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BIOFUELS: GROWING ENERGY

Presentation to The Presidents Council of Advisors on Science and Technology

September 12, 2006

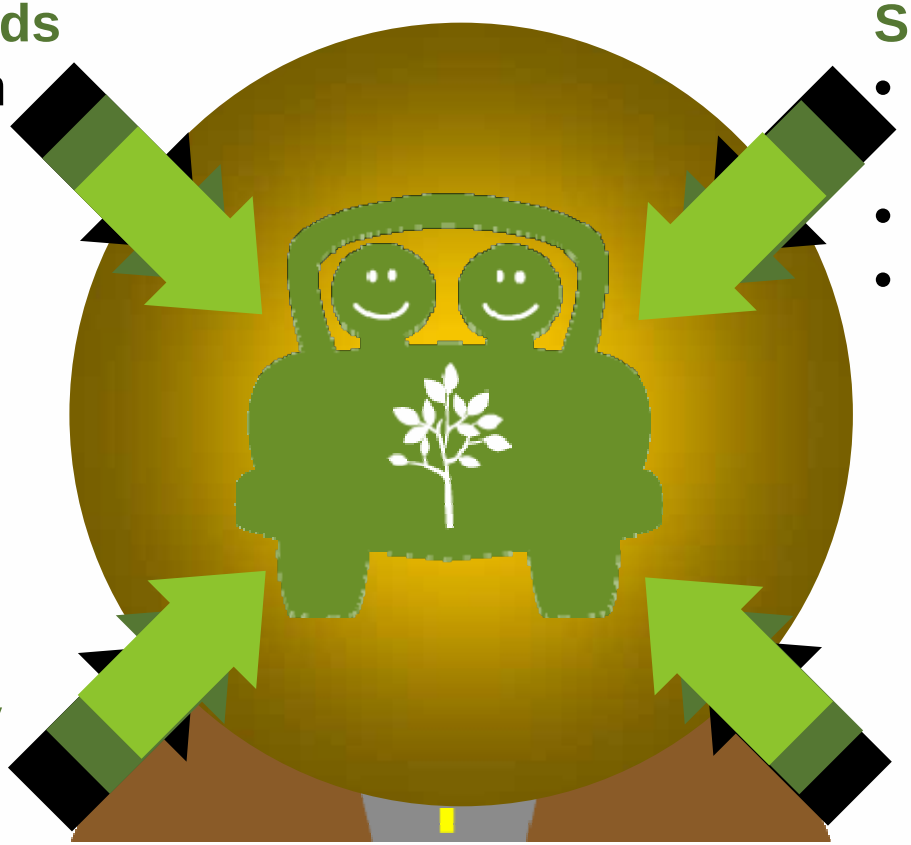
Convergence of Issues Creating the Perfect Environment for the Biofuels Solution

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

President Bush Announces Advanced Energy Initiative (State of the Union Address, 2006)

"Keeping America competitive requires **affordable energy**. And here we have a real problem. America is **addicted to oil**, which is often imported from unstable parts of the world.

The best way to break this addiction is through **technology**… and we are **on the threshold of incredible advances**…

So tonight I announce … push for breakthroughs in two vital areas … change how we power our homes and offices, … **change how we power our automobiles**.

We will also fund additional research in cutting-edge **methods of producing ethanol, not just from corn but from wood chips, stalks or switchgrass**," he said. "Our goal is to make this new kind of ethanol practical and **competitive within six years**."

Conventional Wisdom Says…

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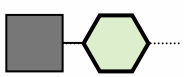
- You will never generate enough biomass to make a significant contribution to total fuel demand
- All available cropland will be needed to feed a growing population
- It will never be more attractive for a farmer to produce biomass than grain
- Biofuels will never be cost competitive with gasoline

Basic Carbohydrate Biochemistry

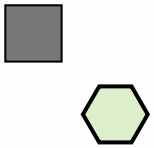
Sucrose (sugarcane)

Starch (corn grain)

Cellulose (cell walls)



