1983
- Commercial R&D mid ’80s – mid ’90s
- First commercial products introduced in 1994-1995
- Flavr-Savr tomato
- Insect-resistant cotton

Despite Controversy….

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Adoption of Ag-biotech Has Been Very Rapid

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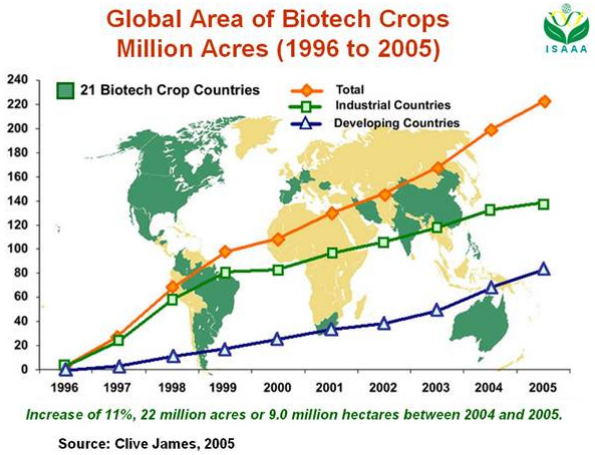

Over 1,000,000,000 hectares have been planted with biotech crops

Biotechnology Is Contributing To Sustainability Today…

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- Reduced insecticide use
- Reduced fungal infection
- Lower aflatoxins

- Increased “con-till”
- Reduced soil erosion

And Will Contribute Tomorrow…

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Drought tolerance

Heat tolerance

Improved nitrogen use

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1. Should society endorse the use of biotechnology in crop plants?
   a) Yes
   b) No

2. Do ENGOs (e.g. Greenpeace) have ulterior motives in opposing food biotechnology?
   a) Yes
   b) No

Agriculture Is Not Perfect…

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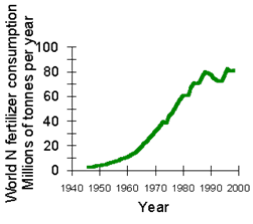
- Loss of biodiversity
- Energy inputs
- Nitrogen run off



But It Can Feed Many People…

- One bushel of corn produces 92,797 calories
- One human requires 1,800 calories per day
- IF *only* the world's corn farmers (146M hectares) achieved the US *average* yield (358 bu/ha) = we could feed 7.46B on corn alone
- IF all the world's corn farmers duplicated the top 10% of US corn yields (>700 bu/ha) = we could feed over 14B people

Incentives, innovation and technology can make it more sustainable

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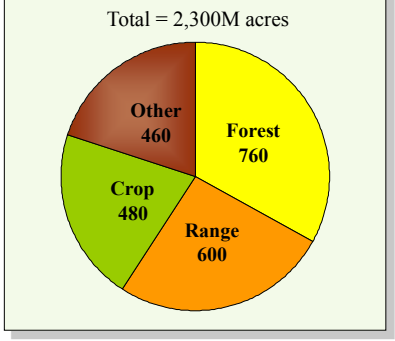
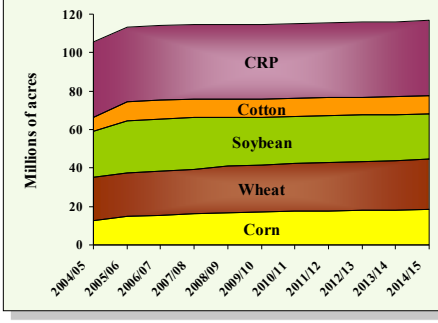
Not Enough Land For Fuels?…

Total U.S. Acreage



U.S. Cropland Unused or Used for Export Crops



At 300bu/acre by 2030, US domestic corn requirements = 30M acres

60M acres X 20t/ac X 100g/t = 120B gallons or 90% of US gasoline demand!

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Survey Questions

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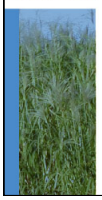

1. Should we embrace 19th century or 21st century farming methods?
   a) Yes
   b) No

2. Do we have enough land to grow biofuels?
   a) Yes
   b) No

Some see the need for change…

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"The greatest service a citizen can do for his country is to add a new crop for his countrymen."

