Biofuels: Think outside the Barrel

Vinod Khosla
vk@khoslaventures.com
May 2006

Ver 3.2

Implausible Assertions ?

We don’t need oil for cars & light trucks

We definitely don’t need hydrogen!

We don’t need new car/engine designs/distribution

Rapid changeover of automobiles is possible!

Little cost to consumers, automakers, government

Not so Magic Answer: Ethanol

Cheaper Today in Denver (May'06)!

Cheaper Today in Brazil!

Plausible?

Brazil "Proof": FFV's 4% to ~80% of car sales in 3 yrs!

Petroleum use reduction of 40% for cars & light trucks

Ethanol cost @ $0.75/gal vs Petroleum @ $1.60-2.20/gal

Rumor: VW to phase out of all gasoline cars in 2006?

Brazil Ethanol ~ 60-80% reduction in GHG

Brazil: $50b on oil imports "savings"!

Possible?

5-6m US FFV vehicles, 4b gals ethanol supply, blending

California: Almost as many FFV's as diesel vehicles!

US prod. costs: Ethanol $1.00/gal vs Gasoline $1.60-$2:20/gal

Rapid (20%+) increase of US ethanol production in process

Easy, low cost switchover for automobile manufacturers

Why Ethanol?

Today’s cars & fuel distribution

Today’s liquid fuel infrastructure

Leverages current trends: FFV’s, Hybrids

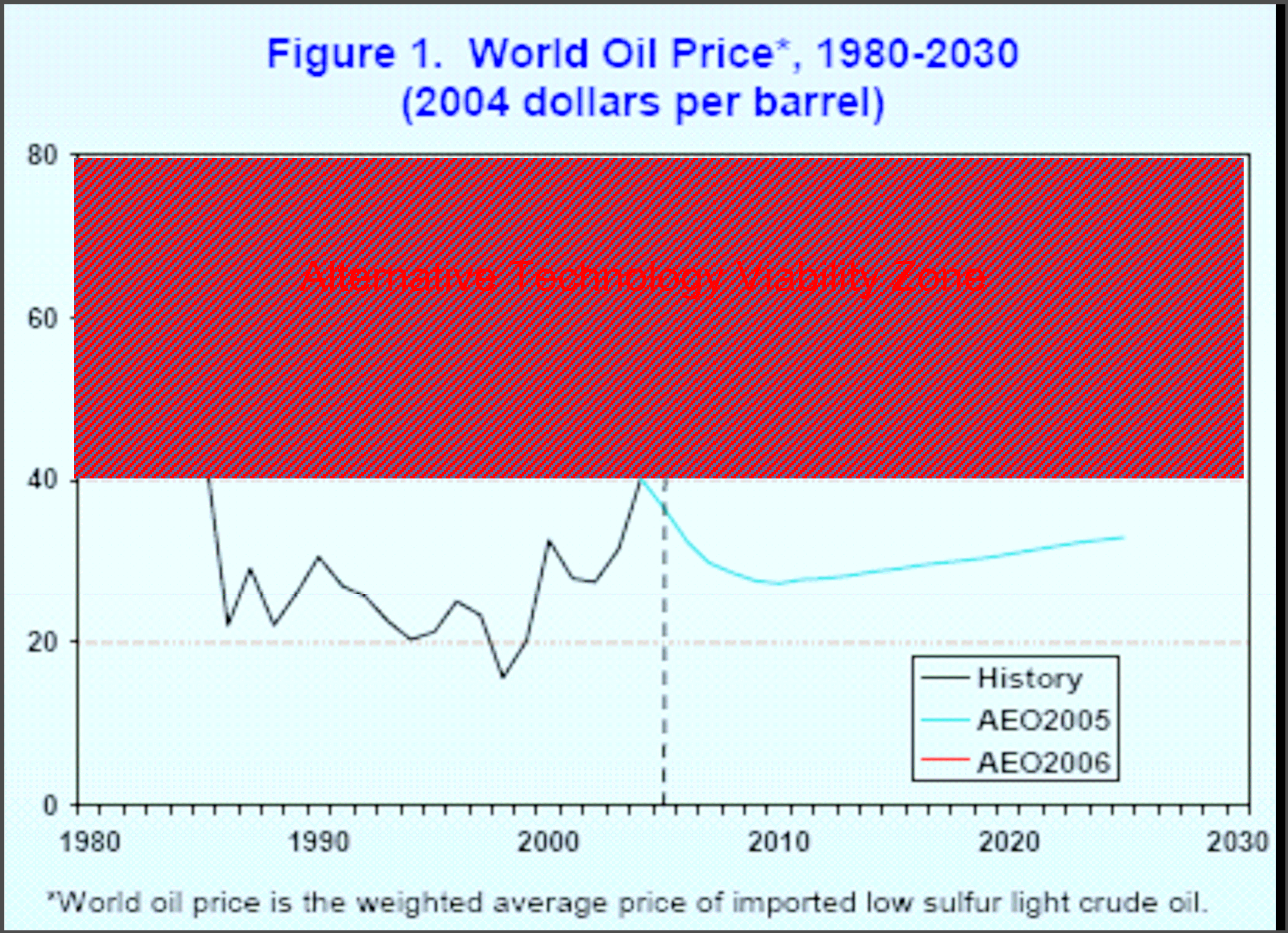
Part of fuel market via “blending” - just add E85

Why Ethanol?

Multiple Issues, One Answer

- **Cheaper fuel** for consumers
- More **energy security** & diversified sources
- Higher **farm incomes & rural employment**
- Significant **carbon emission reduction**
- Faster GDP growth, Lower Imports & energy prices

Projected World Oil Prices (EIA)



Source: EIA Reports

RISK: Oil vs. Hydrogen vs. Ethanol

	Oil	Hydrogen	Biofuels
Energy Security Risk	High	Low	Low
Cost per Mile	Med	Med-High	Low
Infrastructure Cost	Very Low	Very High	Low
Technology Risk	Very Low	Very High	Low
Environmental Cost	Very High	Med-Low	Low
Implementation Risk	Very Low	Very High	Low
Interest Group Opposition	Very High	High	Low
Political Difficulty	?	High	Low
Time to Impact	-	Very high	Low

Source: Khosla

A Darwinian IQ Test?

- Feed mid-east terrorism or mid-west farmers?
- Import expensive gasoline or use cheaper ethanol?
- Create farm jobs or mid-east oil tycoons?
- Fossil fuels or green fuels?
- ANWR oil rigs or “prairie grass” fields?
- Gasoline cars or cars with fuel choices?

What makes it Probable?

Interest Groups

Land Use

Energy Balance

Emissions

Kickstart?

Interest Groups

- US Automakers: less investment than hydrogen; compatible with hybrids
- Agricultural Interests: more income, less pressure on subsidies; new opportunity for Cargill, ADM, farmers, co-operatives,…
- Environmental Groups: faster & lower risk to renewable future; aligned with instead of against other interests
- Oil Majors: equipped to build/own ethanol "factories"& distribution; lower geopolitical risk, financial wherewithal to own ethanol infrastruct.; diversification
- Distribution (old & New): no significant infrastructure change; potential new distribution sources (e.g. Walmart)

Interest Groups: Action Items

- US Automakers: 70%flex-fuel new car mandate in exchange for some regulatory relief

- Agricultural Interests: 70% flex-fuel new cars but no tax on imported ethanol; E85 distribution; "transfer" subsidies from row crops to energy crops

Time for a Grand Compromise

- Environmental Groups: [illegible] "cellulosic ethanol" & debt guarantees for new cellulosic ethanol technologies; less petroleum

- Oil Majors: new business opportunity?

- Distribution (old & New): assist "ethanol third pump" strategy; promote ethanol distribution at destination sites (e.g. Walmart) & fleets

Three Simple Action Items

- Require 70% new cars to be Flex Fuel Vehicles

  … require yellow gas caps on all FFV's & provide incentives to automakers

- Require E85 ethanol distribution at 10% of gas stations

  …. for owners or branders with more than 25 stations;

- Make VEETC credit variable with oil price ($0.20-0.80)

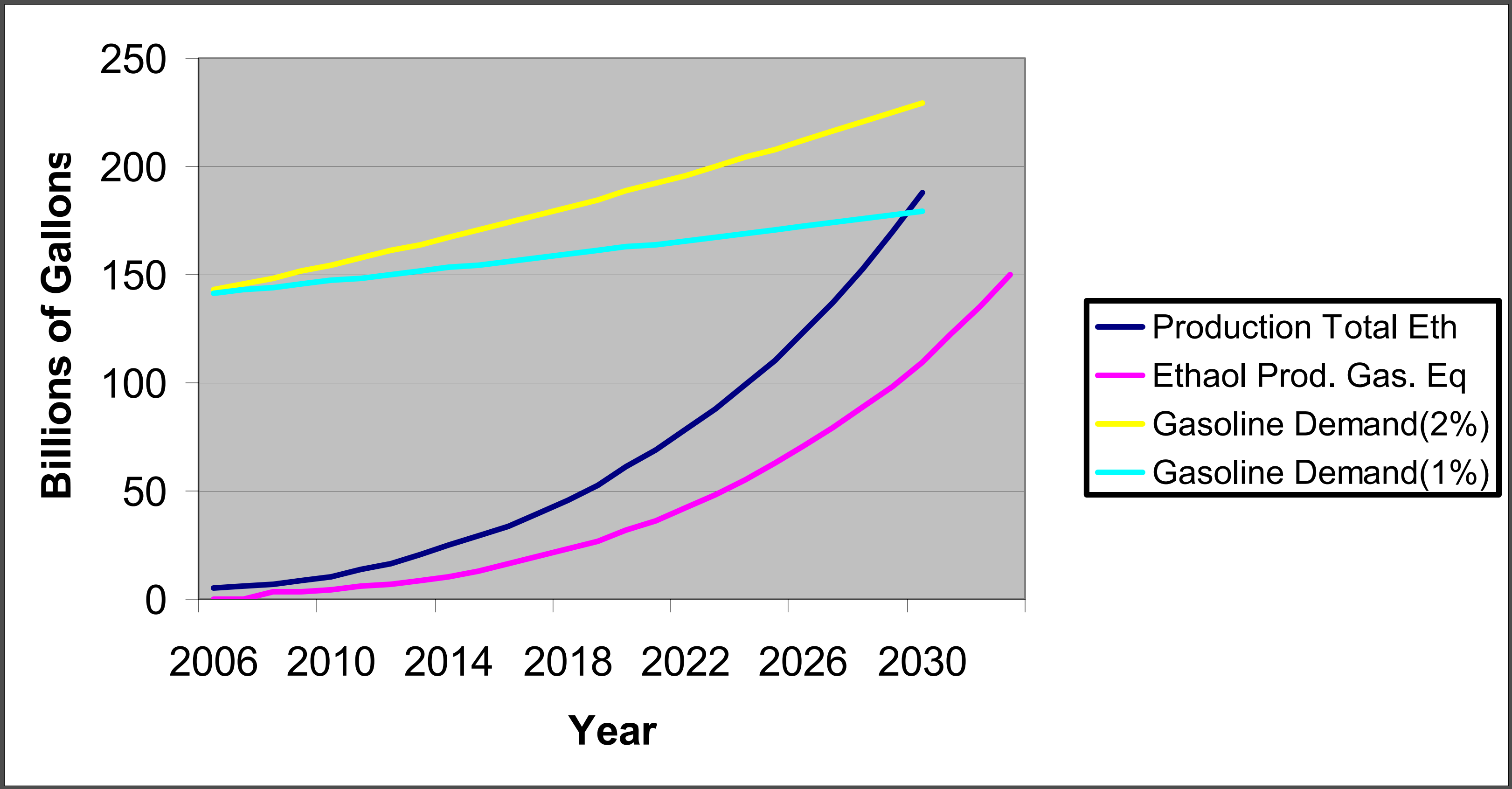
  …. providing protection against price manipulation by oil interests

....ensuring investors long term demand and oil price stability

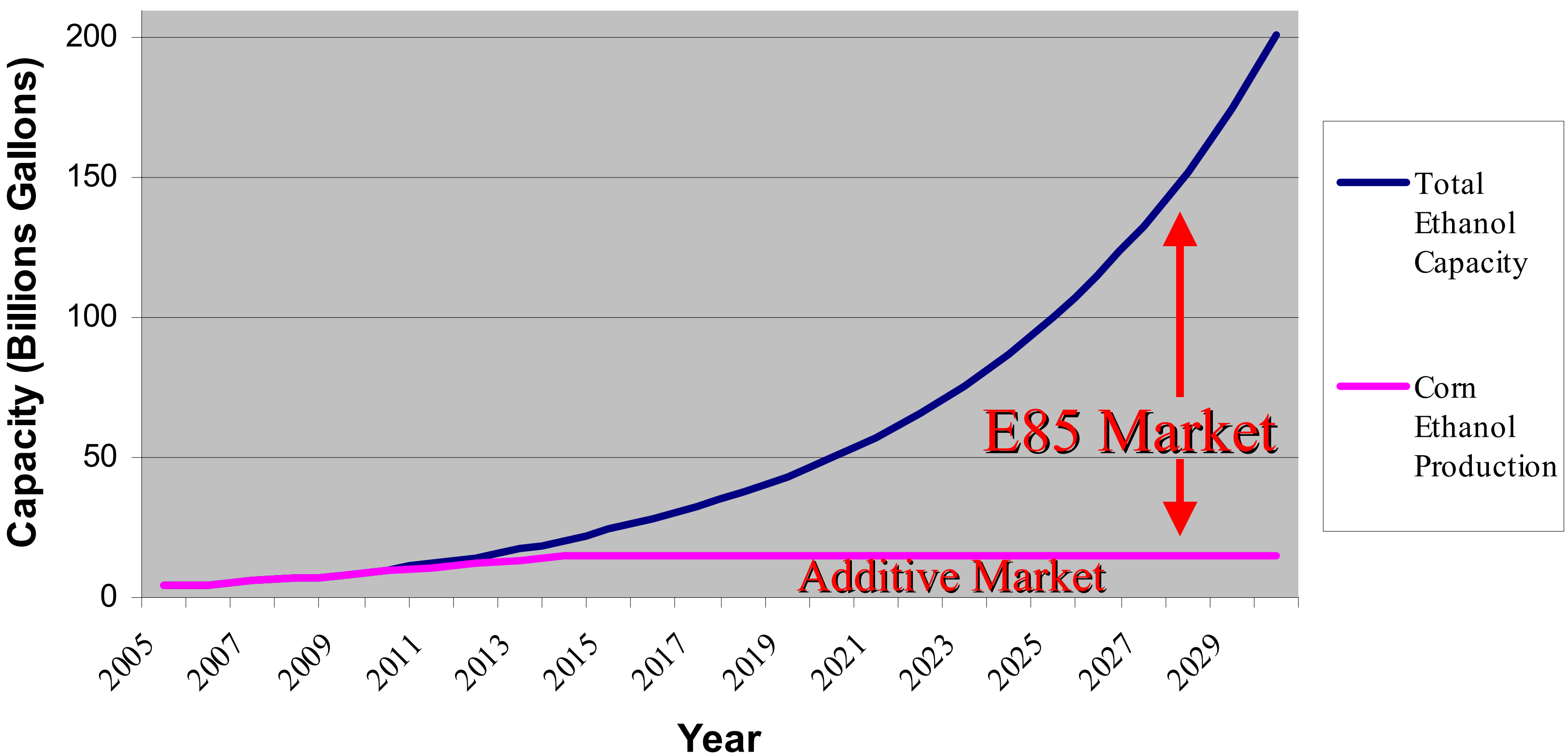
Other "Helpful" Action Items

- Switch ethanol credit from blenders to "producers" (preferably for plant building only)
- Allow imports of foreign ethanol tax free above RFS standard; extend RFS
- Provide "cellulosic" credits above "ethanol" credits; monetize energy act credit
- Institute RFS for E85 & cellulosic ethanol
- Switch CAFÉ mileage to "petroleum CAFÉ mileage"; reform & strengthen CAFE
- Loan guarantees for first few plants built with any "new technology"
- Institute a carbon cap and trade system
- Switch subsidies (same $/acre) to energy crops

Demand/Supply Projections



Ethanol Supply Projections



Projected supply of 173B gallons ethanol for FFV's by 2030

We Must Kick Start the E85 Market!!

Side Bars

Flex Fuel Vehicles (FFV)

Little incremental cost to produce & low risk

Consumer choice: use EITHER ethanol or gasoline

Easy switchover for automobile manufacturers

Fully compatible with Hybrid cars

Incremental Cost of FFV

- Sensor $70 (needed anyway in modern cars; not an additional cost)
- "Other" costs $30
- Amortized Certification & Calib. $10 (volume cars)

Automakers adopting FFV's!

- 2006
  - Ford 200-300K
  - GM 250K
  - Chrysler 100K+
- 2007
  - GM 400K
  - Chrysler 250K
- 2008
  - GM 600K
  - Chrysler 500K

Data from Chrysler PR, GM slides and Ford handout

My Favorite FFV . . .

SAAB 9-5 Launched May'05 with +25hp with E85

25% mileage reduction going to 18%

Another big ethanol mileage increase when hp held to gasoline hp

Petroleum Displacement

Annual Gasoline Savings of 477 Gallons/Year

(Assumes 11,000 miles/year)*

E85 FFV on E85
12 mpg
(EPA Adjusted Combined)

E85 FFV on Gasoline
16 mpg
(EPA Adjusted Combined)

** Personal Transportation Study - Oak Ridge Nat. Lab Data Book*

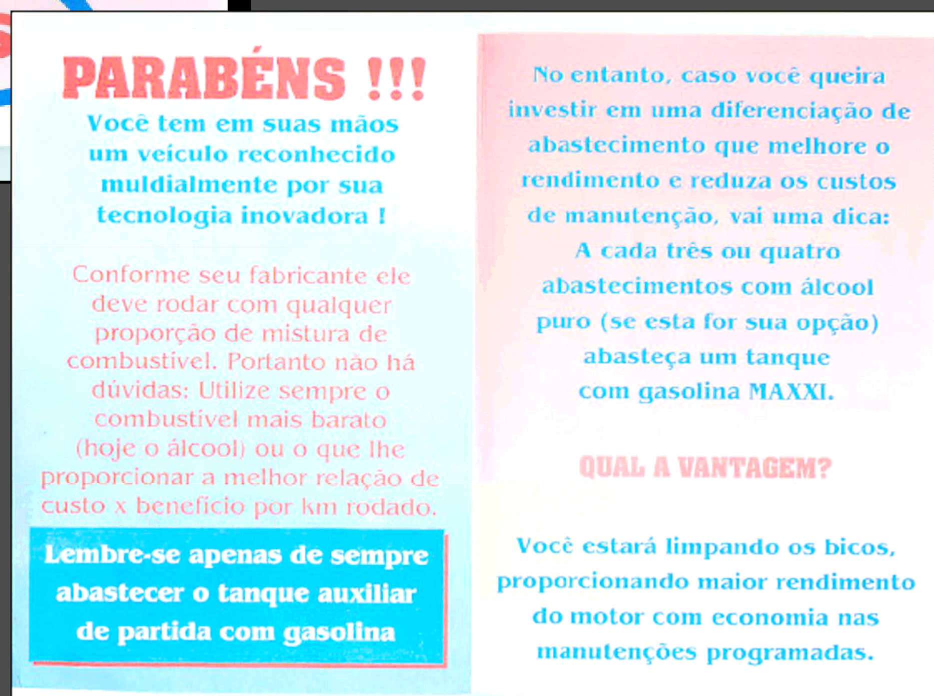
GM

Hybrid or FFV?