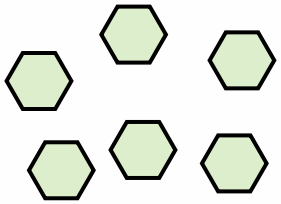
sucrase



C_6 fermentation/ distillation

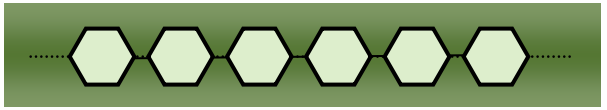
Biofuels

amylase / glucoamylase

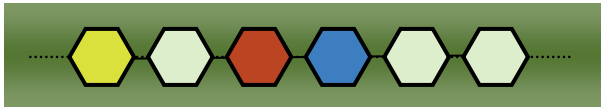


C_6 fermentation/ distillation

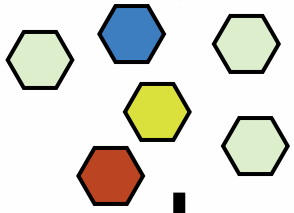
Biofuels



Hemicellulose (cell walls)



Cellulases | **Hemicellulases**



C_5/C_6 fermentation/ distillation

Biofuels

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Is Corn The Only Answer?…

Projected 2015 average corn yield

Projected 2015 biomass yield

Corn Yield (bu/acre)	Stover Yield (tons/acre)	EtOH Yield* (gal/acre)	Biomass Yield* (tons/acre)
(**100** x 3.1 gal/bu) +	(2.3 x 92 gal/ton) =	(517 / 92 gal/ton) =	**5.6**
125	2.8	646	**7.0**
150	3.4	776	**8.4**
164	3.7	846	**9.2**
175	3.9	905	**9.8**
200	4.5	1034	**11.2**
250	5.6	1293	**14.0**
267	6.0	1380	**15.0**
300	6.8	1551	**16.9**
350	7.9	1810	**19.7**

* Assumes projected 2015 EtOH yields of 3.1 gal/bu and 92 gal/ton

Source: USDA, DOE

Growth Requirements for Common Energy Crops

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	Corn grain	Corn Stover	Energy Crops Today	Energy Crops Tomorrow
Yield (t/ac)	4	4	5	20+
Nitrogen (lb/ac)	180	225	50	<30
Water (inches/season)	28	28	23	<18
H,P&F-cide inputs (units)	100	100	30	15
Range (% of US land)	50	50	65	>75

Size of the Prize – Oklahoma Example

Turning Oklahoma into…

	Today	Tomorrow
Farm acres	34 Million	34 Million
Biomass Yield (Tons/acre)	5	15
Conversion (Gallons/ton)	60	80
Thousand barrels/day	466	1,863

…a member of OPEC?!

	Thousand barrels/day
Saudi Arabia	9,400
Iran	3,900
Kuwait	2,600
Venezuela	2,500
UAE	2,500
Nigeria	2,200
Oklahoma	***1,863***
Iraq	1,700
Libya	1,650
Algeria	1,380
Indonesia	925
Qatar	800

Dedicated Energy Crops

Credible studies show that 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, BP

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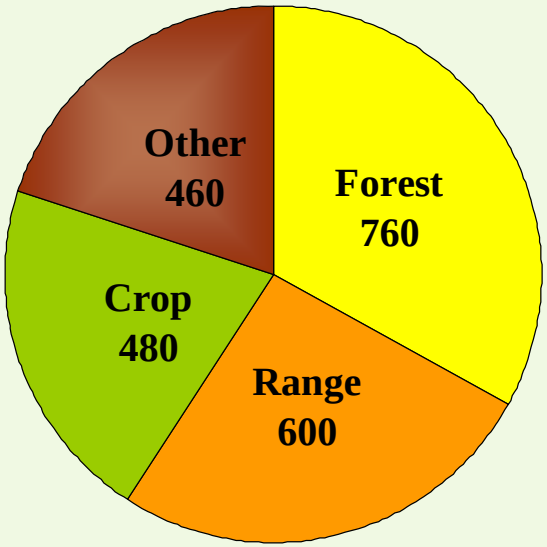
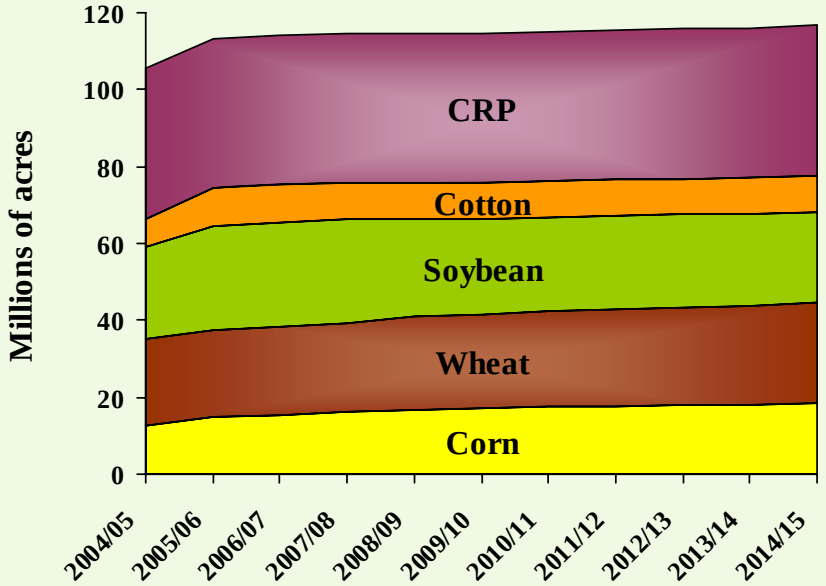
Not Enough Land?…