- Thomas Jefferson

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While others fear change…

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- Copernican view of the universe (poor Galileo)
- Automated looms (Luddites)
- Horseless carriages (automobiles)
- Franglais (cultural change)
- Radar range (1st microwave ovens)
- Cell phones and electromagnetic fields (cancer)
- Agricultural biotechnology (GMO)

All change creates controversy, large scale adoption of biomass/biofuels will be no exception

There Are Many Questions…

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- Is there enough land?
- Which land?
- What is an energy crop?
- Which energy crops are best?
- What is the net fuel benefit?
- What scale is achievable?
- What will the by-products be?
- What will the net emissions be?
- What will sustainable mean?

And Many Choices…

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Today

- Land use choices: cultivate or not cultivate
- Cropping choices: corn or cotton
- Germplasm choices: hybrids and biotech
- Technology choices: US yields vs. ROW
- Food choices: animal protein vs. plant protein

Tomorrow

- Many of the same choices

Choose Wisely…

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Survey Questions

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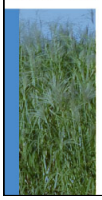

1. Will market forces alone result in wise choices?
   a) Yes
   b) No

2. Who will make "wise" choices?
   a) Government
   b) Individuals
   c) ENGOs
   d) Industry
   e) Bill Gates

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So you want to start a biotechnology company…..

Why start a biotechnology company?

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- Technological innovation can create competitive advantage (when properly protected).
- What can we do better, smarter, faster, cheaper?
- In the early days of biotechnology, the potential was thought to be in drug development
  - That protein-drugs would have
    - lower toxicity
    - superior bioavailability
    - high efficacy
- Technology Push or Market Pull?
- High value, low volume applications

A brief history of biotechnology

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- Recombinant DNA methodologies first invented in late 70's and continually refined
- Courts rule that DNA is patentable
- Scalable
- Flexible
- Enabling
- What should we make?

What is a biotechnology company?

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- Generally refers to any company using recombinant DNA technology

AND

- Any small, start-up company pursuing drug discovery

Survey Questions

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1. Which is most important for starting a biotech company?
   a) Management
   b) Technology
   c) Investment capital
   d) Market demand
   e) Good looks




Management

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- "Always invest in A people with B ideas"
- Entrepreneurial culture
  - What drives this?
  - What prevents it?





What is an entrepreneur?

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- Risk takers
- Pursue opportunity without regard to the resources they currently control
- Have a vision of success
- View change as an opportunity
- View themselves as agents of change
- Can thrive in the right environment

Survey Questions

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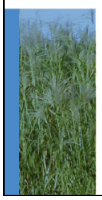
1. Can the government stimulate entrepreneurialism?
   a) Yes
   b) No

2. The best way to do so would be through
   a) Tax policy
   b) Education
   c) University research support
   d) Intellectual property protection
   e) Cloning Bill Gates



Technology

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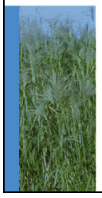
- Sources of technology
  - Universities - Bayh-Dole Act
    - Private versus public ownership
  - Existing companies

- Valuing technology
  - Ask Angelo…



- Protecting technology
  - Are we a knowledge economy?

Challenges to Technology Commercialization

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- Recognition of potential
- Technology push vs market pull
- Regulatory hurdles
- Access to capital
- Product development timelines

Technological innovation is not always obvious!

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"This 'telephone' has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us."

Western Union internal memo, 1876.

Other examples include:

- Steam engines
- Computers
- Internet
- Recombinant DNA

What is Technology Push?

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- An innovator sees an opportunity to profit from a technology that has little or no current market. An "entirely new" market is created, based on the novel capacities of the technology.
- Users do not know they need a product until it is there.

Examples of Technology Push

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- Xerox machines
- Polaroid cameras
- Transistors
- Fax machines
- Integrated electronic circuits
- Email?
- I-pod?
- Others?
- Beware Betamax (think BluRay)

What is Market Pull?

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- Occurs when existing firms seek better technologies to reduce their costs of production or to make marginal improvements in the quality of their existing products.
- The market "pulls" technology into it. A need exists, and there is currently no technology to meet the need.

Examples of Market Pull

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- VHS format
- GUI interfaces
- CD ROM
- Google?
- Apple's music store?
- Biotechnology?
- Biofuels?