	Hybrid	FFV
Cost	$3000	$30
Gasoline Savings (11000 m/yr; 14mpg)	157	477

Big Oil playing hardball!

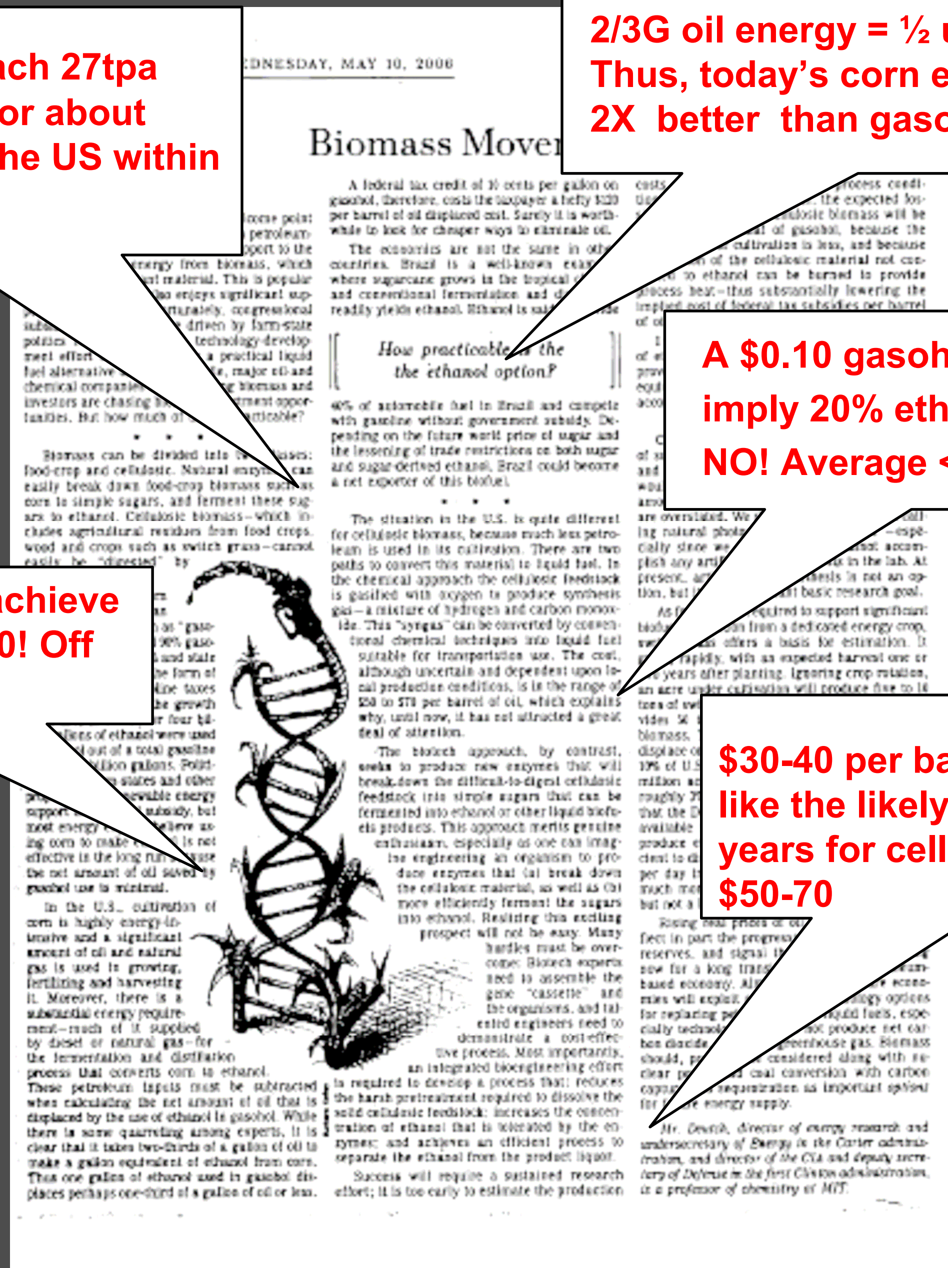
More Resistance!!!



Misinformation about need for periodic gasoline refills in Brazil

Conservatively we will reach 27tpa &110 gallons per dry ton or about 3000 gallons per acre in the US within 25 years. Error by 5-7X!!!

2/3G oil energy = ½ unit of gasoline. Thus, today's corn ethanol is 2X better than gasoline



A $0.10 gasohol credit would imply 20% ethanol blend… NO! Average <10%

Optimistically, we could achieve 5,000 gallons/acre by 2030! Off by 10X?

$30-40 per barrel oil price seems like the likely breakeven within 5-7 years for cellulosic ethanol NOT $50-70

WSJ Oped: Myths & Bad Data Abound!!

Land Use

Land Use: Reality (20-50 years)

- **NRDC: 114m acres for our transportation needs**
- **Jim Woolsey/ George Shultz estim. 60m acres**
- **Khosla: 40-60 m acres**

…. not including

- **Ethanol from municipal & animal waste, forest**
- **Direct/new synthesis technologies**

Land Use Possibilities

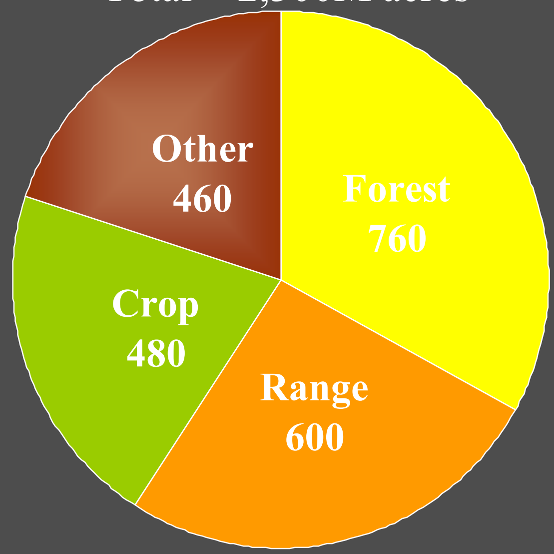
- **Dedicated intensive energy crop plantations**
- **“Export crop” lands**
- **Crop rotate row crops & “prairie grass” energy crops**
- **CRP lands planted with “prairie grasses” or equivalent**
- **Co-production of ethanol feedstocks & animal protein**
- **Waste from currently managed Lands**

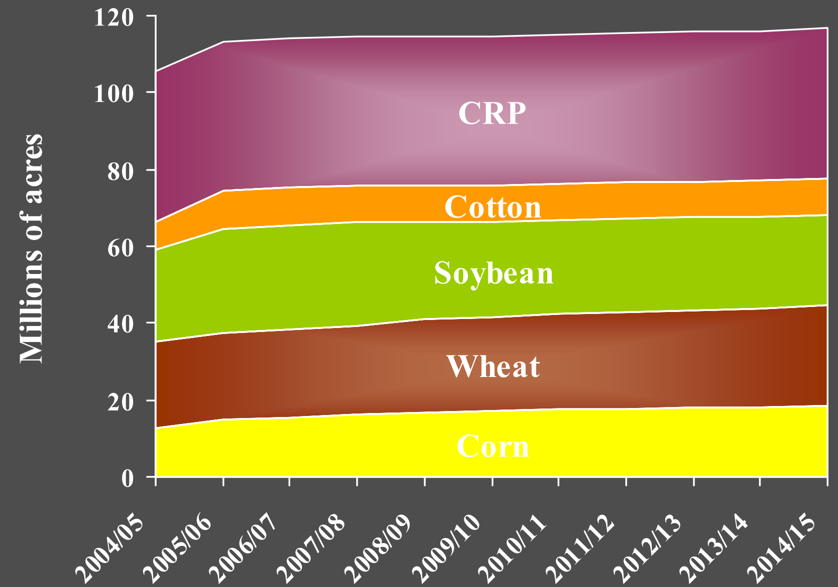
Energy Crops: Miscanthus

1 years growth without replanting!

20 tons/acre? (www.bical.net)
10-30 tons/acre (www.aces.uiuc.edu/DSI/MASGC.pdf)

Export Crop Lands





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

Source: Ceres Company Presentation

Potential for Billion Tons of Biomass

"In the context of the time required to scale up to a large-scale biorefinery industry, an annual biomass supply of more than 1.3 billion dry tons can be accomplished with relatively modest changes in land use and agricultural and forestry practices"

Technical Feasibility of a Billion-Ton Annual Supply
US Department of Energy Report , April 2005.
http://www.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf

…. Or a 130billion++ gallons per year!

Land Use: Reality

- NRDC Estimates : Growing Energy Report
- DOE Report: “ Potential for Billion Tons of Biomass “
- Prof Lee Lynd: Bioenergy from Currently Managed Lands
- New Feedstocks Approach – Miscanthus, Switchgrass,…
  - Miscanthus (www.bical.net or www.aces.uiuc.edu/DSI/MASGC.pdf)
  - New Energy crops (www.ceres.net)
- Futures: New Approaches, New Technologies
  - Prof. Lee Lynd: Re-imagining Agriculture
  - Ceres – New technology Approaches
  - Greenfuels.com
  - Synthetic Genomics
  - Biomass Gasification

Miscanthus vs. Corn/Soy

- Lower fertilizer & water needs
- Strong photosynthesis, perennial
- Stores carbon & nutrients in soil
- Great field characteristics, longer canopy season
- Economics: +$3000 vs -$300 (10yr profit per U Illinois)

Energy Crops: Switch Grass

- Natural prairie grass in the US; enriches soil
- Less water; less fertilizer; less pesticide
- Reduced green house gases
- More biodiversity in switchgrass fields (vs. corn)
- Dramatically less topsoil loss
- High potential for co-production of animal feed

Biomass Will Make a Difference

Turning South Dakota into…

	Today	Tomorrow
Farm acres	44 Million	44 Million
Tons/acre	5	15
Gallons/ton	60	80
Thousand barrels/day	857	**3,429**

…a member of OPEC?!

	Thousand barrels/day
Saudi Arabia	9,400
Iran	3,900
South Dakota	*3,429*
Kuwait	2,600
Venezuela	2,500
UAE	2,500
Nigeria	2,200
Iraq	1,700
Libya	1,650
Algeria	1,380
Indonesia	925
Qatar	800

Source: Ceres Company Presentation

Farmers Are Driven By Economics

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

	Biomass	Corn	Wheat
Grain yield (bushel)	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**

Source: Ceres Company Presentation

Biomass as Reserves: One Exxon every 10 yrs!!

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);Ceres presentation

Energy Balance
&
Fossil Fuel Use Reductions

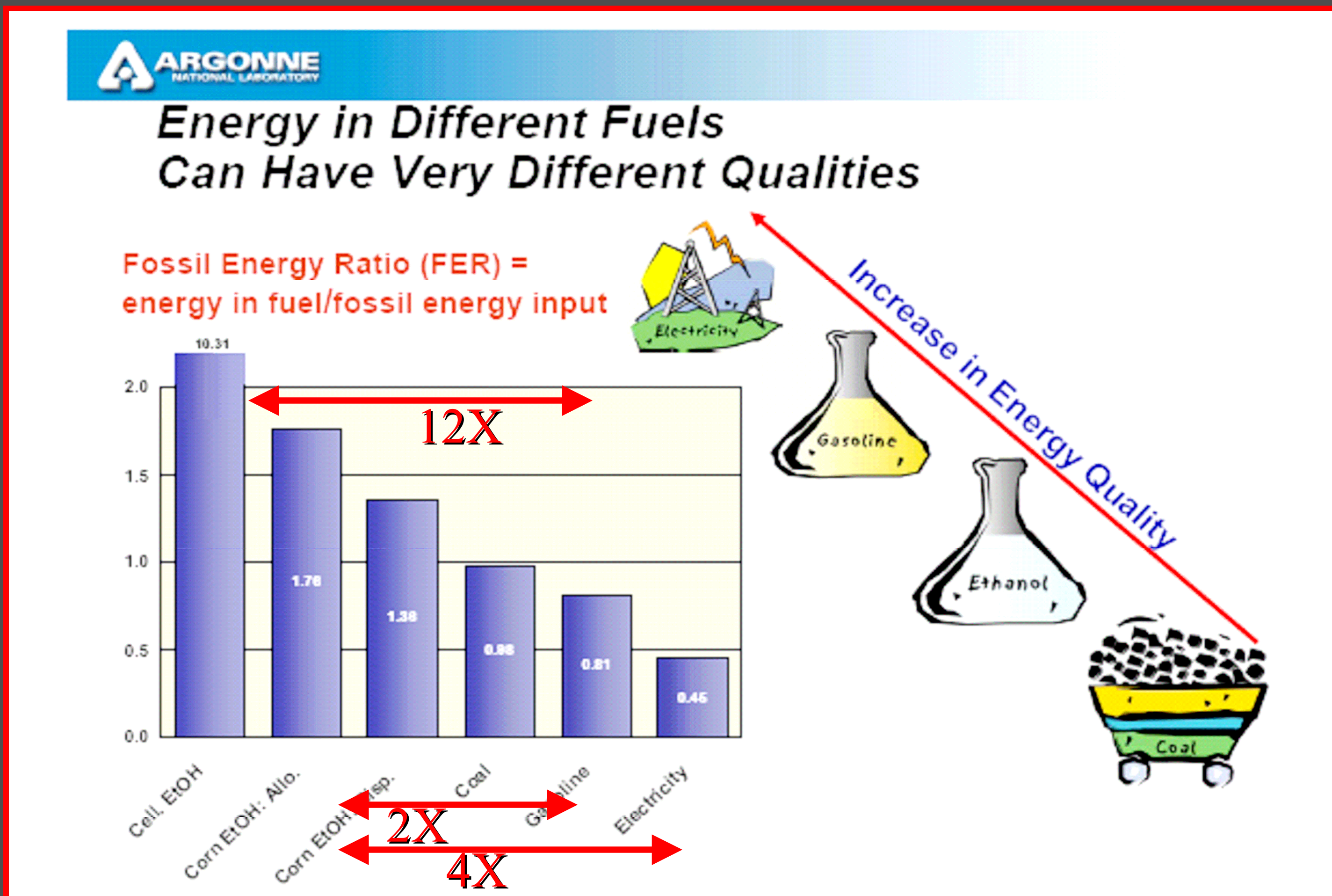
Energy Balance (Energy OUT vs. IN)

- Corn ethanol numbers ~1.2-1.8X
- Petroleum energy balance at ~0.8

….but reality from non-corn ethanol is…

- Sugarcane ethanol (Brazil) ~8X
- Cellulosic ethanol ~4-8X

Fossil Fuel Use: Argonne Study



Legend	EtoH	=	Ethanol
	Allo.	=	Allocation
	Disp.	=	Displacement

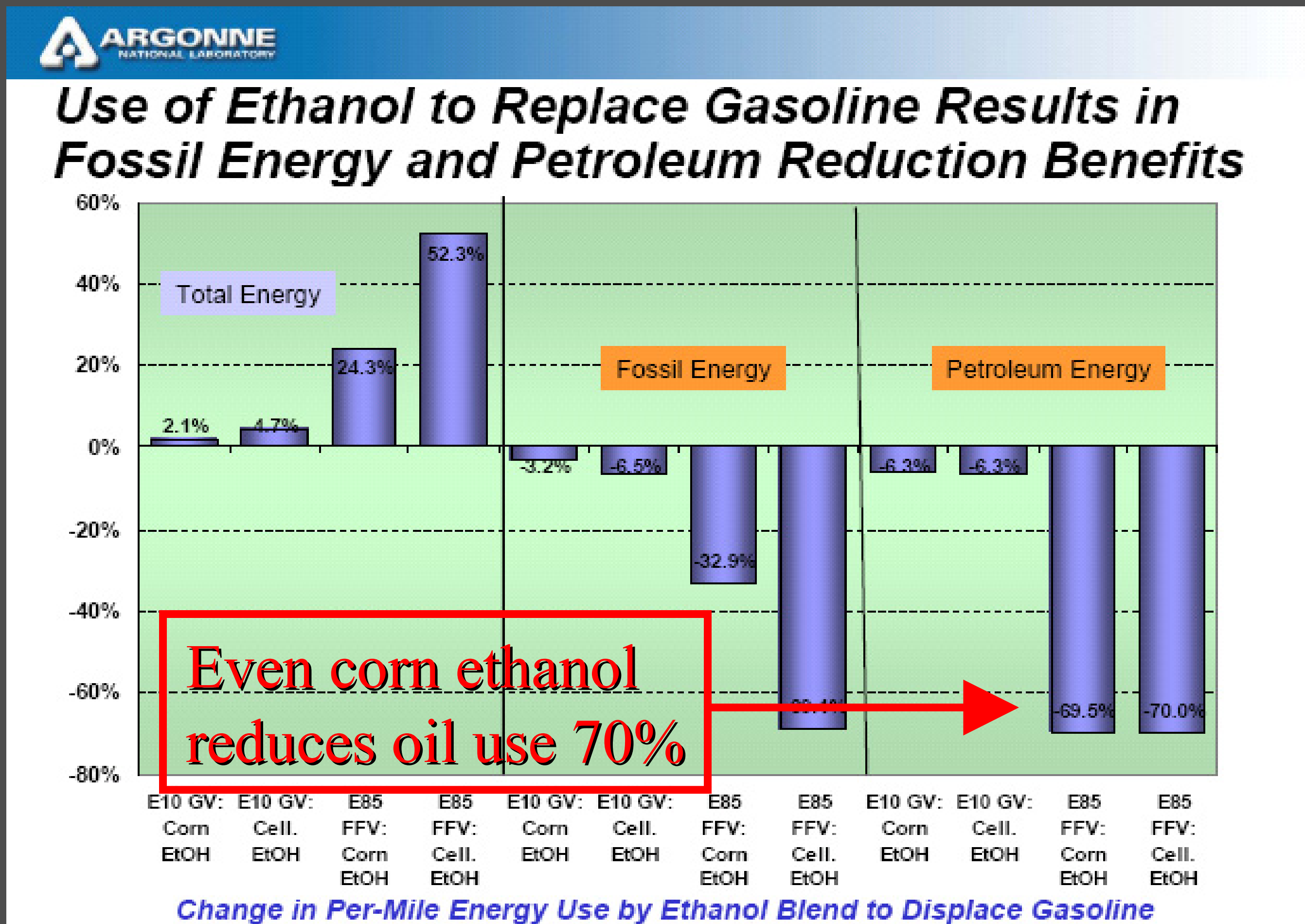
Red: Khosla Comments

ARGONNE NATIONAL LABORATORY

A Recent Study by Pimentel&Patzek Conclude Increases in Fossil Energy Use by Biofuels