Total U.S. Acreage

Total = 2,300M acres



U.S. Cropland Unused or Used for Export Crops



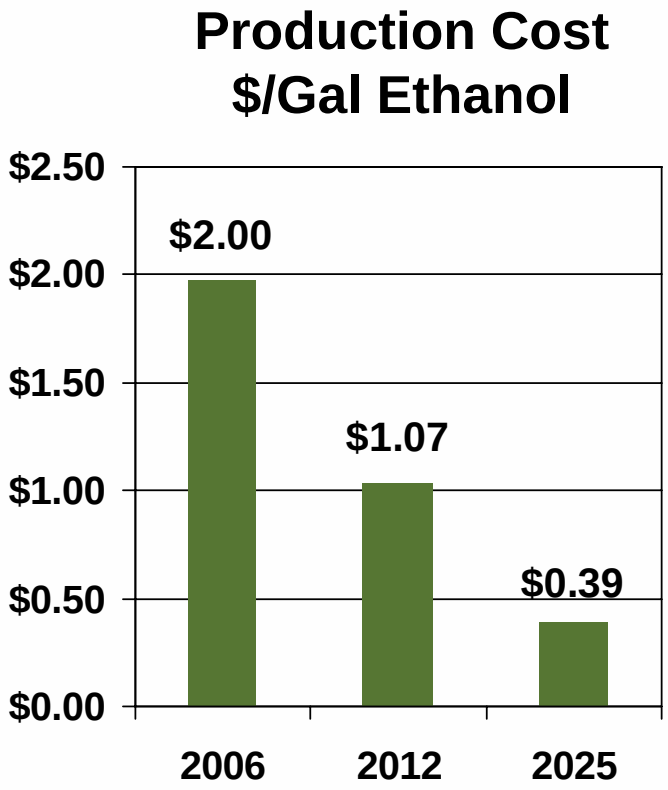
In 2015, 78M export acres plus 39M CRP acres could produce 384M gallons of ethanol per day or ~75% of current U.S. gasoline demand

Farmers Are Driven By Economics…

Per acre economics of dedicated biomass crops vs. traditional row crops

	Biomass crop	Corn	Wheat
Grain yield (bushels)	N/A	162	46
Grain price ($/bushel)	N/A	$2	$3
Biomass yield (tons)	15	2	2
Biomass price ($/ton)	$20	$20	$20
Total revenue	**$300**	**$364**	**$178**
Variable costs	$84	$168	$75
Amortized fixed costs	$36	$66	$36
Net return	**$180**	**$120**	**$57**

Never Cost Competitive?



Source: DOE, NRDC Cost Projections

Who is Ceres?