Technology push can be revolutionary, market pull is often evolutionary

Survey Questions

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1. Should taxpayer funded research be exclusively licensed to private companies?
   - Yes
   - No

2. The best way for the U.S. government to stimulate high tech company formation is to:
   a) Cut corporate taxes
   b) Fund University R&D
   c) Strengthen intellectual property laws
   d) Clone Bill Gates

Refining Technology Opportunities

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- Reduce enzyme cost
- Improve enzyme specific activity
- Use all the sugar (C5 and C6)
- Improve tolerance of fermentation organisms
- Consolidate digestion and fermentation
- Improve continuous off-take systems
- Improve end molecule

GENENCOR® A Danisco Division

novozymes®

VERENIUM THE NATURE OF ENERGY™

MASCOMA

LS9, INC. the renewable petroleum company™

DUPONT The miracles of science™

Chevron

bp

Survey Questions

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1. Will cellulosic refining technology be cost effective in the next decade?
   a) Yes
   b) No

2. The biofuels industry will be dominated by the existing players or start-ups (Think IBM vs. Apple)
   a) Yes
   b) No

Money

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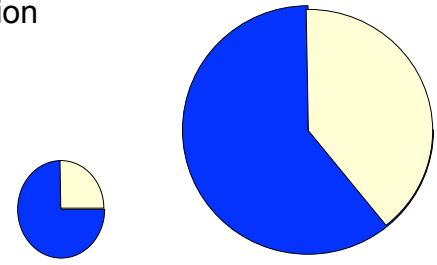
- How do entrepreneurs fund their companies?
  - Venture capital sources
    - How does it work?
  - The three F's
- What is equity?
  - Private versus public markets
  - Market capitalization
  - Dilution
  - Growing the pie…



Survey Questions

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1. How should venture capitalists determine a value for a company?
   a) Net present value of future cash flows (NPV)
   b) Comparison to other companies
   c) Return on equity calculation (ROE)
   d) Internal rate of return (IRR)
   e) Ask Bill Gates

Markets

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- Find a niche and fill it
  - High value, low volume products
    - Ceredase
  - Low value, high volume products
    - Proteases
  - Look for market pull
- Competitive landscape
- Government

Biofuel Market Issues

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- OPEC
- CAFE standards
- Chindia
- Carbon tax/credit systems (see government)
- "Ethical consumerism"
- Government mandates
- Disruptive technologies – electric cars, artificial photosynthesis…

Creating And Capturing Value

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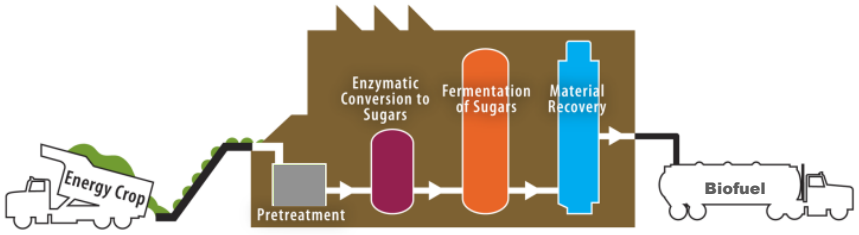
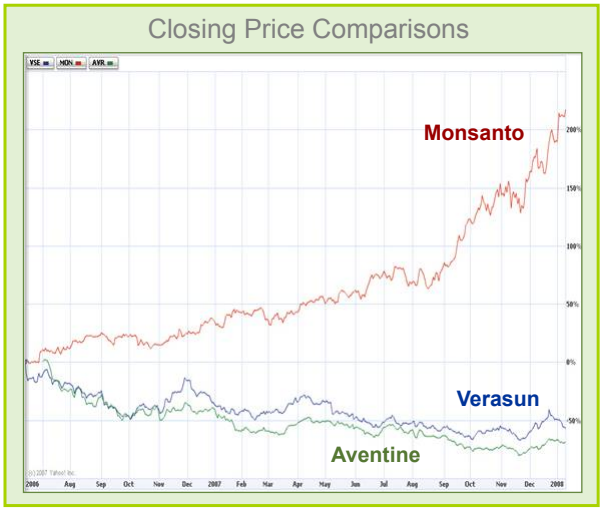
- Software
- Entertainment
  - Who pays? How much? To whom?
  - How is the value chain enforced?
  - Who gets squeezed?
- The corn ethanol value chain
  - Germplasm
  - Farmers
  - Aggregators
  - Refiners
  - Distributers