- Pimentel&Patzek conclude that
  - Corn ethanol *increases* fossil energy use by 29%
  - Cellulosic biomass-based ethanol by 50-57%
  - Biodiesel by 27-118%
- Other studies have very different conclusions
  - Argonne has shown
    - Corn ethanol *reduces* fossil energy use by 26%
    - Cellulosic biomass-based ethanol *reduces* by 90%
  - National Renewable Energy Laboratory has shown that biodiesel *reduces* fossil energy use by 69%
- Differences between Pimentel&Patzek and others lie in
  - Corn farming energy use
  - Energy use for producing nitrogen fertilizer
  - Ethanol plant energy use
  - Credits for co-products from biofuel plants

Petroleum & Fossil Fuel Reduction Benefits



Red: Khosla Comments

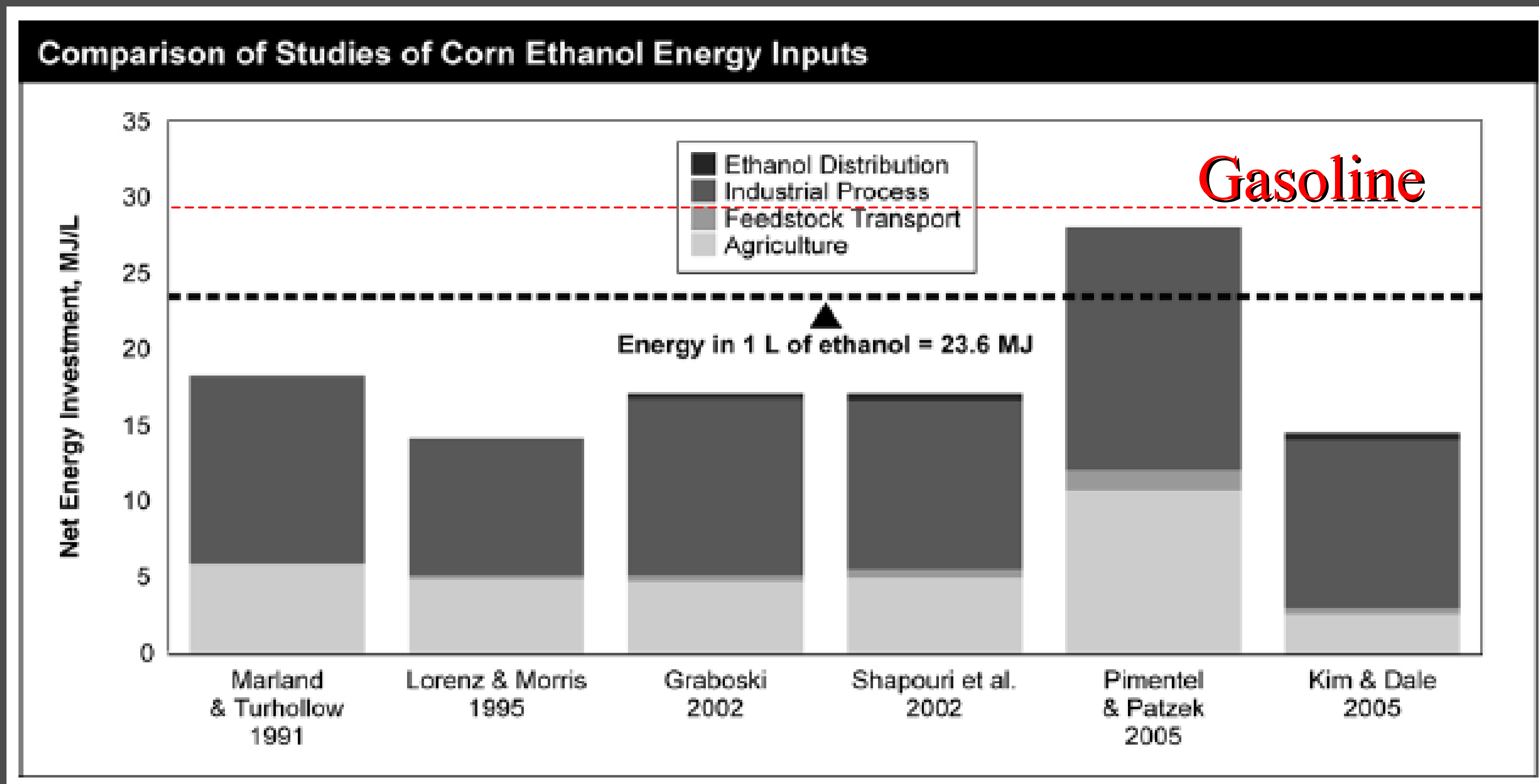
ARGONNE NATIONAL LABORATORY

Conclusions

- Energy balance value for a given energy product alone is not meaningful in evaluating its benefit
- Any type of fuel ethanol helps substantially reduce transportation's fossil energy and petroleum use, relative to petroleum gasoline
- Corn-based fuel ethanol achieves moderate reductions in GHG emissions
- Cellulosic ethanol can achieve much greater energy and GHG benefits

(For more information, please visit the GREET model website at http://greet.anl.gov)

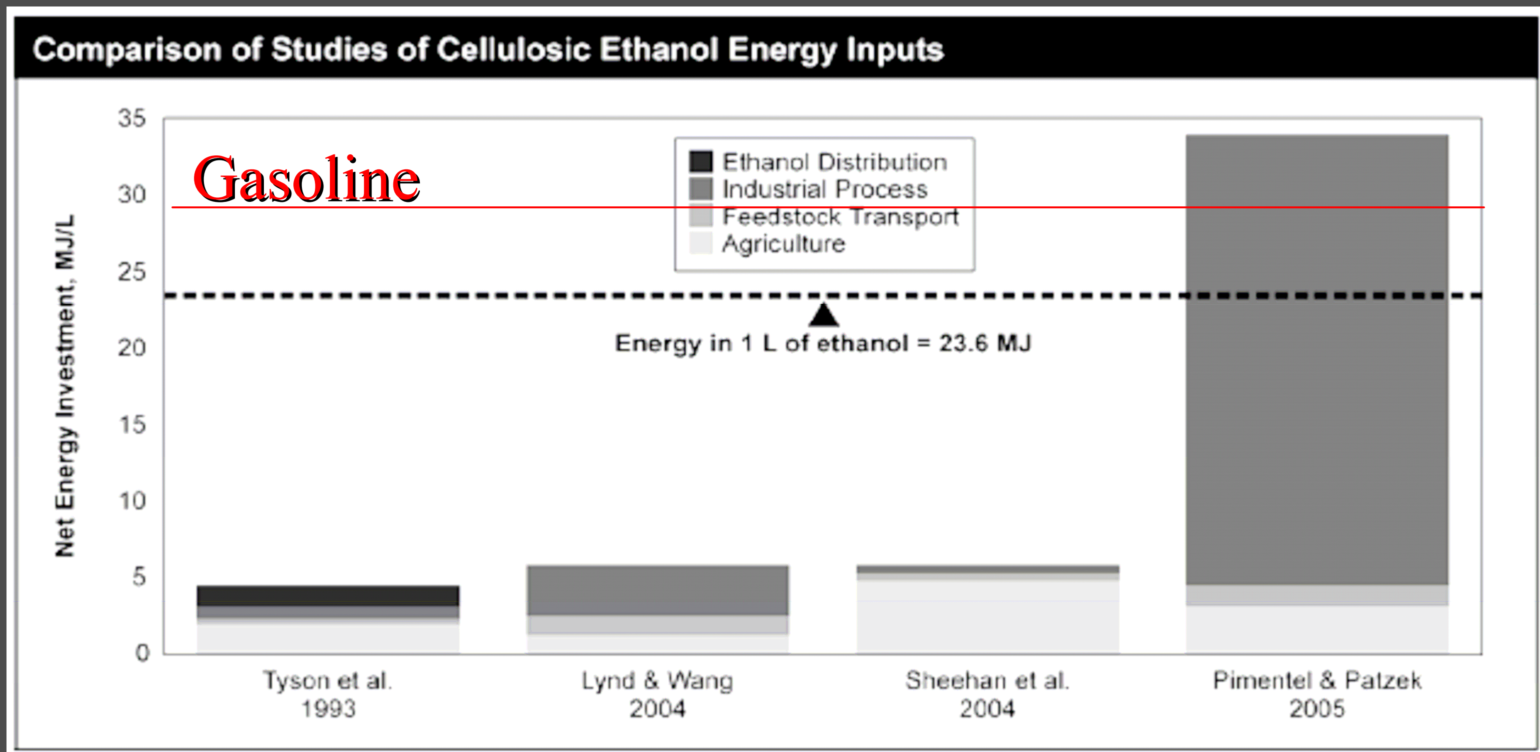
NRDC Report - “Ethanol: Energy Well Spent”



“It is notable that Pimental is the only study in the last ten years to show a negative balance” – White House Memo, 2005

Red: Khosla Comments

NRDC Report - "Ethanol: Energy Well Spent"



Red: Khosla Comments

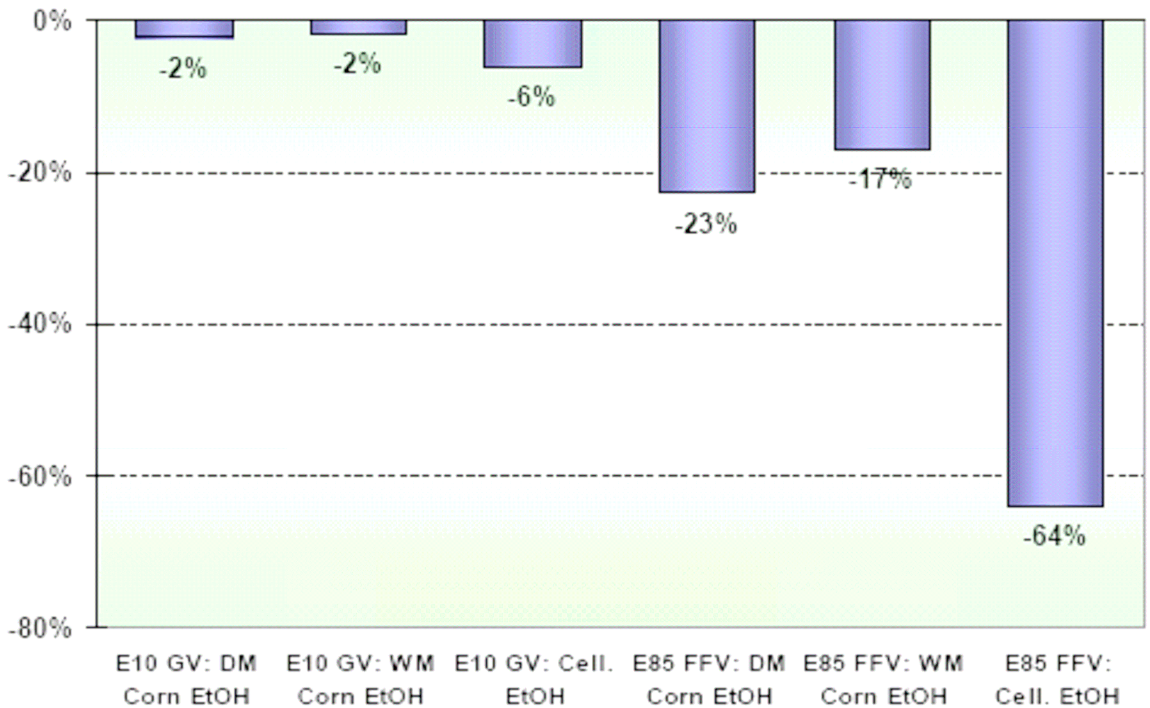
NRDC Report - “Ethanol: Energy Well Spent”

- “corn ethanol is providing important fossil fuel savings and greenhouse gas reductions”
- “cellulosic ethanol simply delivers profoundly more renewable energy than corn ethanol”
- “very little petroleum is used in the production of ethanol …..shift from gasoline to ethanol will reduce our oil dependence”

Environmental Issues

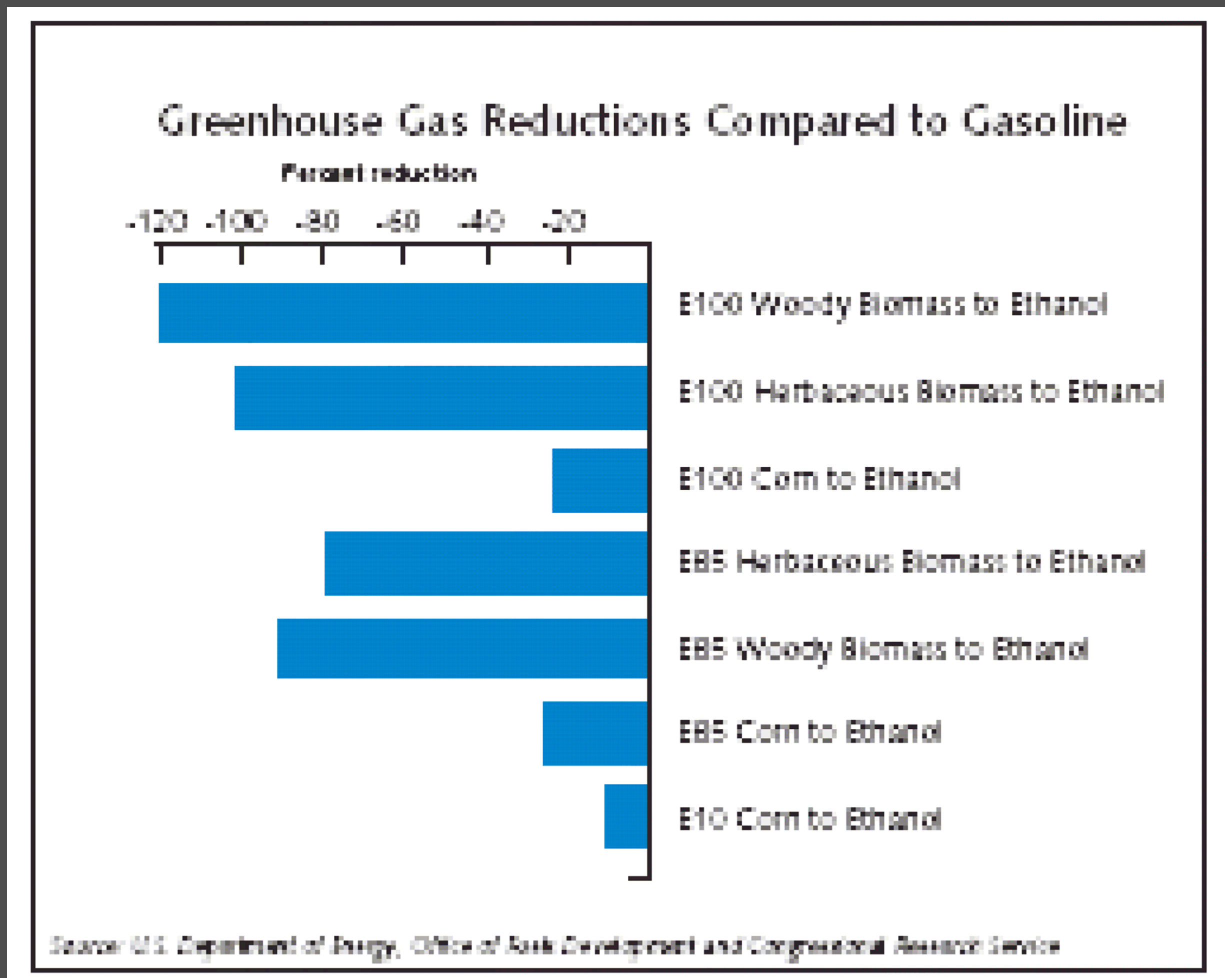
ARGONNE NATIONAL LABORATORY

Per Mile Driven with EtOH Blends, E85 (Especially with Cellulosic EtOH) Reduces Far Greater GHG Emissions



Per-Mile GHG Emission Reductions by Ethanol Blends to Displace Gasoline

Another View (Gary Herwick Whitepaper)



Emission Levels of Two 2005 FFVs

(grams per mile @ 50,000 miles)

Vehicle Model	Fuel	NOx (CA std.=0.14)	NMOG (CA std.=0.10)	CO (CA std. =3.4)
2005 Ford Taurus	E85	0.03	0.047	0.6
	Gasoline	0.02	0.049	0.9
2005 Mercedes-Benz C 240	E85	0.01	0.043	0.2
	Gasoline	0.04	0.028	0.3

source: California Air Resources Board, On-Road New Vehicle and Engine Certification Program, Executive Orders; http://www.arb.ca.gov/msprog/onroad/cert/cert.php

Ethanol Blends: Emissions

- E85
  - Low Evaporative emissions (Lower RVP)
  - Expected Low Permeation emissions in FFV's
  - Low Nox in modern vehicles with oxygen sensors

- E6 (low ethanol blends)
  - Low Nox in modern vehicles with oxygen sensors (higher in older vehicles)
  - Increased RVP and increased VOC's (and hence ozone formation)
  - Increased permeation emissions in older vehicles
  - Reduced CO emissions

  …but

  - Reduced permeation emissions (thicker hoses & plastics) in newer vehicles
  - California Low Emissions Vehicle II program reduces permeation and evaporative emissions (part of 2007 Federal Law)

… reasons to not like ethanol are disappearing!