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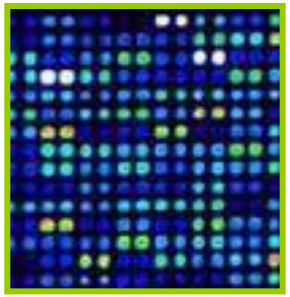
- World's leading plant genomics company
  - More plant genes-traits identified than any other entity
- Monsanto's largest external gene technology supplier
  - Technology and IP validated by $137M collaboration
- Developer of dedicated energy crops leveraging technology platforms
  - Genes/traits for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

Ceres' High-Throughput Pipeline

Proprietary Genomic Technology Enables Rapid Product Development

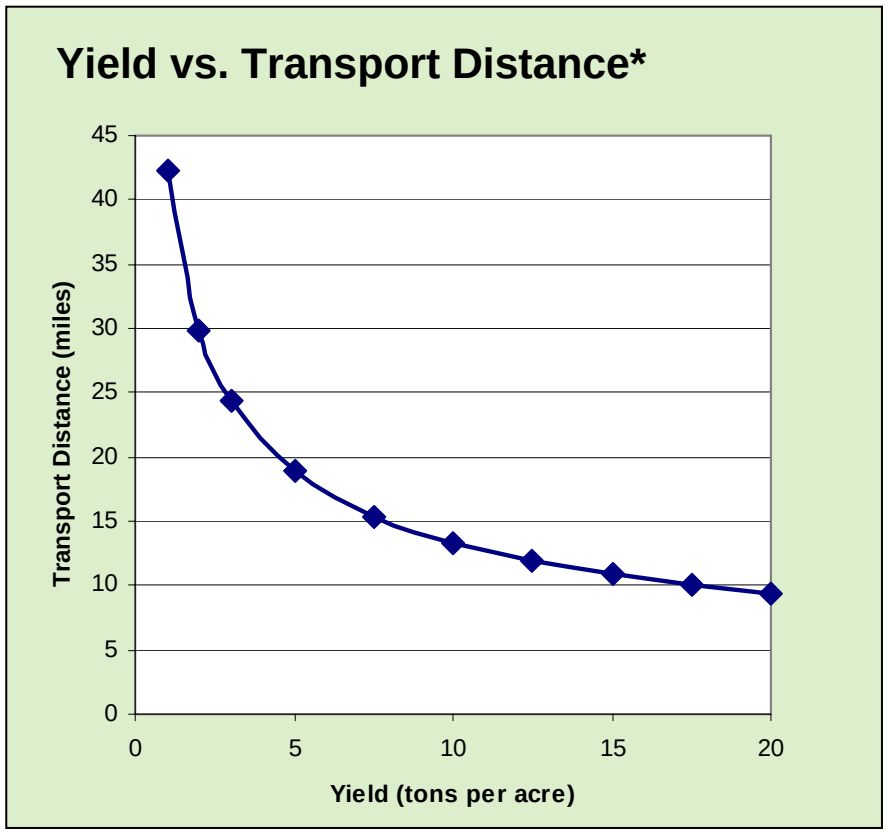
Identify cDNA	Transform into Model Plant	Screen for Traits	Transform into Crops	Transform into Energy Crops
				
Various Plant Species	**Arabidopsis**		**Rice**	**Switchgrass Miscanthus**
Sequence & characterize >70,000 genes >10,000 promoters	Transform gene-promoter combinations into model plant	Define valuable gene-trait combinations via high-throughput screens	Move successful gene-promoter combinations into commercial food crops	Move valuable gene-promoter combinations into cellulosic energy crops
	(4,000/qtr)	(3,600/qtr)	(150/qtr)	*(Proprietary)*