Cellulosic Biofuels Production Chain



	Challenges	Opportunities
Feedstock	Cost, Recalcitrance	Biomass yield and composition
Pretreatment	Capital costs	Scale, Engineering, Biomass composition
Enzymes	Cost, Activity	Genetic engineering
Fermentation	Efficiency, End product	C5/C6 fermentors, Butanol, biomass composition
Fuel Delivery	End product, infrastructure	Butanol, dedicated pipelines, market pull

Value Chain: STEEL or SEED in the Ground?



Seed providers create and capture value

Intangibles

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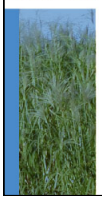
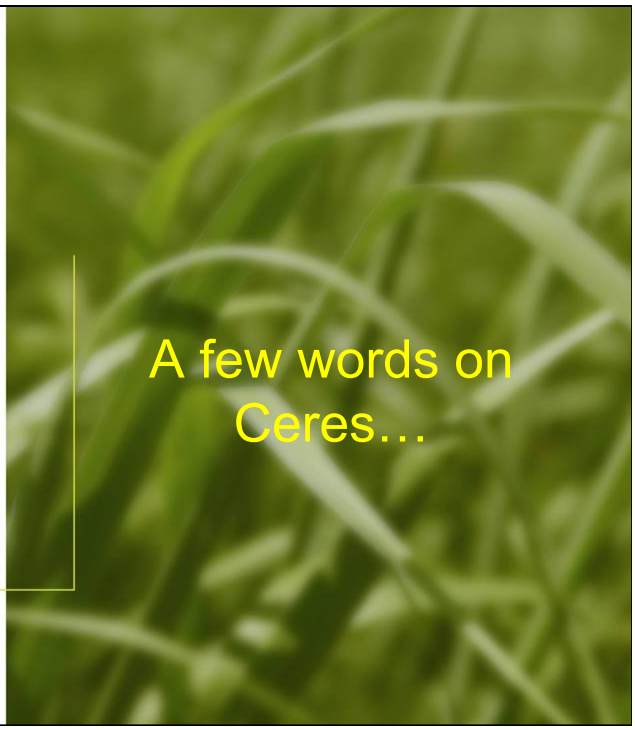


- Slope of technology cost curve
- Agriculture: food vs. fuel vs. environment
- Biotechnology: public acceptence
- NIMBY/BANANA
- Government policies
- Markets: supply, demand, OPEC, etc
- Black Swans: unanticipated events…

Hint: Bet on management teams, not just technology…

ceres

growing tomorrow's fuel today



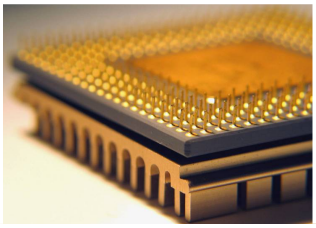
A Third Technological Revolution

"Changes that will have effects comparable to those of the Industrial Revolution and the computer-based revolution are now beginning. The next great era, a genomics revolution, is in an early phase.

Thus far, the pharmacological potentials of genomics have been emphasized, ***but the greatest ultimate global impact of genomics will result from the manipulation of the DNA of plants****.*

Ultimately, the world will obtain most of its food, fuel, fiber, chemical feedstocks, and some of its pharmaceuticals from genetically altered vegetation and trees."

Philip H. Abelson, Editor
Science, March 1998


Who is Ceres?