Source: Personal Communications

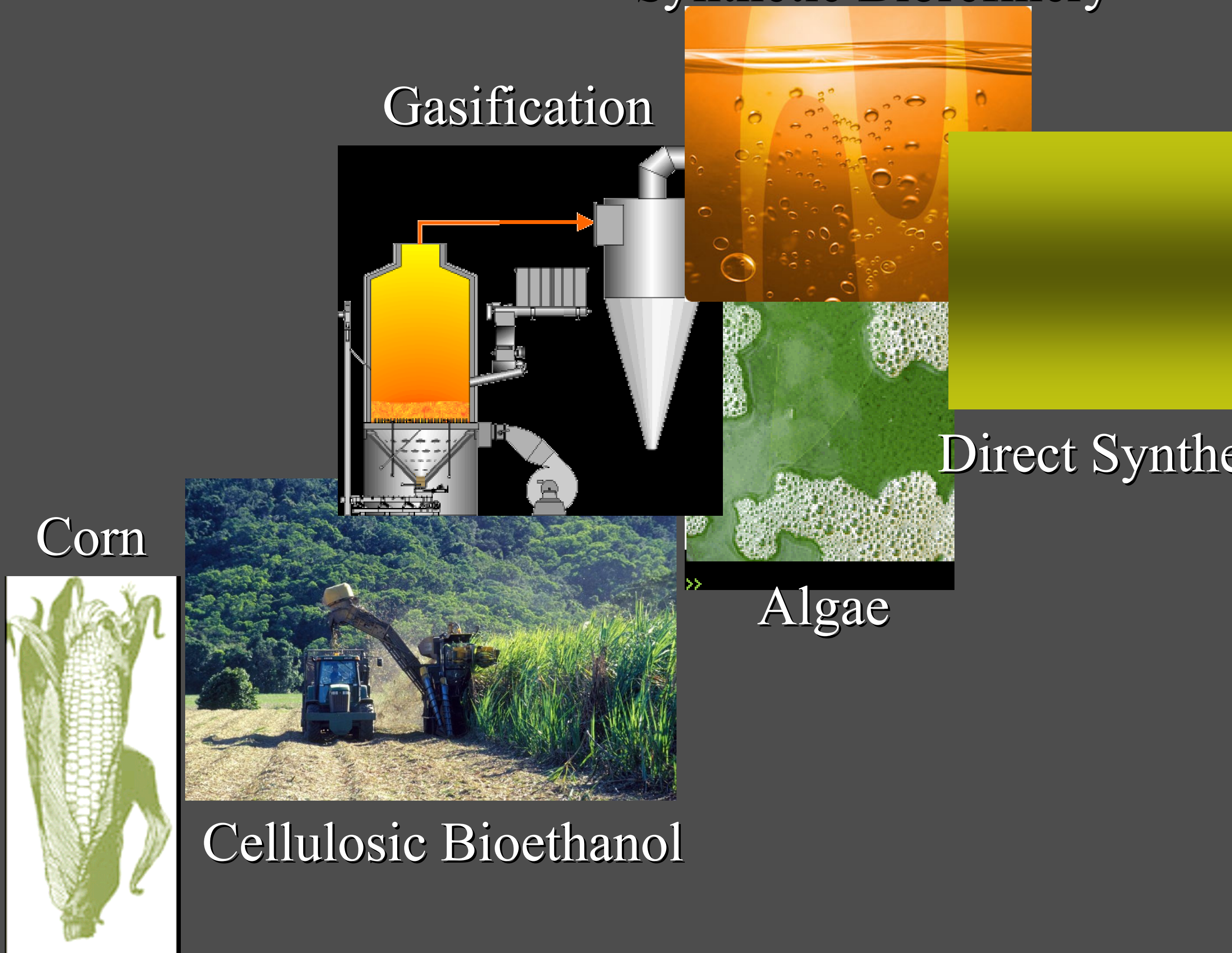
Environmental Issues (Cellulosic E85)

- Carbon emission reduction of 80%++ for light transportation
- Zero sulphur, low carbon monoxide, particulate & toxic emissions
- Co-production of animal protein & cellulosic biomass
  - Allows existing cropland to produce our energy needs
  - Reduces cost of animal feed & energy
- Energy Crops (Switchgrass):
  - Carbon enrichment of soil (immediate)
  - 2-8X lower nitrogen run-off
  - 75-120X lower topsoil erosion (compared to corn)
  - 2-5X more bird species
  - Resistant to infestation & disease; lower pesticide use

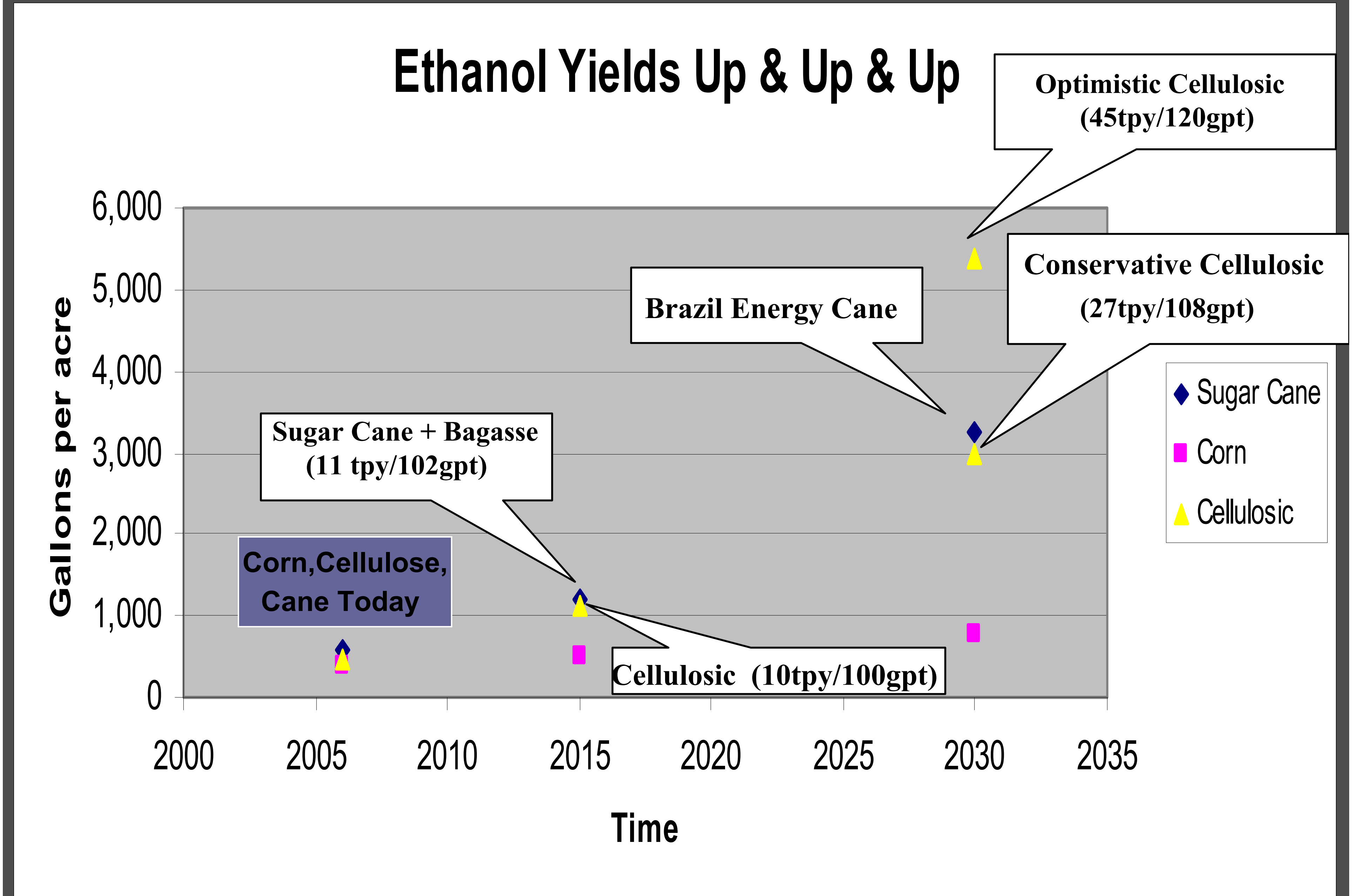
Technology Improvements

- Bioengineering
  - Enzymes
  - Plant engineering
- Process & Process Yields
  - Process Cost
  - Pre-treatment
  - Co-production of chemicals
  - Process Yield gals/ ton
  - Consolidated bioprocessing
- Energy crops
  - Miscanthus
  - Switch grass
  - Poplar
  - Willow
- "Out of the Box"
  - Thermochemical
  - Synthetic Biology
  - ????

Technology Progression



Exponential Improvements Are Not Just For Silicon



Companies & Technologies

- Celunol
- Clearfuels
- Canavialis
- Edenspace
- Agrivada
- Mascoma
- Synthetic Genomics
- Alellyx
- Unannounced….

- Novazyme
- Genencor
- Diversa
- Iogen
- Ceres
- Corn Ethanol Cos.
- Coal to Liquids
- MSW to Ethanol
- Big guys….

Ceres: What one company is doing…

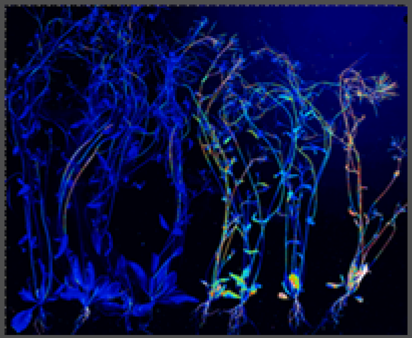
Expanding Usable Acreage…

Drought tolerance

Heat tolerance

Cold germination

Drought recovery



Drought Inducible Promoters

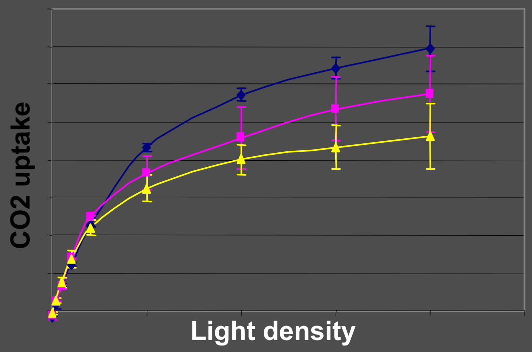
Salt tolerance

Source: Ceres Company Presentations

Increasing Tons per Acre…

Increased biomass

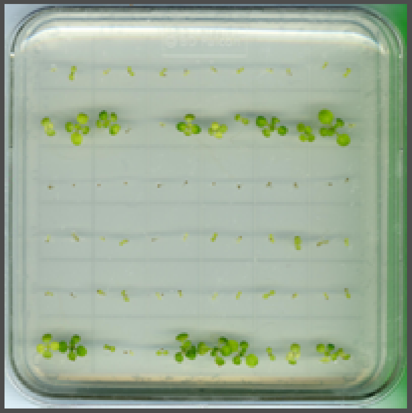
Flowering time



Photosynthetic Efficiency

Shade tolerance

Stature control

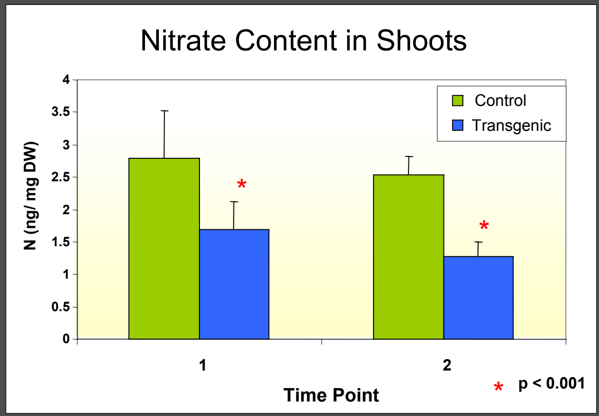


Herbicide tolerance

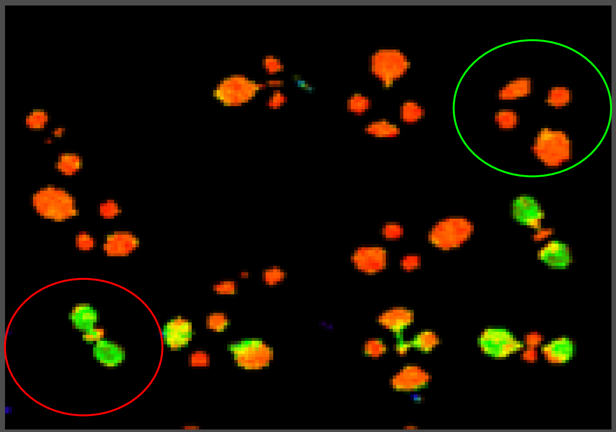
Source: Ceres Company Presentations

Reducing Dollars per Acre…

Nitrogen uptake



Nitrogen partitioning

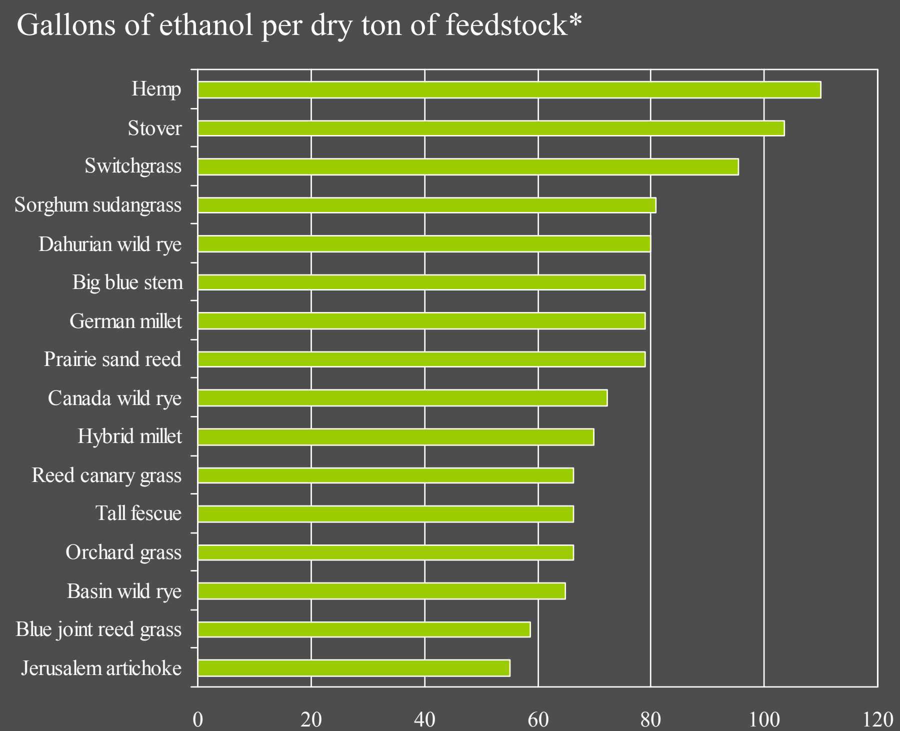


Photosynthetic efficiency
under low nitrogen

Increased root biomass

Source: Ceres Company Presentations

Increasing Gallons per Ton…



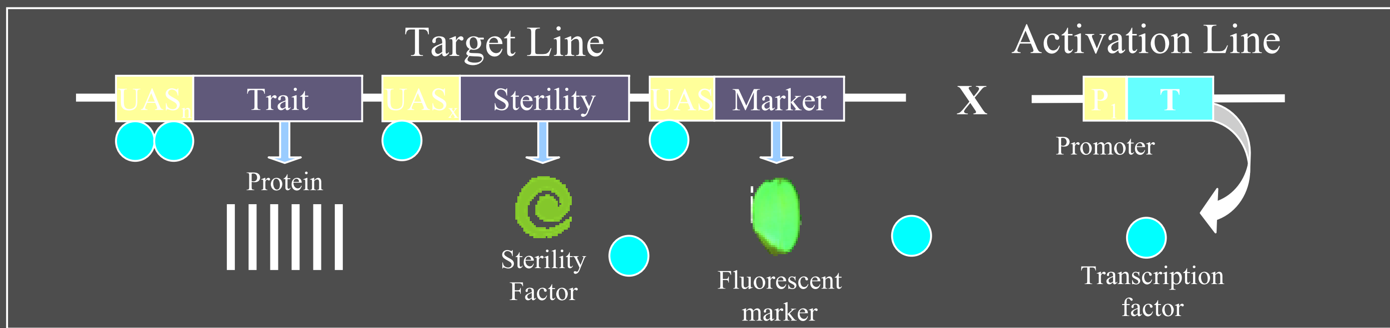
Composition
(How much carbohydrate is there?)

Plant structure
(How easy is it to access and digest?)

*Data represents theoretical yields as reported by Iogen

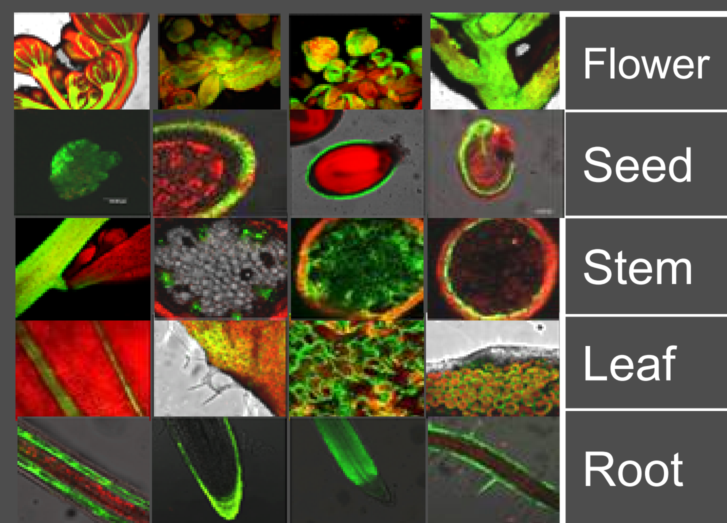
Source: Ceres Company Presentations

Reducing Cost Through Enzyme Production…



Ceres' proprietary gene expression system

Ceres promoter **Industry standard promoter**



Tissue-specific promoters

Source:Ceres Company Presentations

Ceres : Developing Commercial Energy Crops

Generating Plant Material for DNA Libraries to be Used in Molecular Assisted Breeding

1 day after trimming

Re-growth after 15 days

Transformation with Ceres' Traits

Embryogenic callus

Shoot regenerated from callus

Plant regeneration

Ceres expects to have proprietary commercial varieties ready for market in 2-3 years and transgenic varieties in 5-7

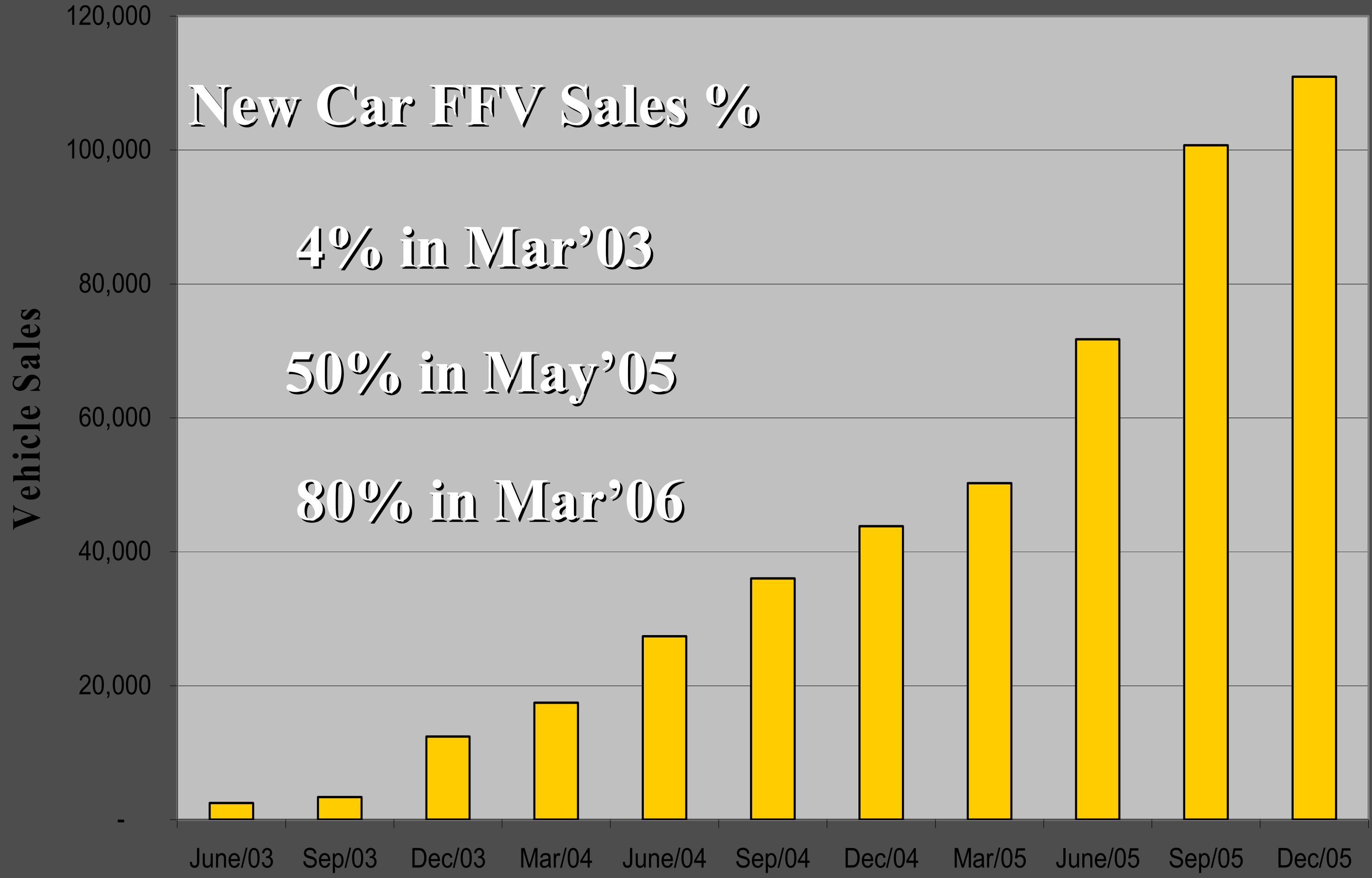
Source: Ceres Company Presentations

Strategy & Tactics

- Choice: Oil imports or ethanol imports?
- GDP – "beyond food to food & energy " rural economy
- Add $5-50B to rural GDP
- Better use for subsidies through "energy crops"
- Rely on entrepreneurs to increase capacity
- Biotechnology & process technology to increase yields