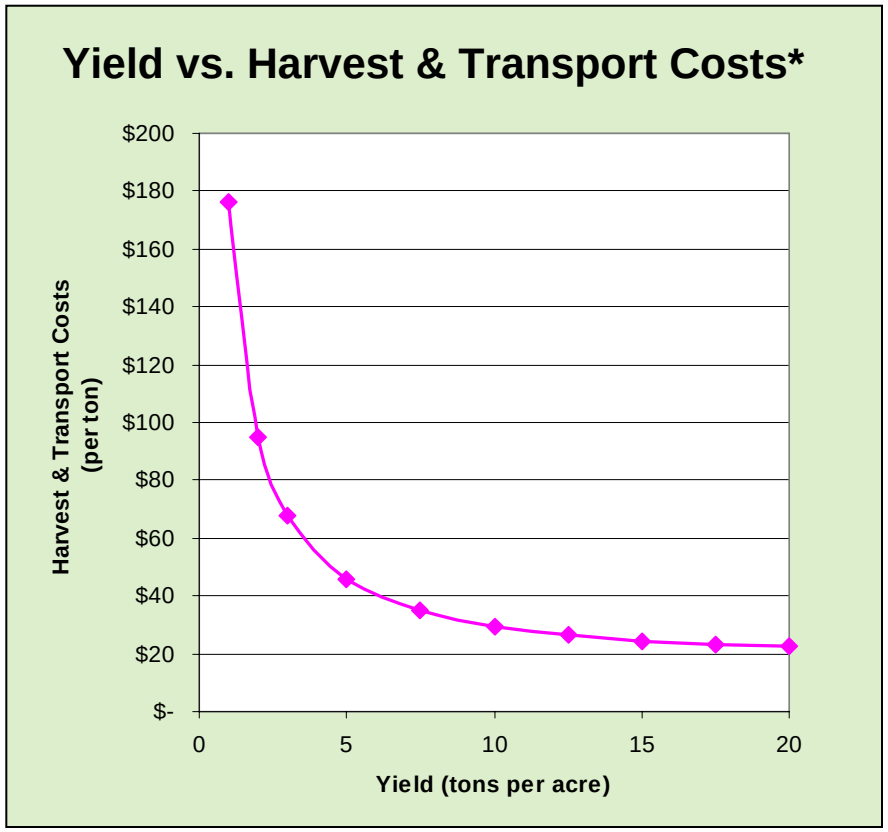
Plant Genomics is Game Changing

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 N2O emissions
Gallons per ton	▪ Composition & structure (e.g. C5/C6, 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

The Tyranny of Distance

Yield density both reduces transport distance (thereby reducing transport cost) and improves economy of scale for use of harvesting equipment





* Assumes a 10,000 ton/day processing facility with 50% of surrounding land used for biomass

Increasing Tons per Acre…

Control Transgenic

Control Transgenic

Reduced Agronomic Inputs…

Expanding Usable Acres: Heat Stress

RICE

Arab gene **Control** **Corn gene**

TOMATO

Control **Arabidopsis gene**

Expanding Usable Acres: Drought

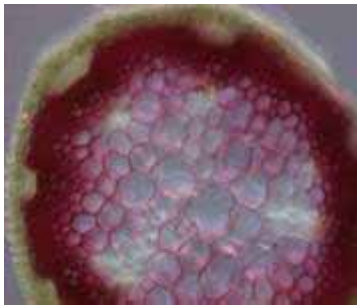
Control

Transgenic

Expanding Usable Acres: Cold Stress

Improving Composition…

Non-transgenic
Wild type



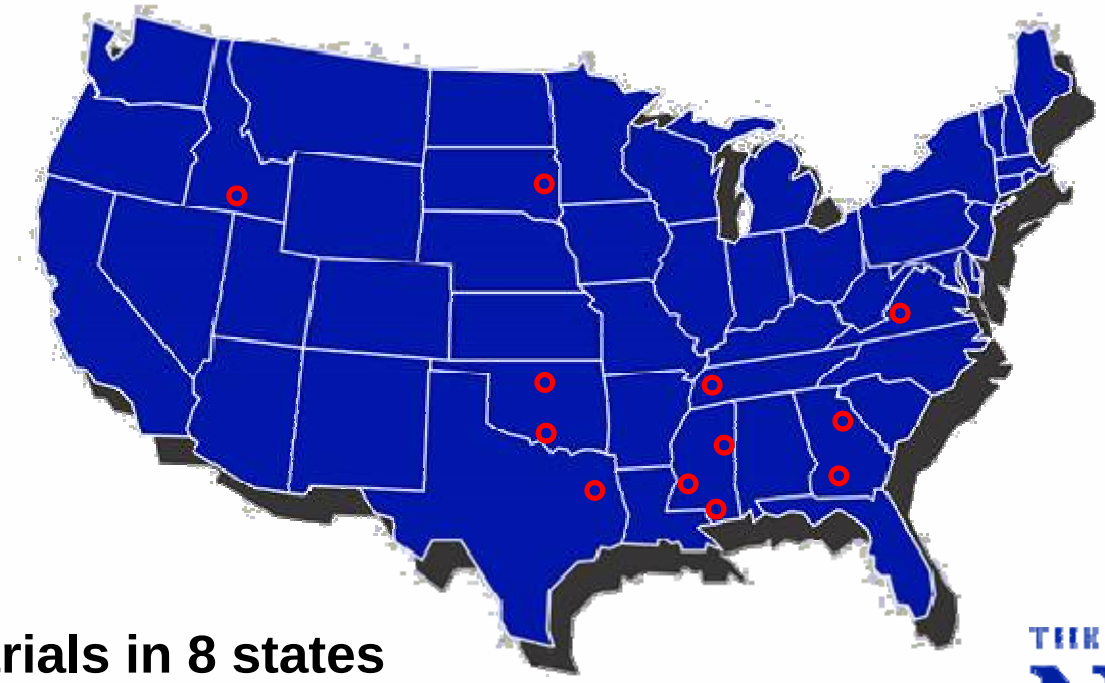
Transgenic line
increased lignin
deposition