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- World's leading plant genomics company
  - More plant genes-traits identified than any other entity
- Monsanto's largest external gene technology supplier
  - Technology and IP validated by $137M collaboration
- Developer of dedicated energy crops leveraging technology platforms
  - Genes/traits for drought, biomass, nitrogen, composition, processing etc. already identified
- Exclusive R&D and commercialization partner of the Noble Foundation, and the Institute for Grassland and Environment Research (IGER) - world's foremost forage grass research institutes.
  - Seed multiplication of improved commercial energy crops underway

Feedstock Technology Opportunities

Remember: Feedstock = > 50% of cost

Parts of the Equation	Relevant Traits	Impact
Acres	• Stress tolerance (e.g. drought, heat, cold, salt)	• Growth on marginal acreage helps enable critical mass
Tons per acre	• Increased yield (e.g. photosynthetic efficiency)	• Lower production and transport costs and increased carbon sequestration
Dollars per acre	• Nutrient requirements (e.g. nitrogen utilization)	• Lower fertilizer costs and less N_2O emissions
Gallons per ton	• Composition & structure (e.g. C_5/C_6, cell wall structure)	• Increase theoretical yield of ethanol per ton of biomass
Capital cost of refinery & variable cost per gallon	• Composition, structure & enzyme production (e.g. cellulases)	• Eliminate need for acid hydrolysis, reduce need for enzymes and bring actual yield closer to theoretical
Co-products	• Metabolic engineering & sequestration	• Enhance overall economics

Ceres' High-Throughput Pipeline

70,000 Plant Genes, 10,000 Promoters and Hundreds of Candidate Trait Genes Identified

DNA Sequencing

Various Plant Species

Sequence & characterize

>70,000 genes

>10,000 promoters

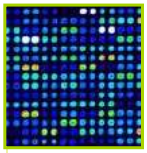
Markers for breeding

Transform into Model Plant

Arabidopsis

Transform gene-promoter combinations into model plant

Screen for Traits



Determine valuable gene-trait combinations via high-throughput screens

Phenotype linkages for breeding

Field Evaluation in Model Plant

Rice

Transform commercial constructs into monocot plant

Food Crops

Corn, Soybean, etc.

Energy Crops

Switchgrass, Miscanthus, etc.

Robust Product Development Pipeline

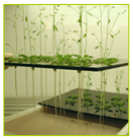

Drought tolerance


Increased yield


Heat tolerance


Drought recovery


Nutrient utilization


Root growth


Cold germination


Increased biomass


Shade tolerance


Flowering time


Stature control


Salt tolerance

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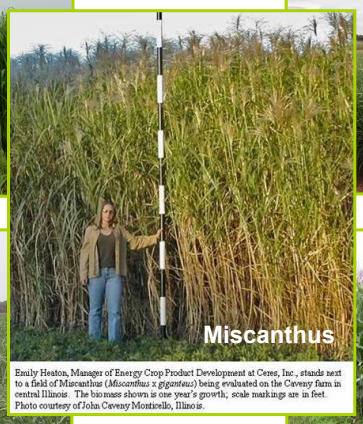
Ceres Energy Crops


Sorghum


Switchgrass


Miscanthus

Emily Heaton, Manager of Energy Crop Product Development at Ceres, Inc., stands next to a field of Miscanthus (*Miscanthus x giganteus*) being evaluated on the Caveny farm in central Illinois. The biomass shown is one year's growth; scale markings are in feet. Photo courtesy of John Caveny Monticello, Illinois.


Switchgrass


Energycane

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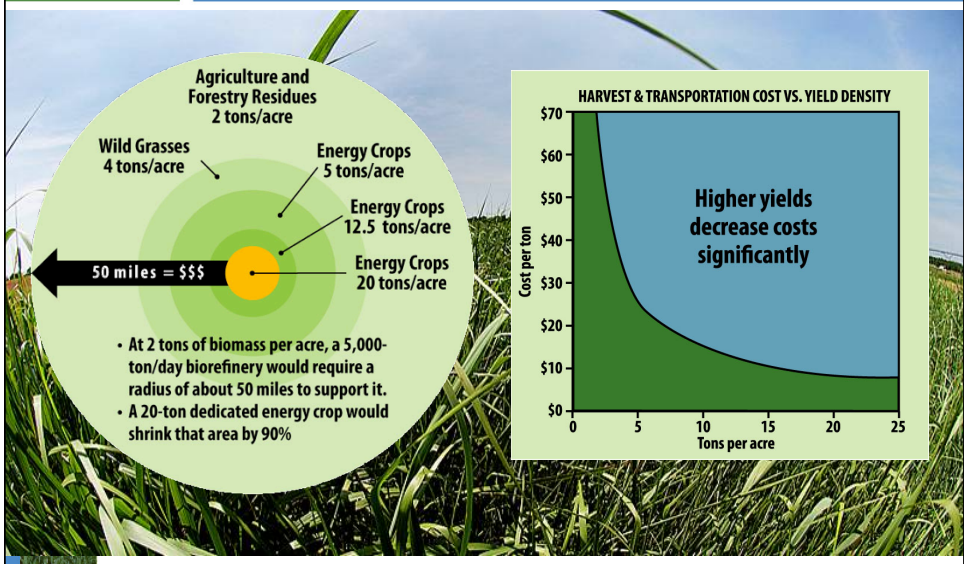
Biomass Yield Matters