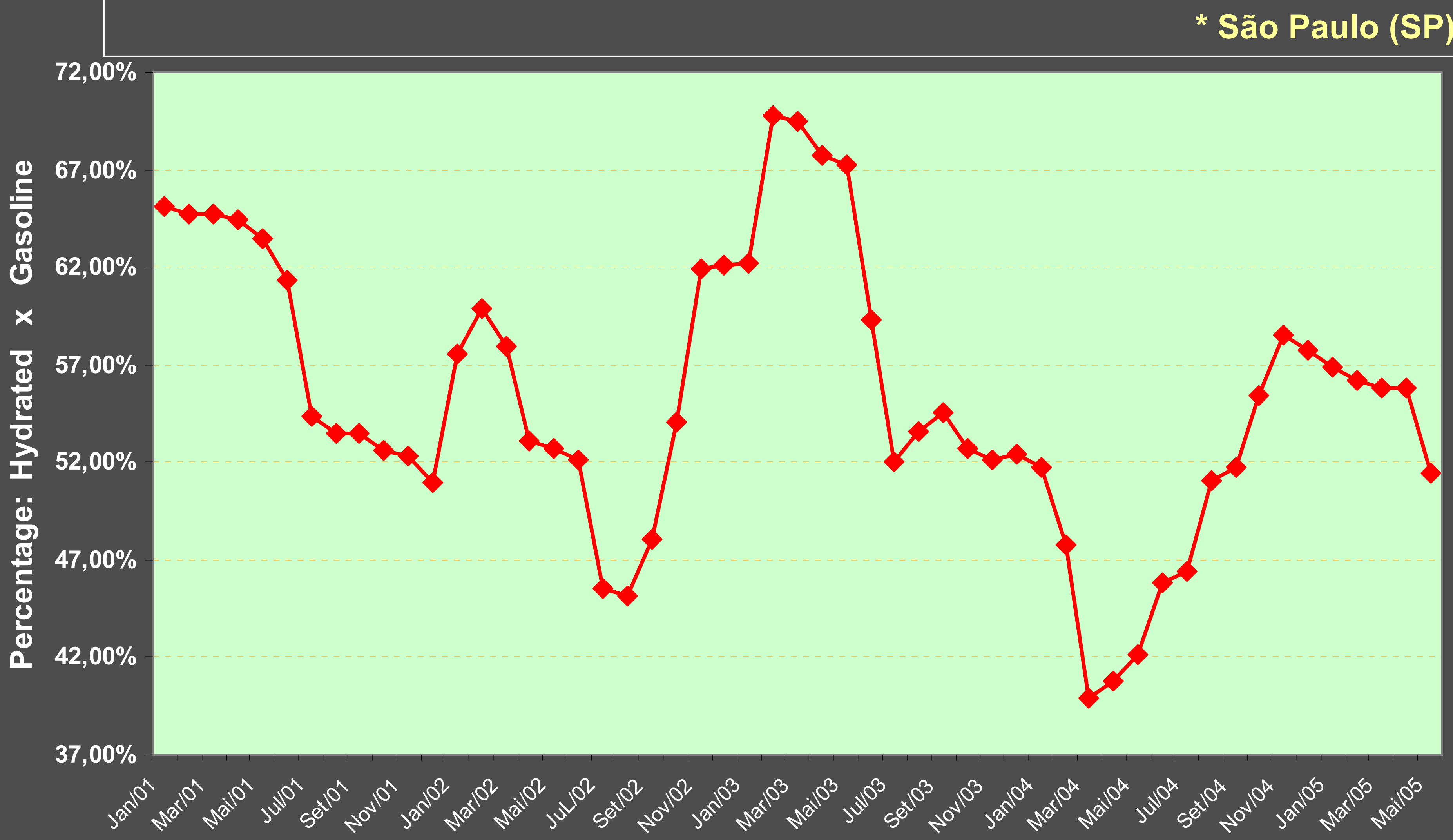
Brazil: A Role Model

Can Rapid Adoption of FFV Happen?



Nearly 8x increase in sales in only 2 years

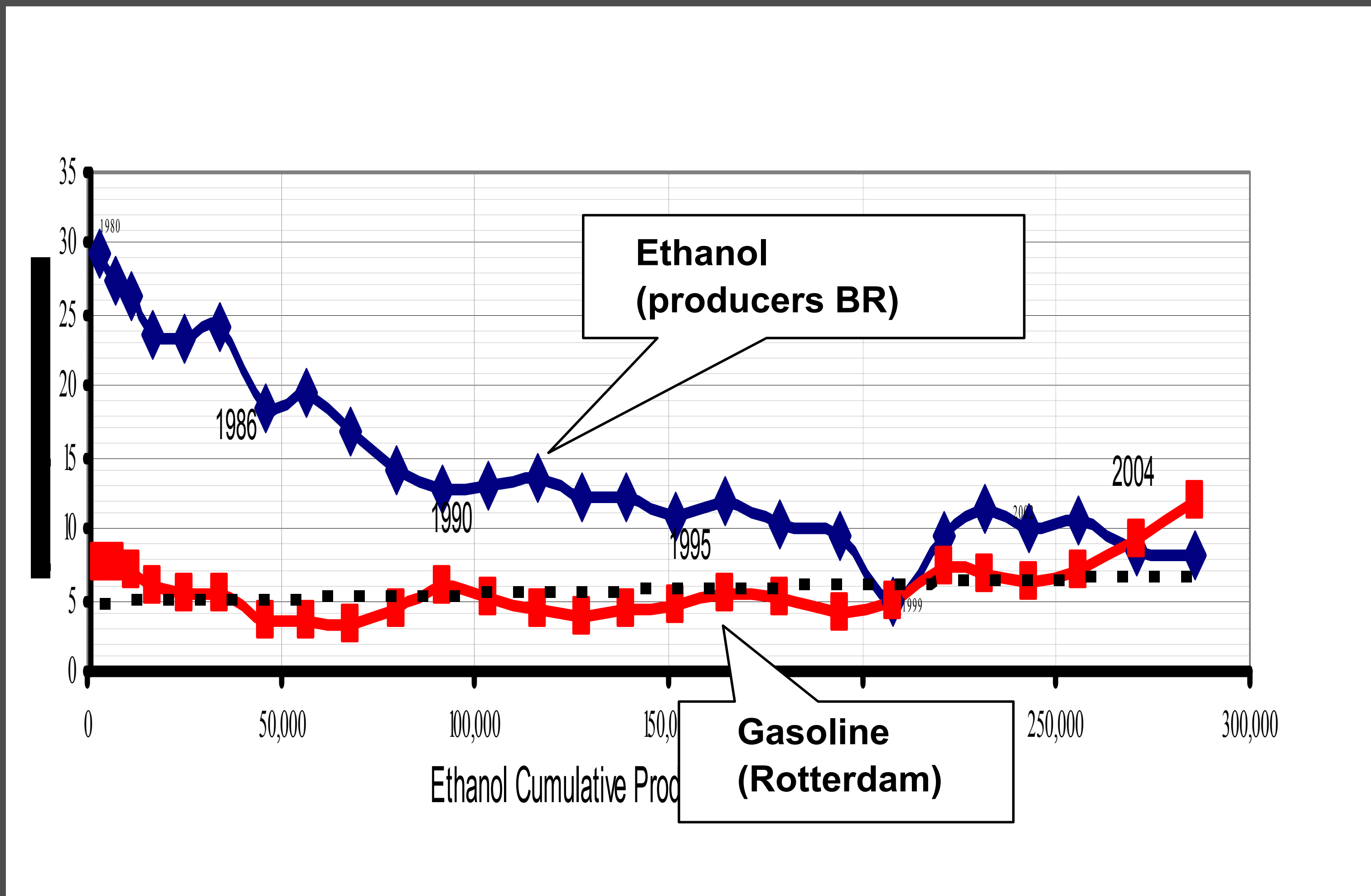
Consumer Price Ratio



Source: Honorable Roberto Rodrigues, Minister of Agriculture, Brazil
(Assessing Biofuels Conf., June 2005)

SOURCE: MAPA

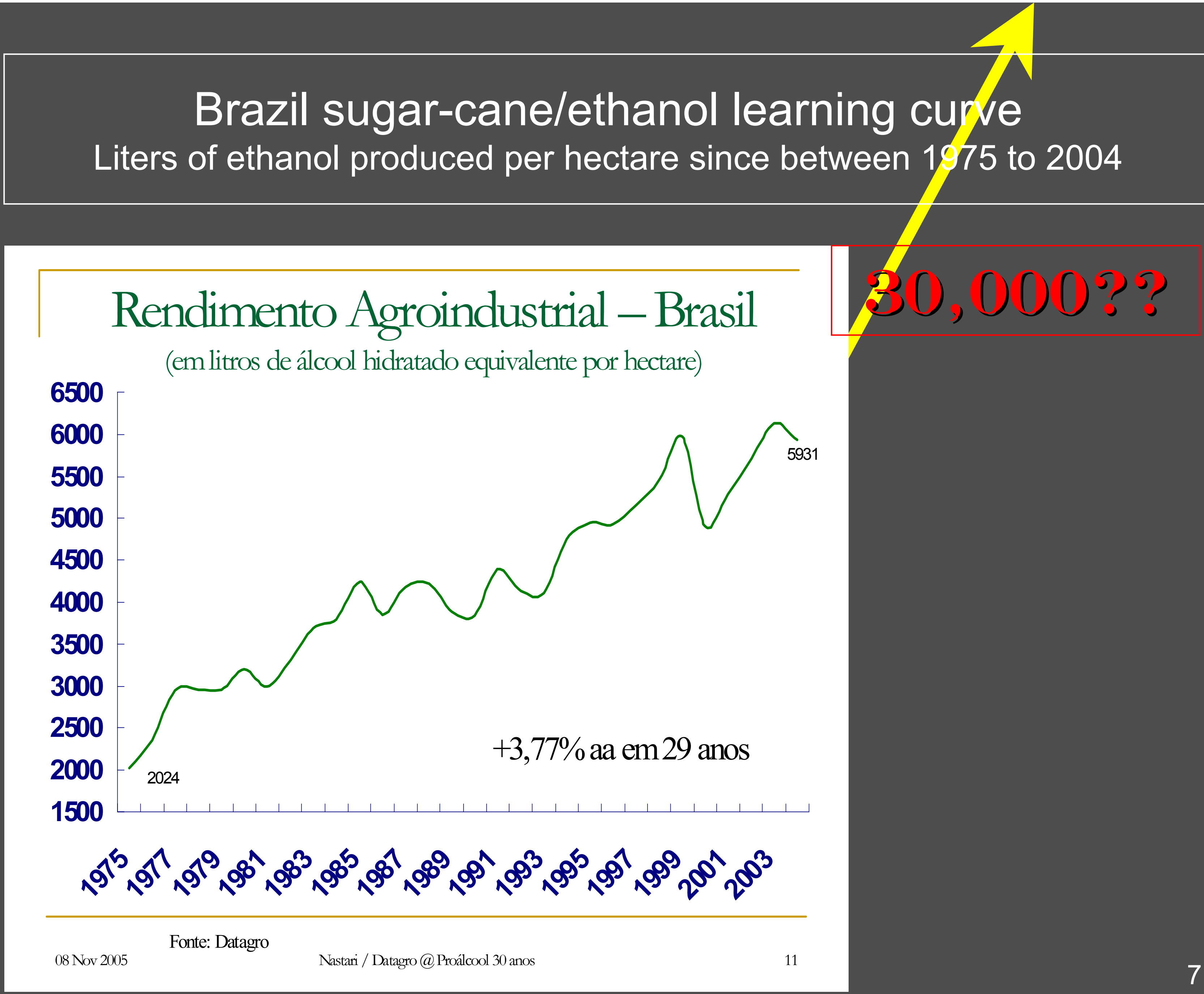
Ethanol: LEARNING CURVE



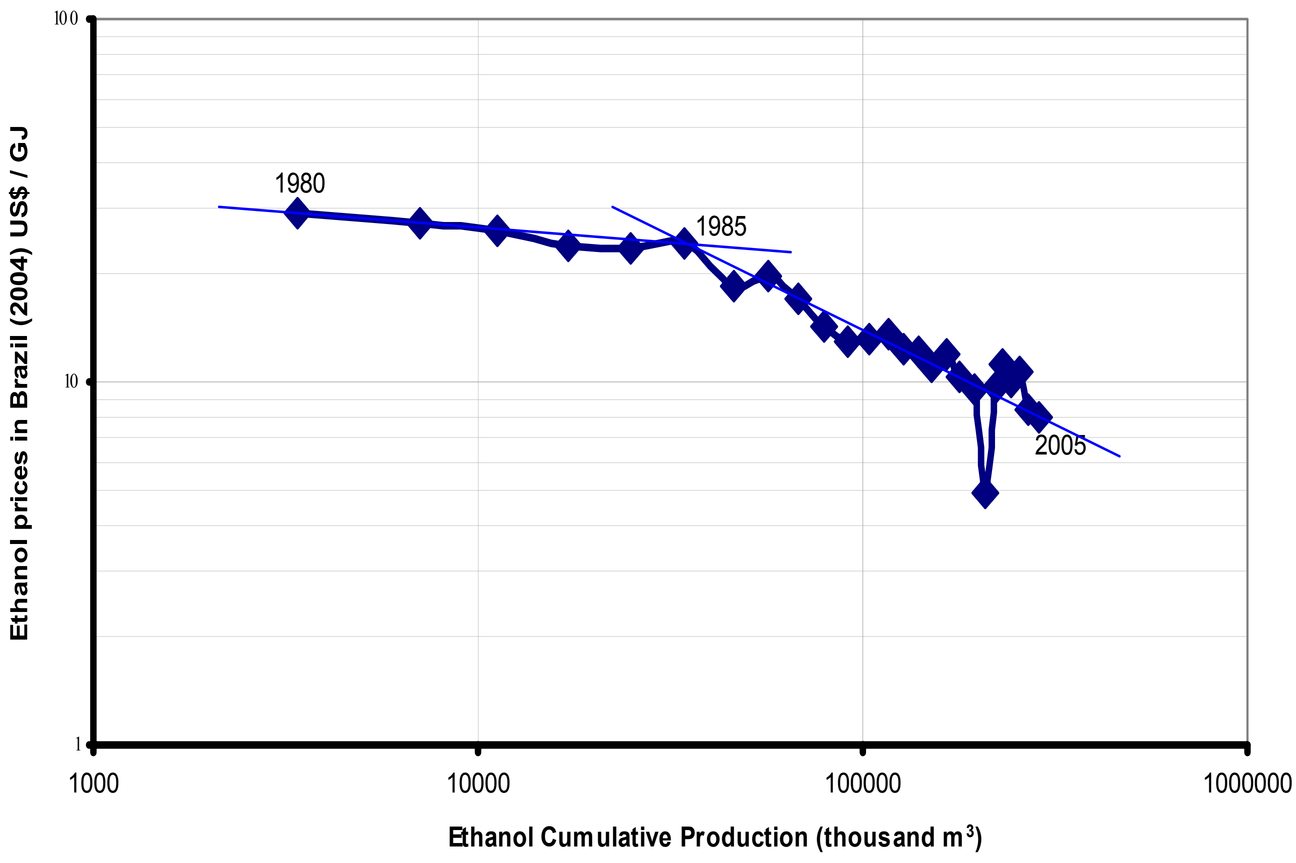
(J Goldemberg, 2004)