Transgenic line
decreased lignin
deposition

- Genes for cell-wall biosynthesis in hand.
- Actively screening plant lines for improved processing and energy content
- Working with processing and enzyme companies to develop tailored solutions

Switchgrass Field Trials

Development of Switchgrass Cultivars for Dedicated Energy Crops



- **12 Field trials in 8 states**

THE SAMUEL ROBERTS NOBLE FOUNDATION

Commercial Breeding Efforts

Comparison with wild-type

Commercial Seed Multiplication Underway

Other Energy Crops Under Development

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.

Crystal Ball Gazing…

	Phase I "Commercial"	Phase II "Scale-up"	Phase III "Roll-out"
Scale	5-50 MG facilities	100 MG facilities	250+ MG facilities
Economics	$ > Starch/sucrose	$ = Starch/sucrose	$ < Starch/sucrose
Processing	Multiple. + enzyme activity, - enzyme costs	Single. First generation consolidated bioprocessing	Mature consolidated bioprocessing
Fermentation	C6 to ethanol	C5 & C6 to multiple fuels	High fermentation yields
Feedstock	Ag residues with some energy crops	Mostly energy crops	Multiple energy crops
Government	Grants, Guarantees Basic R&D	Mandates, requirements, tax incentives	Phase out of grants Other incentives e.g. CO2
I.P.	Early movers begin	Integration	Exclusion
Capacity	200 MG/year	2,000 MG/year	20,000 MG/year

What Should the Government Do?

- **DoE**
  - **Get the first generation commercial cellulosic biorefineries built!**
  - Advance *basic* research in plants and microbes for use in bioenergy
  - Create an Industry Advisory Board for both Bioenergy Research Centers
  - Establish robust intellectual property protection and licensing capabilities

- **USDA**
  - Pilot program to encourage farmers to plant small acreages to energy crops
  - Let energy crops qualify for federal farmer protection programs
  - Create a two-year farmer assistance program to transition to energy crops

- **SEC**
  - Allow energy companies to count contracted energy crop acreage as part of renewable reserves

Biomass as Reserves

1 acre	=	209 barrels of oil*
100M acres	=	20.9 billion barrels

	Proven Reserves (billion barrels)
Exxon Mobil	22.20
BP	18.50
Royal Dutch Shell	12.98
Chevron	9.95
Conoco Phillips	7.60

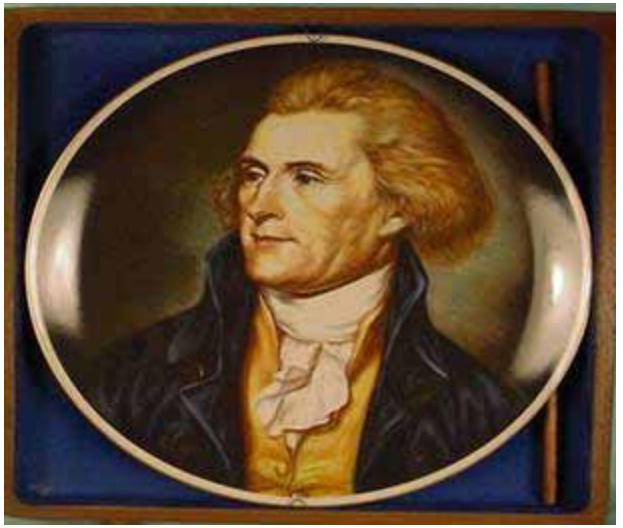
* Assumes 10 yr contract

Source: Energy Intelligence (data as of end of 2004)

Jefferson Would Have Loved Energy Crops!

"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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