Ceres Has Dramatically Increased Plant Biomass

- Ceres has identified **>1,000 genes** that affect plant biomass
- Many are being field tested in rice, a grass model for energy crops
- Energy crop transformation is in progress

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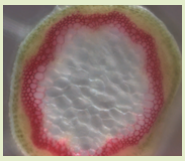
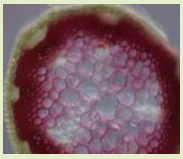
Energy Crop Composition Matters

- Energy Crop Variations
  - 40% spread in amount of fermentable sugars within a specific switchgrass variety
  - 100% spread in hydrolysis of fermentable sugars
- Variability means risk to biorefinery profits
- Game Changing Impact of Composition
  - Increase of ethanol productivity of up to 400 gal/acre*
  - Capital reduction for pretreatment and enzymatic hydrolysis



Non-transgenic Wild type



Transgenic line - increased lignin deposition

Transgenic line - decreased lignin deposition

**Assuming 100% conversion of glucose and xylose sugars to ethanol*

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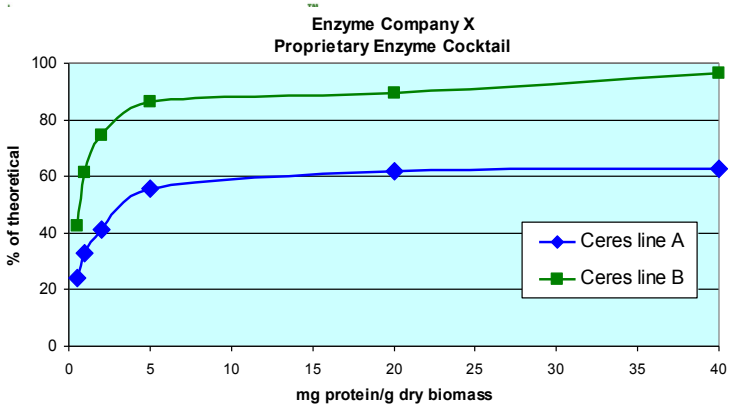
Biomass Differs in Extent of Conversion



- Reduced enzyme cost
- Reduced hydrolysis time
- Reduced capital expenditure

With "Plausible Technology Development" Cellulosic biofuels tomorrow…(~2012)

	Cellulosic	Corn Starch
Feedstock	Feedstock $0.68 ($50/ton / 90 g/ton)	Feedstock $1.25 (0.357 bu @ $3.50/bu)
Enzymes	Enzymes $0.10	Enzymes $0.03
Capital	Capital $0.40	Capital $0.20
Operating costs	Operating costs $0.22	Operating costs $0.22
Natural Gas		Natural Gas $0.25
$/gallon (gross)	**$1.40**	**$1.95**
energy/feed credit	**(- $0.10) lignin**	**(- $0.26) DDG**
Net $/gallon	***$1.30***	***$1.69***

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Ceres is Rapidly Developing Commercial Energy Crops

Bringing the first products to market:

- Commercial scale-up of first energy crop germplasm (2009)
- Agricultural management practices and logistics
- Development agreements with cellulosic biorefineries and technology providers
- Field trialing to understand geographic range
- Expanding seed production

Rapid improvement through advanced breeding:

- Sequencing and marker identification to create proprietary marker maps
- Marker-assisted breeding using hundreds of proprietary gene-trait associations
- Hybrids
- Propagation techniques

Sustainable advantage through biotech traits:

- Broad portfolio of proven traits
  - Biomass
  - Plant architecture
  - Drought tolerance
  - Nitrogen use efficiency
  - Disease tolerance
  - Etc.
- High-throughput transformation
- Composition profile