Brazil sugar-cane/ethanol learning curve

Liters of ethanol produced per hectare since between 1975 to 2004



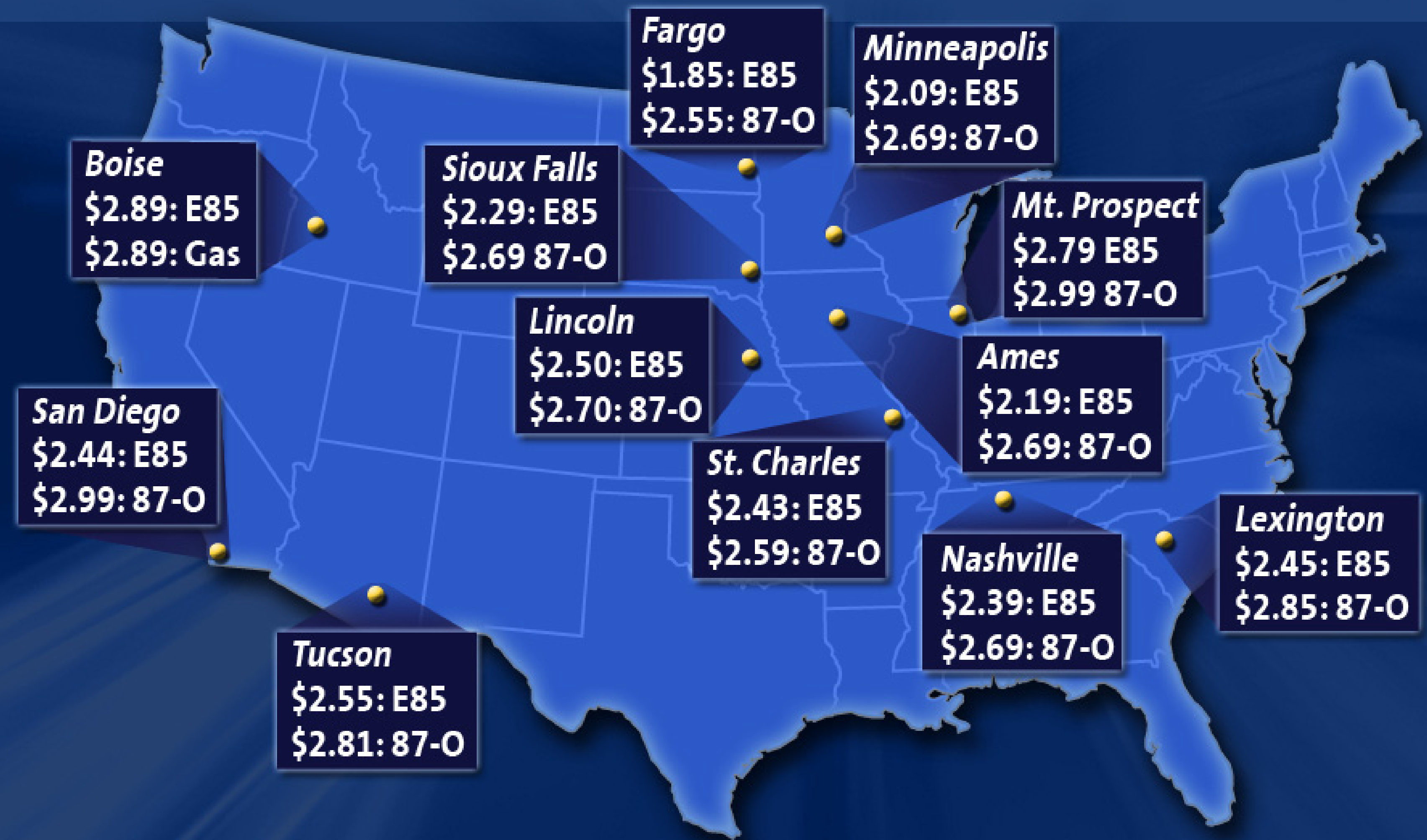
Ethanol Cost vs. Production Experience



Status: United States

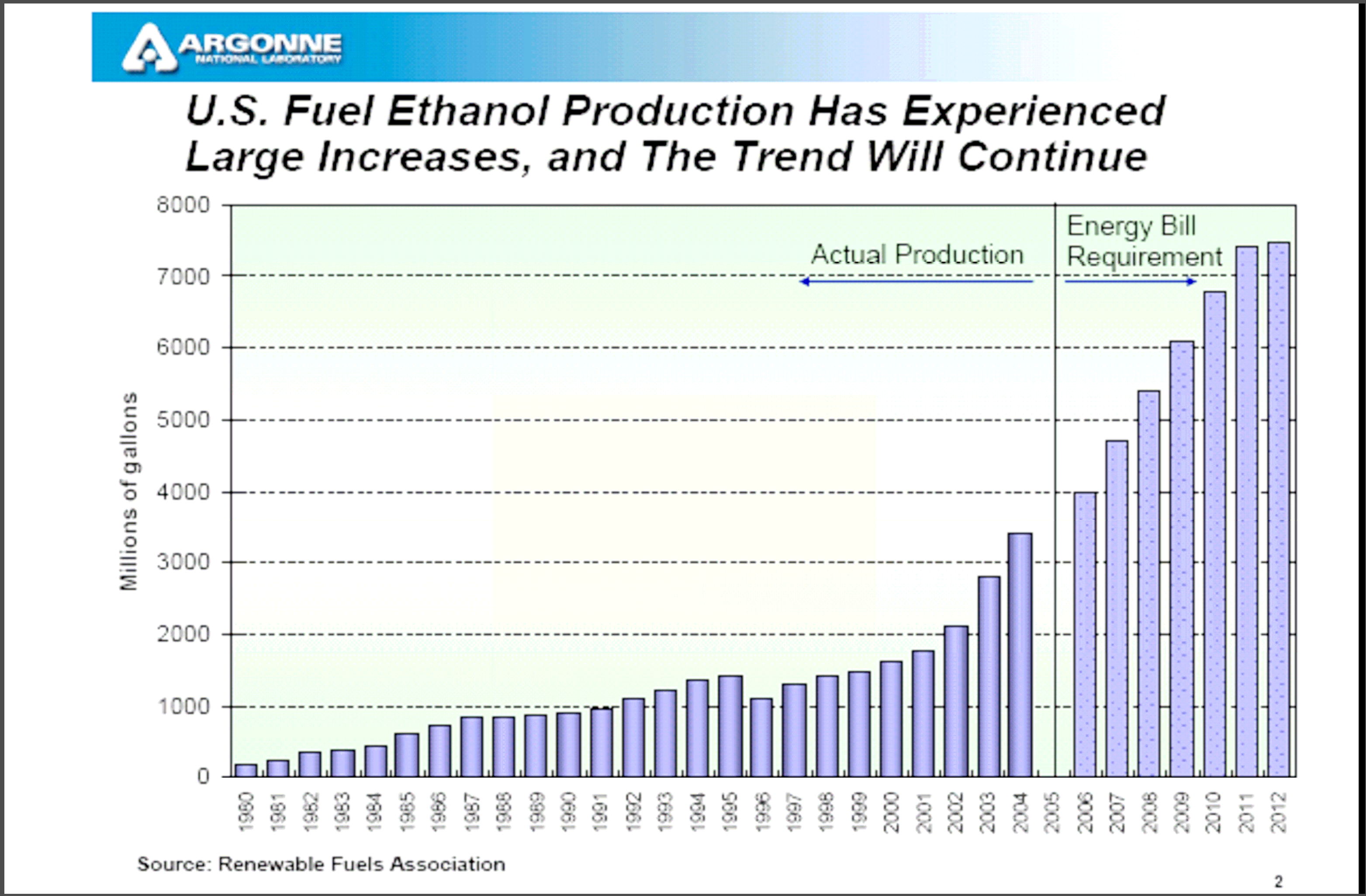
E85 Availability and Appeal

September 2005

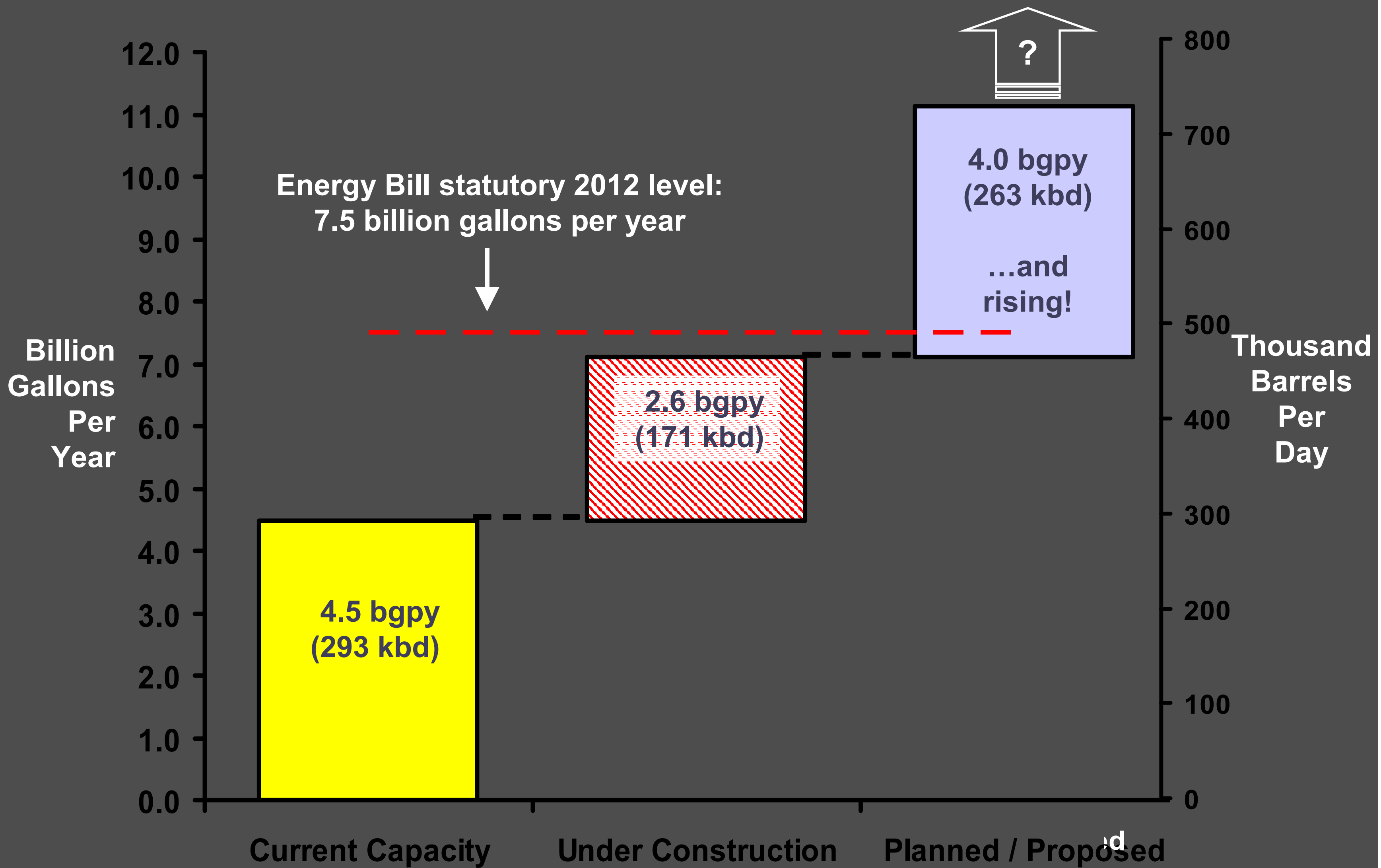


GM

Ethanol Capacity Expansion is Underway



US Ethanol Capacity Build-up



Source: Cambridge Energy Research Associates, Renewable Fuels Association

Ethanol FFVs Are Here!
California's Motor Vehicle Population

Vehicle Type	Gasoline	Diesel	**Ethanol FFV**	Hybrid gas/ elec	CNG	Electric	LPG/ other	H2
Light-Duty	24,785,578	391,950	**257,698**	45,263	21,269	14,425	538	13
Heavy-Duty	372,849	471,340	**--**	--	5,401	806	1,172	--

source: California Energy Commission joint-agency data project with California Department of Motor Vehicles. Ethanol FFV data as of April 2005; all other data as of October 2004.

Costs

	Wet Mills	Dry Mills	Overall Weighted Average
Electricity & Fuel	$0.112/gallon	$0.131/gallon	$1.118/gallon
Operating Labor, Repairs and Maintenance	$0.124/gallon	$0.109/gallon	
Yeast, Enzymes, Chemicals and Other	$0.114/gallon	$0.090/gallon	
Administration, Insurance and Taxes	$0.038/gallon	$0.037/gallon	
All Other Costs	$0.072/gallon	$0.051/gallon	
Total Cash Costs	$0.46/gallon	$0.42/gallon	
Combined with Net "NET" cost of corn	$0.48/gallon	$0.53/gallon	$0.94/gallon
Depreciation (plant & Equip)	$0.10-$0.20	$0.10-$0.20	

Note: Capital costs of ethanol production are estimated to be between $1.07/gallon to $2.39/gallon, varying with facility type, size, and technology.

Source: Encyclopedia of Energy (Ethanol Fuels , Charlie Wyman)

NY Times Poll (3/2/2006)

- Washington mandate more efficient cars – 89%
- No on Gasoline tax -87%
- No on Tax to reduce dependence on foreign oil -37%
- No on gas tax to reduce global warming – 34%

Energy Bill 2005

ARGONNE
NATIONAL LABORATORY

The Energy Bill Encourages Production of Cellulosic Ethanol

- Creates a credit-trading program where 1 gallon of cellulosic ethanol is equal to 2.5 gallons of renewable fuel
- Creates a program for production of 250 million gallons of cellulosic ethanol in 2013
- Creates a Loan Guarantee Program of $250 million per facility
- Creates a $650 million Grant Program for cellulosic ethanol
- Creates an Advanced Biofuels Technologies Program of $550 million

Comments?

Vinod Khosla
vk@khoslaventures.com

Ethanol Forecast

Year	Billion Gals Eth. Capacity		Yield (tons/ac)	Yield (Gals/ton)	Million Acres Biomass Ac.	Production Cellu.Eth. Gals (Billions)	Production Corn Eth. Gals (Billions)	Year	Production Total Eth (Billions gals)	Ethaol Prod. Gas. Eq (Billions gal)	Gasoline Demand(2%) (Billions Gal)	Gasoline Demand(1%) (Billions Gal)	Investment $ (Billions $$)
2005	4	4	6	80	0	0	4.0	2005	4.0	3.2	140	140	1.0
2006	4.8	4.6	6.3	83.2	0	0	4.8	2006	4.8	3.8	142.8	141.4	1.2
2007	5.8	5.3	6.6	86.5	0	0	5.8	2007	5.8	4.6	145.7	142.8	1.7
2008	6.9	6.1	6.9	90.0	0.2	0.1	6.9	2008	7.0	5.6	148.6	144.2	2.0
2009	8.3	7.0	7.3	93.6	0.4	0.3	8.3	2009	8.6	6.9	151.5	145.7	3.0
2010	10.0	8.0	7.8	97.3	1	0.8	10.0	2010	10.7	8.6	154.6	147.1	4.7
2011	11.9	9.3	8.3	98.3	3	2.5	10.9	2011	13.4	10.7	157.7	148.6	5.3
2012	14.3	10.6	8.9	99.3	5	4.4	12.0	2012	16.5	13.2	160.8	150.1	7.0
2013	17.2	12.2	9.6	100.3	7.5	7.2	13.2	2013	20.4	16.4	164.0	151.6	8.0
2014	20.6	14.1	10.2	101.3	10	10.4	14.6	2014	24.9	19.9	167.3	153.1	8.4
2015	24.8	16.2	10.9	102.3	13	14.6	14.6	2015	29.1	23.3	170.7	154.6	9.6
2016	28.5	17.8	11.7	103.3	16	19.4	14.6	2016	33.9	27.1	174.1	156.2	11.0
2017	32.8	19.6	12.5	104.4	19	24.8	14.6	2017	39.4	31.5	177.6	157.8	12.5
2018	37.7	21.5	13.4	105.4	22	31.1	14.6	2018	45.7	36.5	181.1	159.3	14.2
2019	43.3	23.7	14.3	106.5	25	38.2	14.6	2019	52.8	42.2	184.7	160.9	16.1
2020	49.8	26.1	15.4	107.5	28	46.2	14.6	2020	60.8	48.6	188.4	162.5	17.1
2021	57.3	28.7	16.3	108.6	31	54.8	14.6	2021	69.3	55.5	192.2	164.2	17.8
2022	65.9	31.5	17.2	108.6	34	63.7	14.6	2022	78.3	62.6	196.0	165.8	19.6
2023	75.8	34.7	18.3	108.6	37	73.5	14.6	2023	88.0	70.4	200.0	167.5	21.4
2024	87.1	38.2	19.4	108.6	40	84.2	14.6	2024	98.8	79.0	204.0	169.1	23.5
2025	100.2	42.0	20.5	108.6	43	95.9	14.6	2025	110.5	88.4	208.0	170.8	25.7
2026	115.2	46.2	21.8	108.6	46	108.8	14.6	2026	123.3	98.7	212.2	172.5	28.1
2027	132.5	50.8	23.1	108.6	49	122.8	14.6	2027	137.4	109.9	216.4	174.3	30.7
2028	152.4	55.9	24.5	108.6	52	138.2	14.6	2028	152.7	122.2	220.8	176.0	33.5
2029	175.2	61.5	25.9	108.6	55	154.9	14.6	2029	169.5	135.6	225.2	177.8	36.5
2030	201.5	67.6	27.5	108.6	58	173.2	14.6	2030	187.7	150.2	229.7	179.5	35.0

Source: Vinod Khosla

References

- NRDC Report: “Growing Energy” (Dec 2004)
- http://soilcarboncenter.k-state.edu/conference/carbon2/Fiedler1_Baltimore_05.pdf
- George Schultz & Jim Woolsey white paper “Oil & Security”
- Rocky Mountain Institute: “Winning the Oil Endgame”
- http://www.unfoundation.org/features/biofuels.asp
- http://www.transportation.anl.gov/pdfs/TA/354.pdf
- The Future of the Hydrogen Economy (http://www.oilcrash.com/articles/h2_eco.htm#8.2)
- Fuel Ethanol: Background & Public Policy Issues (CRS Report for Congress, Dec. 2004)

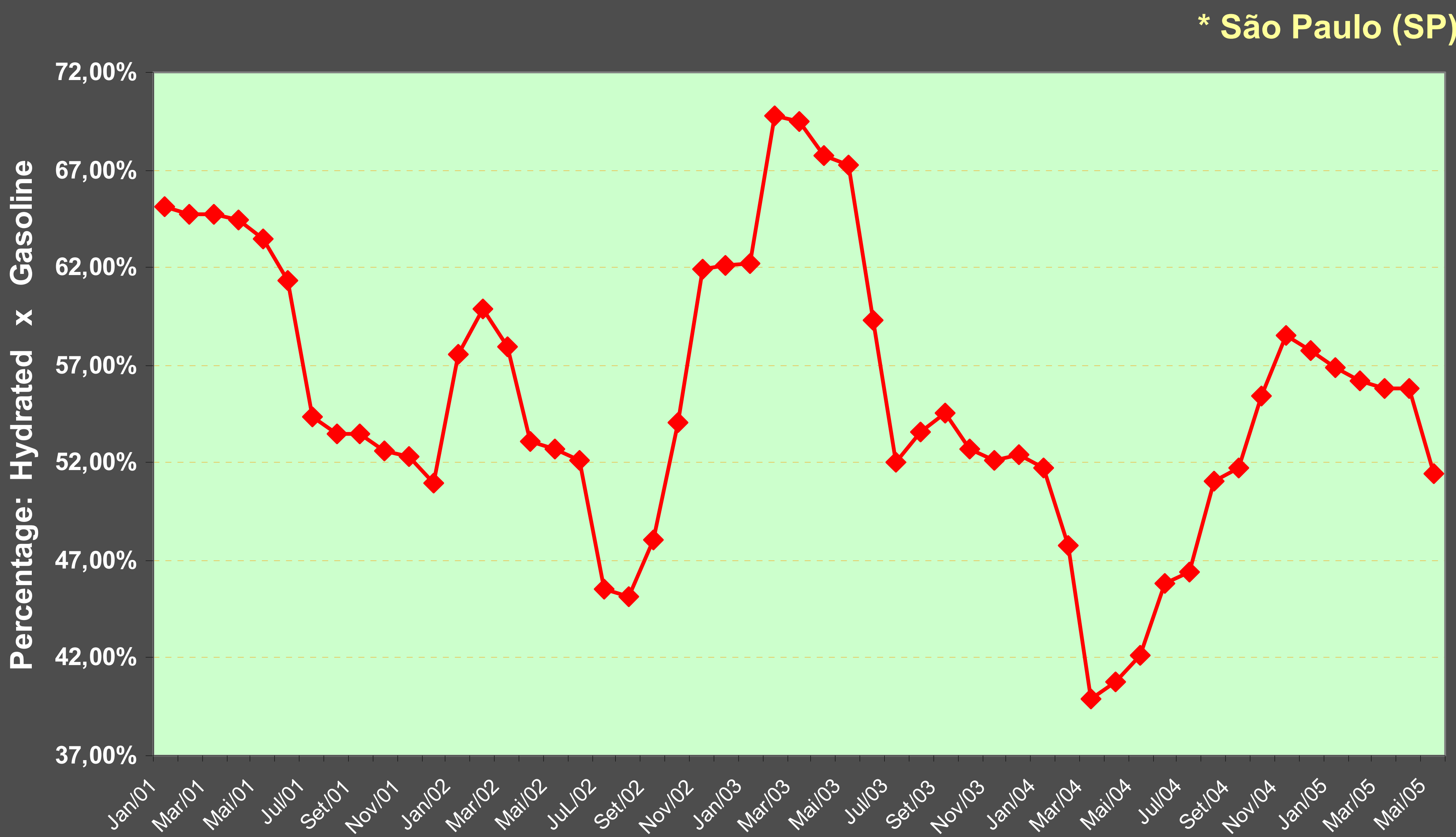
ETHANOL: MARKET PERSPECTIVE

Luiz Carlos Corrêa Carvalho
Sugar and Alcohol Sectorial Chamber, Ministry of Agriculture, Brazil

Assessing the Biofuels Option

Joint Seminar of the International Energy Agency, the Brazilian Government and the United Nations Foundation
Paris, 20 – 21 June 2005

Consumer Prices Ratio*



Source: Honorable Roberto Rodrigues, Minister of Agriculture, Brazil (Assessing Biofuels Conf., June 2005

SOURCE: MAPA

Current Situation

- **Alcohol-gasoline mixture set to 25% since July, 2003.**
- **The automotive industry has launched "flexible-fuel cars" in March, 2003.**
- **Advantage to alcohol consumption if oil prices are above US$ 35 / per barrel.**
- **Total consumption: ~ 200,000 barrels / day of equivalent gasoline (30,000 gas-stations).**
- **~ 40% of total consumption of spark ignition cars (Otto Cycle Engines).**
- **May, 2005: for the first time, flexi-fuel vehicles sales exceeded gasoline-fueled vehicle sales, 49.5% against 43.3%.**

Source: Honorable Roberto Rodrigues, Minister of Agriculture, Brazil
(Assessing Biofuels Conf., June 2005

Comparative Energy Balance

Raw Material	Total Energy Ratio
Corn	1.21
Switchgrass	4.43
Sugarcane	8.32

Source: Leal, Regis, CO_2 Life Cycle Analysis of Ethanol Production and Use, LAMNET, Rome, may 2004

LIFE CYCLE GHC EMISSIONS IN ETHANOL PRODUCTION AND USE

	Kg CO_2 equiv./ t cane	
	Average	Best Values
Emissions	34,5	33,0
Avoided Emissions	255,0	282,3
Net Avoided Emissions	220,5	249,3
Anhydrous Ethanol	2,6 to 2,7 t CO_2 equiv./m^3 ethanol	

Source: Leal, Regis, CO2 Life Cycle Analysis of Ethanol Production and Use, LAMNET, Rome, may 2004

ETHANOL AND EMPLOYMENT

(IN THE PRODUCTION OF THE VEHICLE AND OF FUEL)

VEHICLES	RATIO OF EMPLOYMENTS
ETHANOL	21,87
"C" GASOLINE	6,01
"A" GASOLINE	1

Considering that an ethanol driven vehicle consumes, on average, 2.600 litres of ethanol per year (one million litres of ethanol, per year, generates 38 direct jobs);for gasoline, spends 20% less fuel (one million litres of gasoline, per year, generates 0,6 direct jobs); "C" gasoline contains 25% ethanol.

Source: Copersucar/Unica/ANFAVEA/PETROBRAS

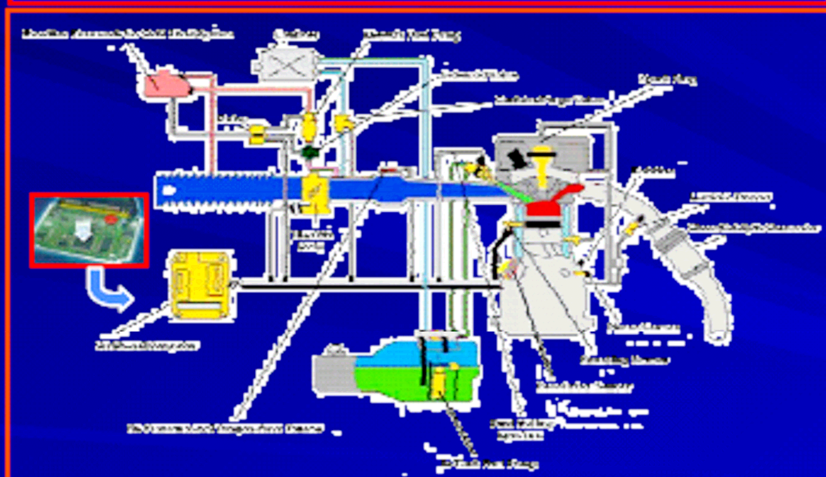

160°
140°
120°
100°
80°
60°
40°
20°
0°
20°
40°
60°
80°
100°
120°
140°
160°
180°
80°
60°
40°
20°
0° EQUADOR
20°
40°
60°
OCEANO GLACIAL ÁRTICO
CÍRCULO POLAR ÁRTICO
AMÉRICA DO NORTE
EUROPA
ÁSIA
TRÓPICO DE CÂNCER
AMÉRICA CENTRAL
ÁFRICA
AMÉRICA DO SUL
OCEANO ÍNDICO
OCEANIA
TRÓPICO DE CAPRICÓRNIO
OCEANO ATLÂNTICO
OCEANO PACÍFICO
LINHA INTERNACIONAL DA DATA
CÍRCULO POLAR ANTÁRTICO
OCEANO GLACIAL ANTÁRTICO
ANTÁRTIDA

The Ethanol application as vehicular fuel in Brazil.

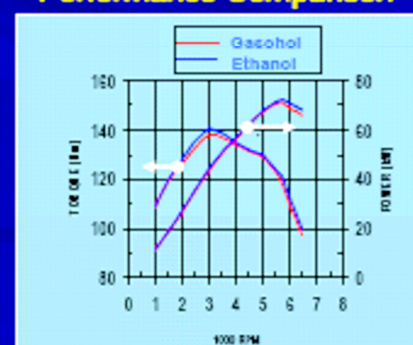
Brazilian Automotive Industry Association - ANFAVEA
Energy & Environment Commission
Henry Joseph Jr.

Flex Fuel Vehicles (FFV)

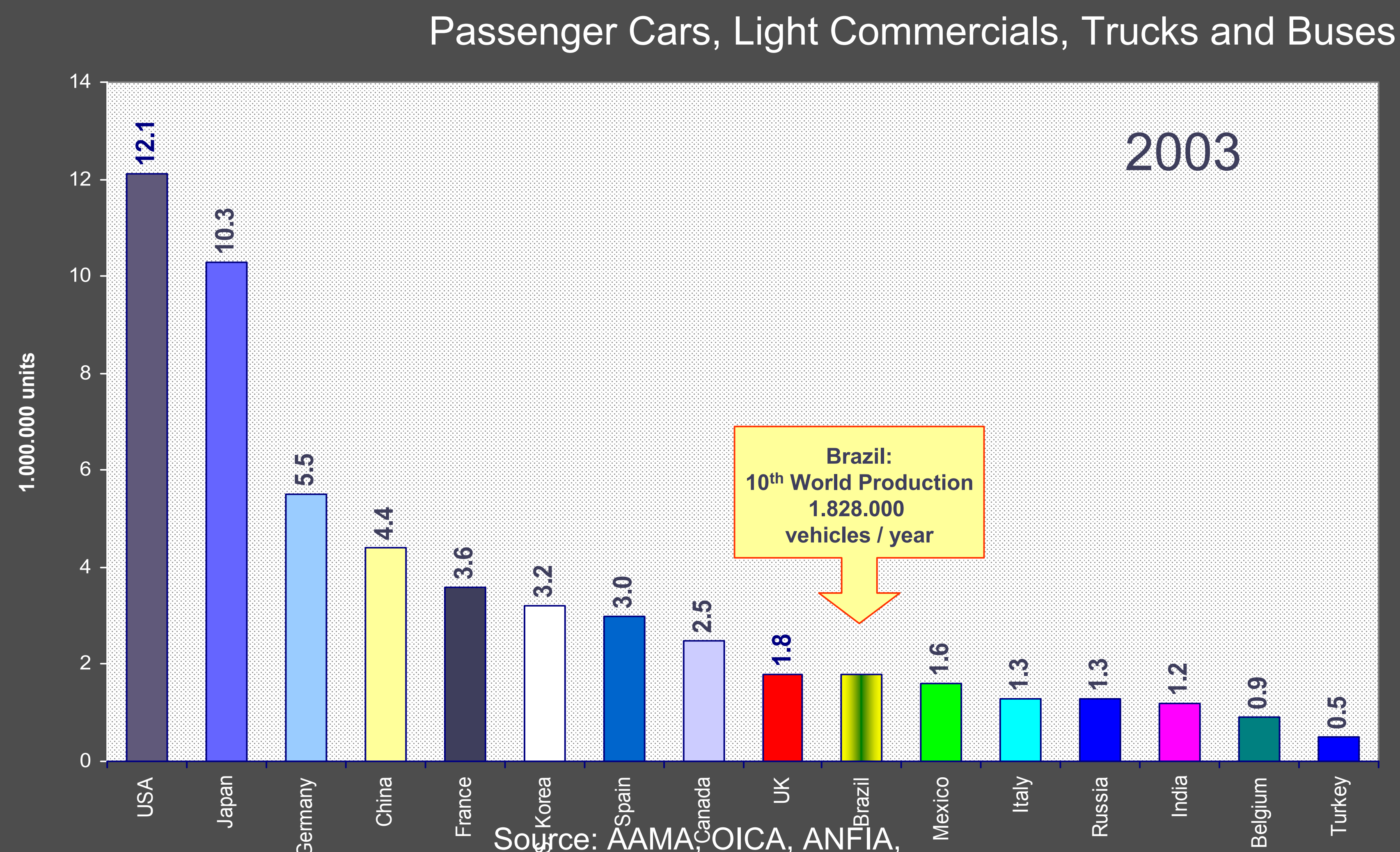
Through some special electronic sensors, the on-board computer recognizes the fuel and properly adjust the engine combustion parameters without any interference from the driver.



Performance Comparison



3. Brazilian Domestic Production of Vehicles



Source: AAMA, OICA, ANFIA, IMT, INA, ANFAVEA, SMMT, Wards Comm.

Vehicle Modifications

Carburetor

The material of the carburetor body or carburetor cover cannot be aluminum or exposed Zamak; if it is, must be substituted, protect with surface treatment or anodize;

Any component in polyamide 6.6 (Nylon) that has contact with the fuel must be substituted by other material or protected;

The material of buoy, nozzle, metering jet, floating axle, seals, gaskets and o-rings must be appropriated.

Engine

The engine compression ratio should be higher;

Camshaft with new cam profile and new phase;

New surface material of valves (intake and exhaust) and valve seats.

Intake Manifold

With new profile and less internal rugosity, to increase the air flow;

Must provide higher intake air temperature.

Fuel Tank

If the vehicle fuel tank is metallic, the internal surface of tank must be protected (coated);

Any component in polyamide 6.6 (Nylon) that has contact with the fuel must be substituted by other material or protected.

Higher fuel tank capacity, due to the higher fuel consumption.

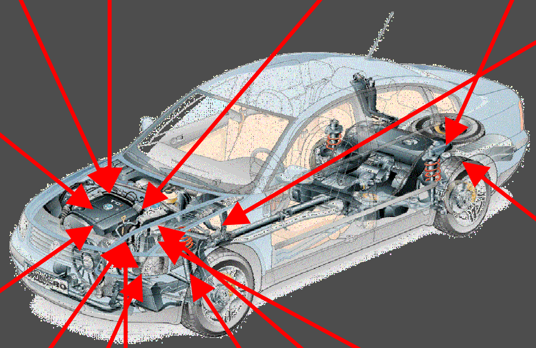
Electronic Fuel Injection

Substitution of fuel injector material by stainless steel;

New fuel injector design to improve the "fuel spray";

New calibration of air-fuel ratio control and new Lambda Sensor working range;

Any component in polyamide 6.6 (Nylon) that has contact with the fuel must be substituted by other material or protected.



Catalytic Converter

It is possible to change the kind and amount of noble metal present in the loading and wash-coating of catalyst converter;

The catalyst converter must be placed closer to the exhaust manifold, in order to speed up the working temperature achievement (light-off).

Exhaust Pipe

The internal surface of pipe must be protected (coated);

The exhaust design must be compatible with higher amount vapor.

Fuel Pump

The internal surface of pump body and winding must be protected and the connectors sealed;

Any component in polyamide 6.6 (Nylon) that has contact with the fuel must be substituted by other material or protected.

The pump working pressure must be increased.

Fuel Pressure Device

The internal surface of the fuel pressure device must be protected;

Any component in polyamide 6.6 (Nylon) that has contact with the fuel must be substituted by other material or protected.

The fuel pressure must be increased.

Motor Oil

New additive package.

Cold Start System

Auxiliary gasoline assisted start system, with temperature sensor, gasoline reservoir, extra fuel injector and fuel pump;

The vehicle battery must have higher capacity.

Fuel Filter

The internal surface of the filter must be protected;

The adhesive of the filter element must be appropriated;

The filter element porosity must be adjusted.

Ignition System

New calibration of advance control;

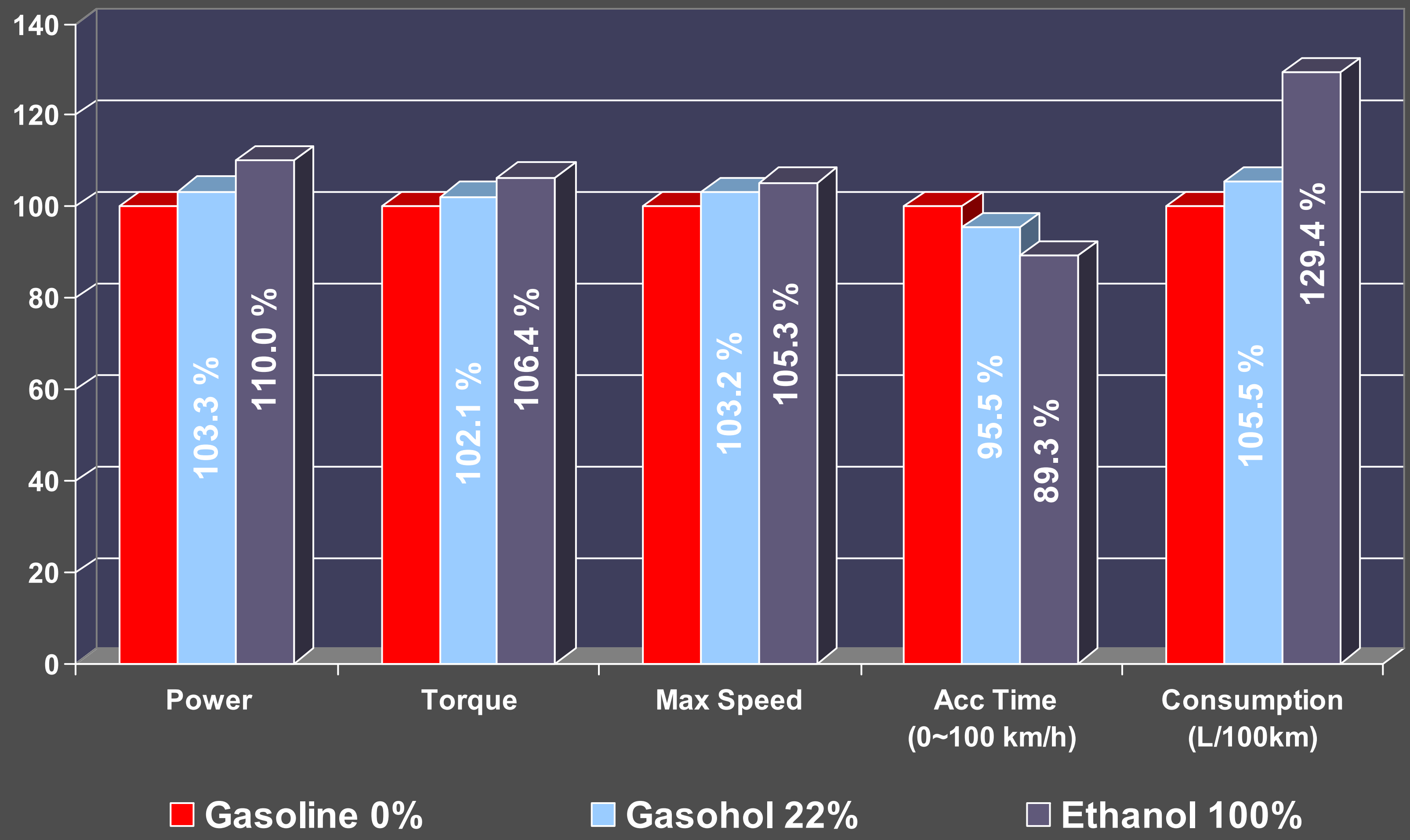
Colder heat rating spark plugs.

Evaporative Emission System

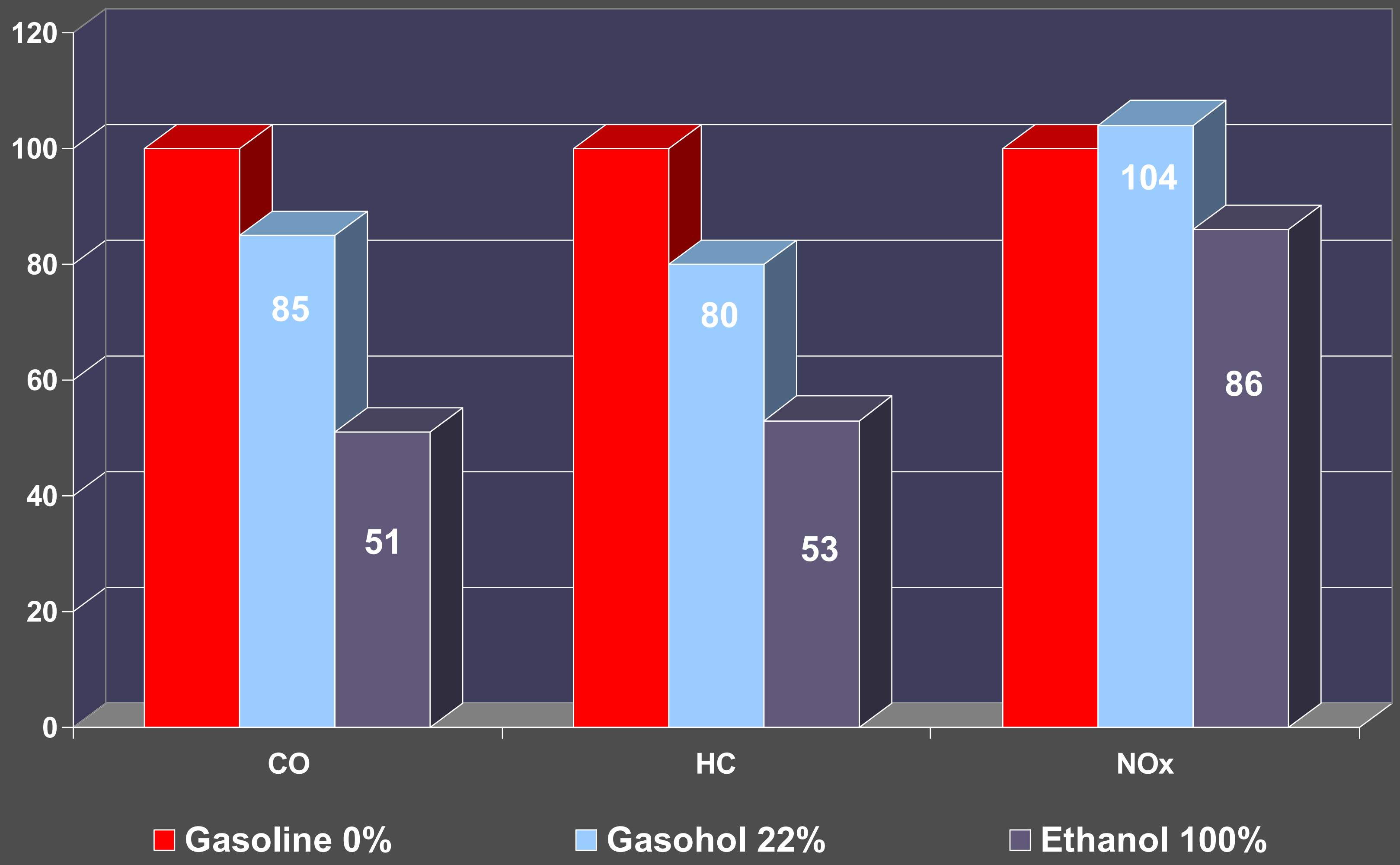
Due to the lower fuel vapor pressure, it is not necessary evaporative emission control.