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Survey Questions

1. Do cellulosic biofuels represent a good business opportunity?
   a) Yes
   b) No

2. Should farmers pay an annual technology fee for seeds with improved yield or conversion profile?
   a) Yes
   b) No

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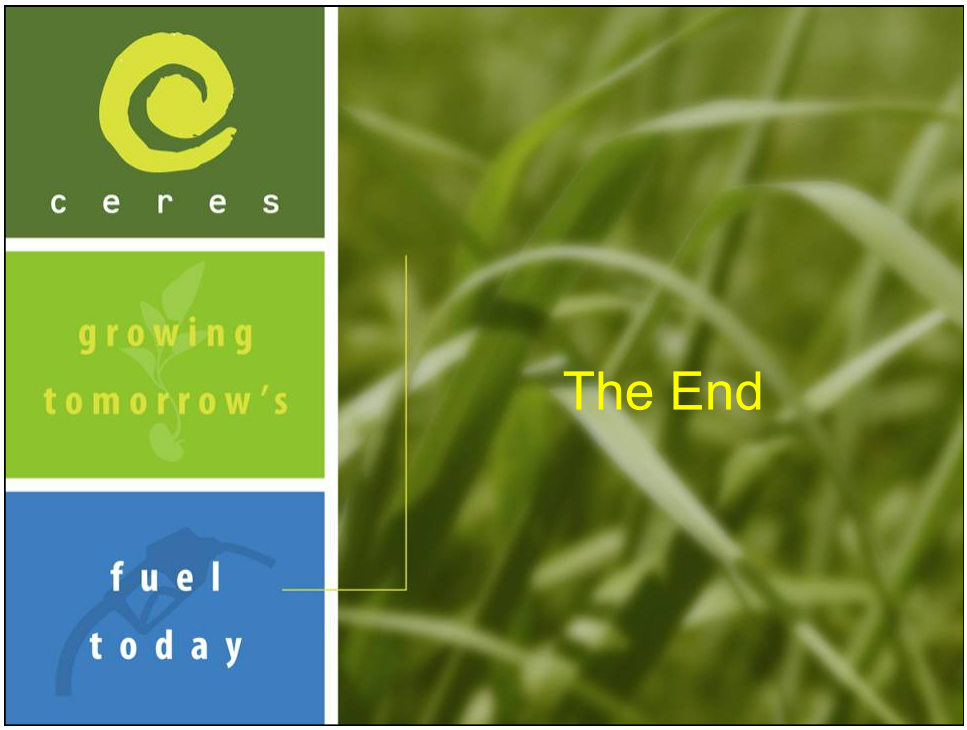

The Best Way to Predict the Future…

December 17, 1903

July 20, 1969

…is to create it!

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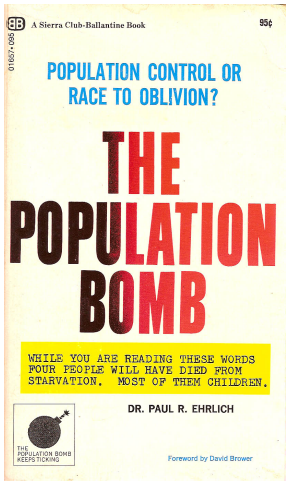
Other predictions in 1968…



- "the battle to feed all of humanity is over"
- "In the 1970s and 1980s hundreds of millions of people will starve to death in spite of any crash programs embarked upon now."
- "India couldn't possibly feed two hundred million more people by 1980,"
- "I have yet to meet anyone familiar with the situation who thinks that India will be self-sufficient in food by 1971."

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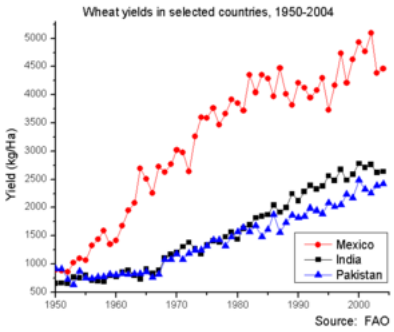
Other activities in 1968…



Innovation is game changing…

"The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil."

Sheikh Zaki Yamani
Former Saudi Arabia Oil Minister