(Otto Engines)

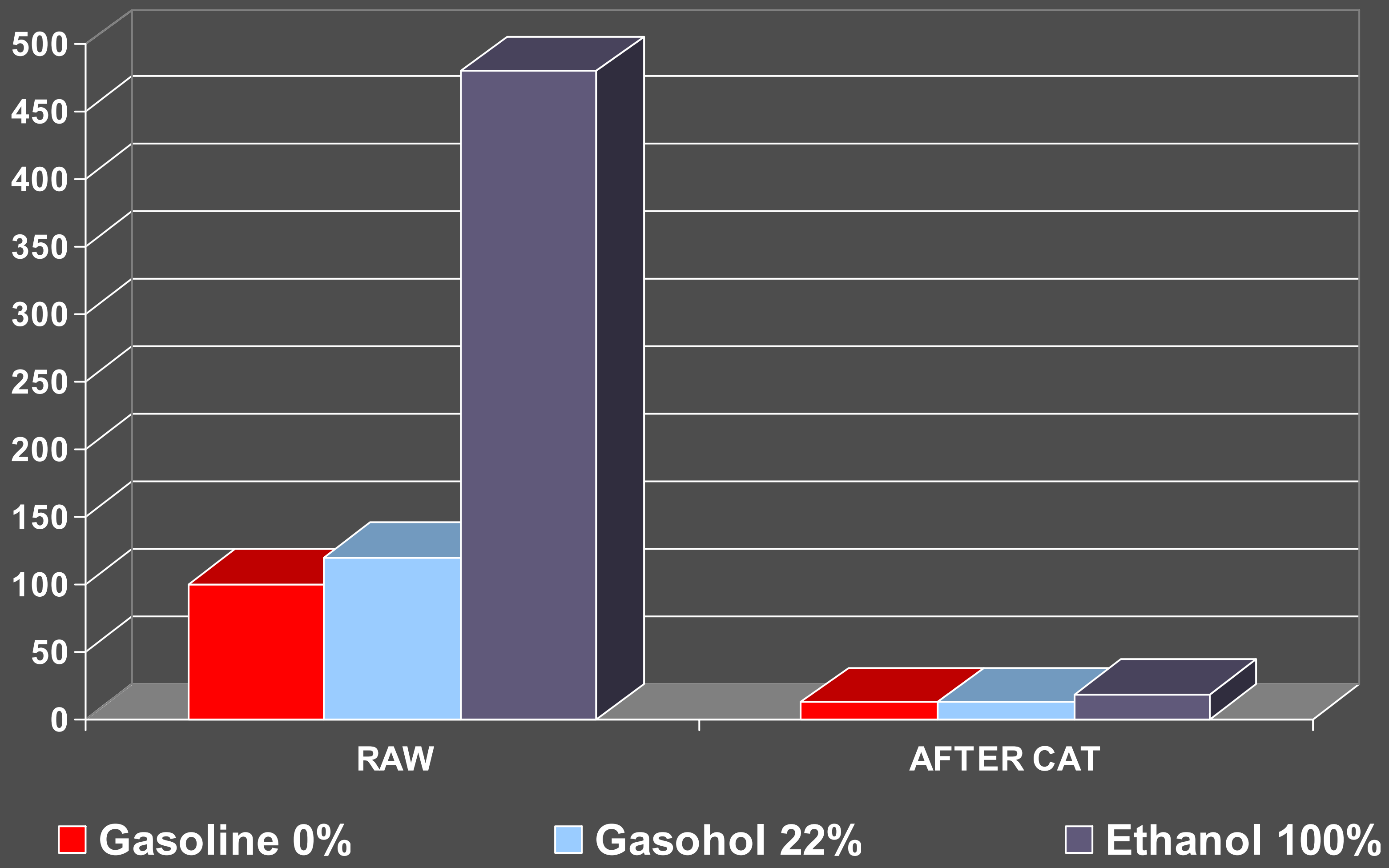
8. Relative Performance of Ethanol Engines



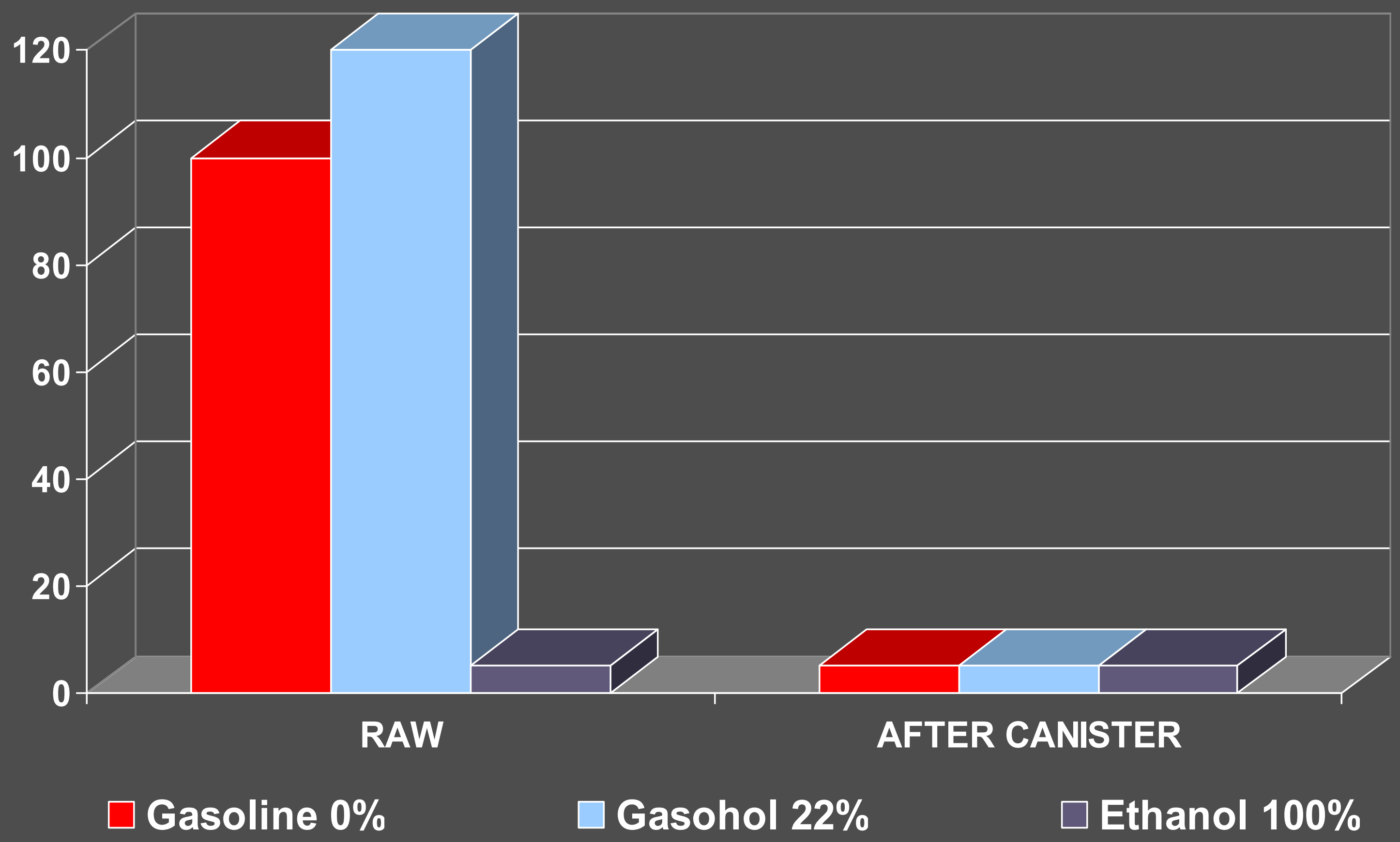
10. Comparative Raw Exhaust Emission



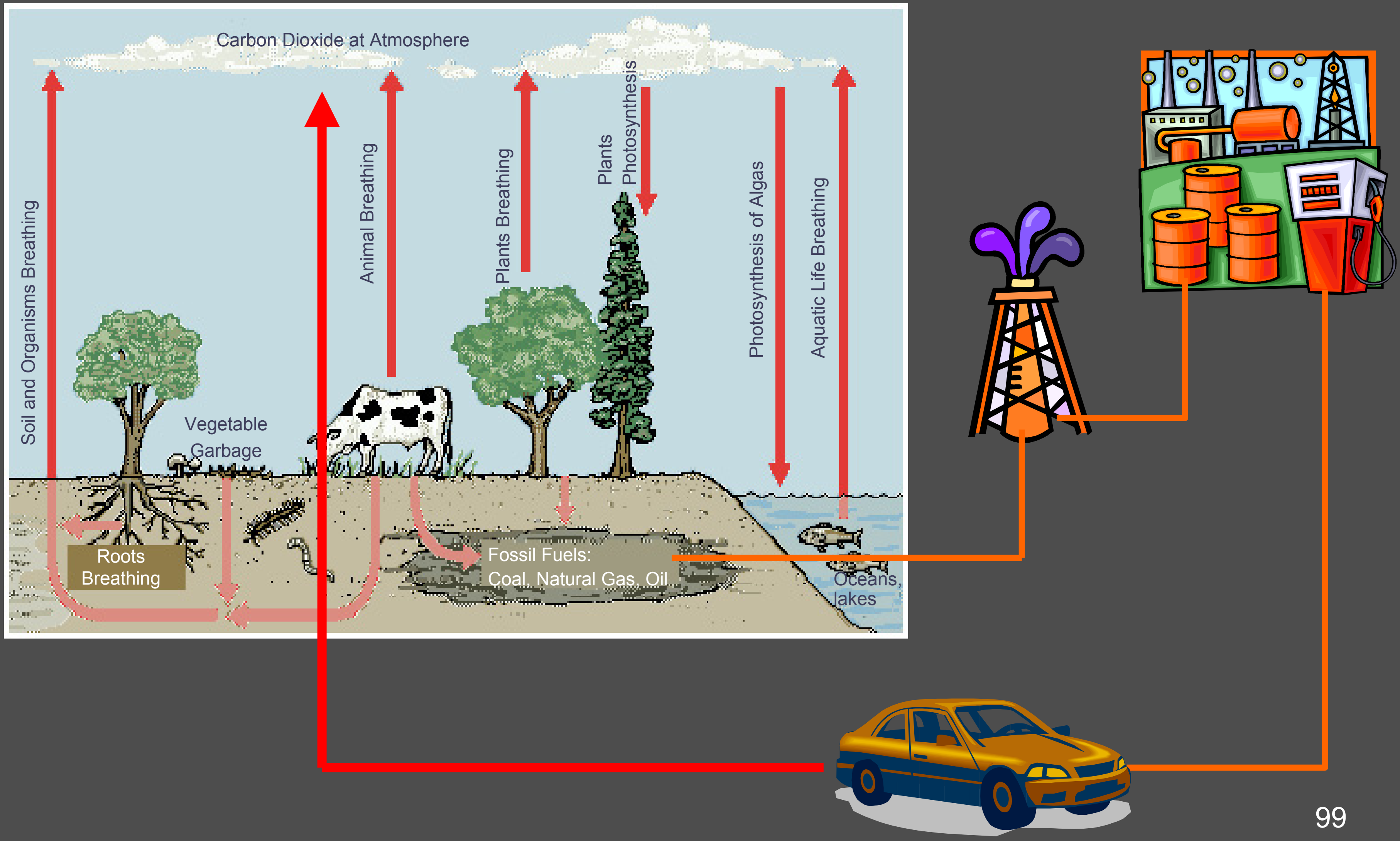
15. Comparative Aldehyde Emission



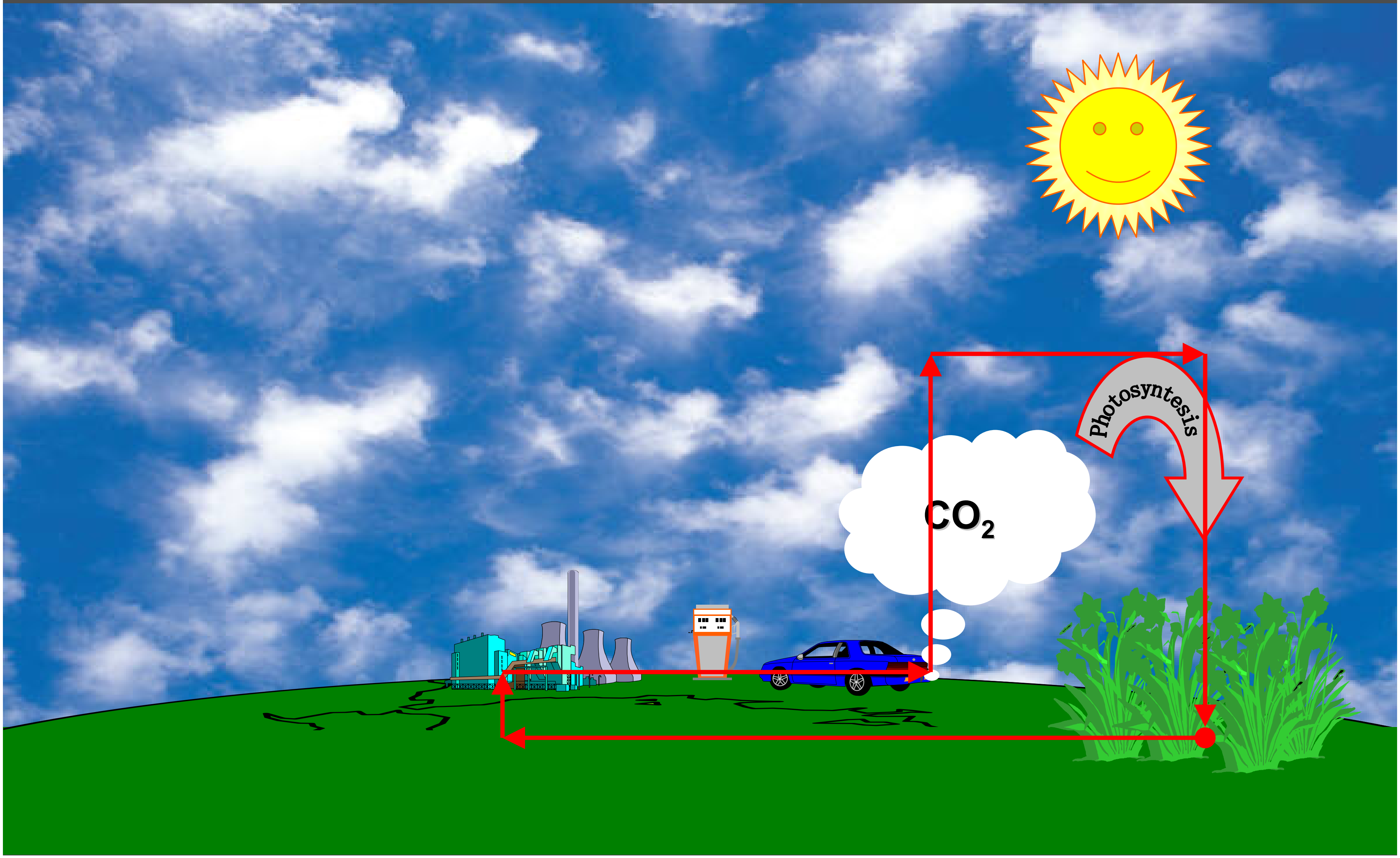
16. Comparative Evaporative Emission



11. The Fossil Fuels



12. The Renewable Fuels



Comparative Vehicle Prices (Brazil)

Ford EcoSport XL

- 1.6L 8V gasoline - € 14.859,00
- 1.6L 8V Flex Fuel - € 15.231,00

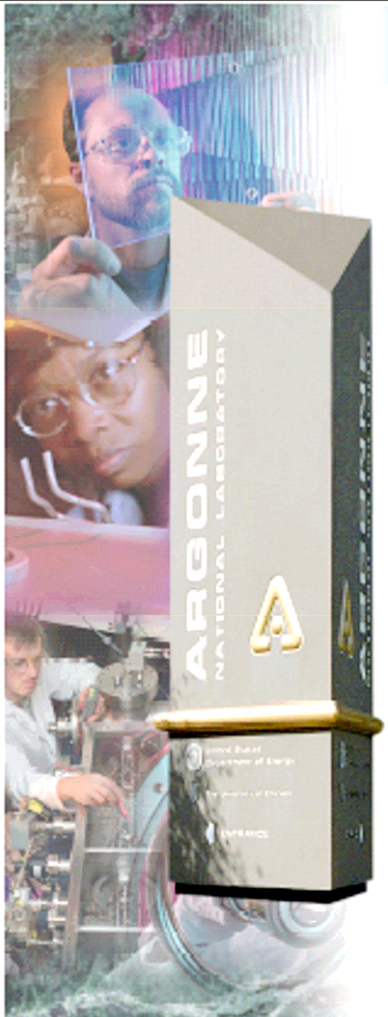
Volkswagen Gol 2d

- 1.0L 8V Special gasoline - € 7.496,00
- 1.0L 8V Special alcohol - € 7.649,00
- 1.0L 8V City Total Flex - € 8.035,00

Renault Scénic Privilège 4d

- 2.0L 16V gasoline - € 22.597,00
- 1.6L 16V Hi-Flex - € 21.540,00

(€ 1,00 = R$ 2,933)



ARGONNE NATIONAL LABORATORY

The Debate on Energy and Greenhouse Gas Emissions Impacts of Fuel Ethanol

Michael Wang
Center for Transportation Research
Energy Systems Division
Argonne National Laboratory

Energy Systems Division Seminar
Argonne National Laboratory
August 3, 2005

THE UNIVERSITY OF CHICAGO

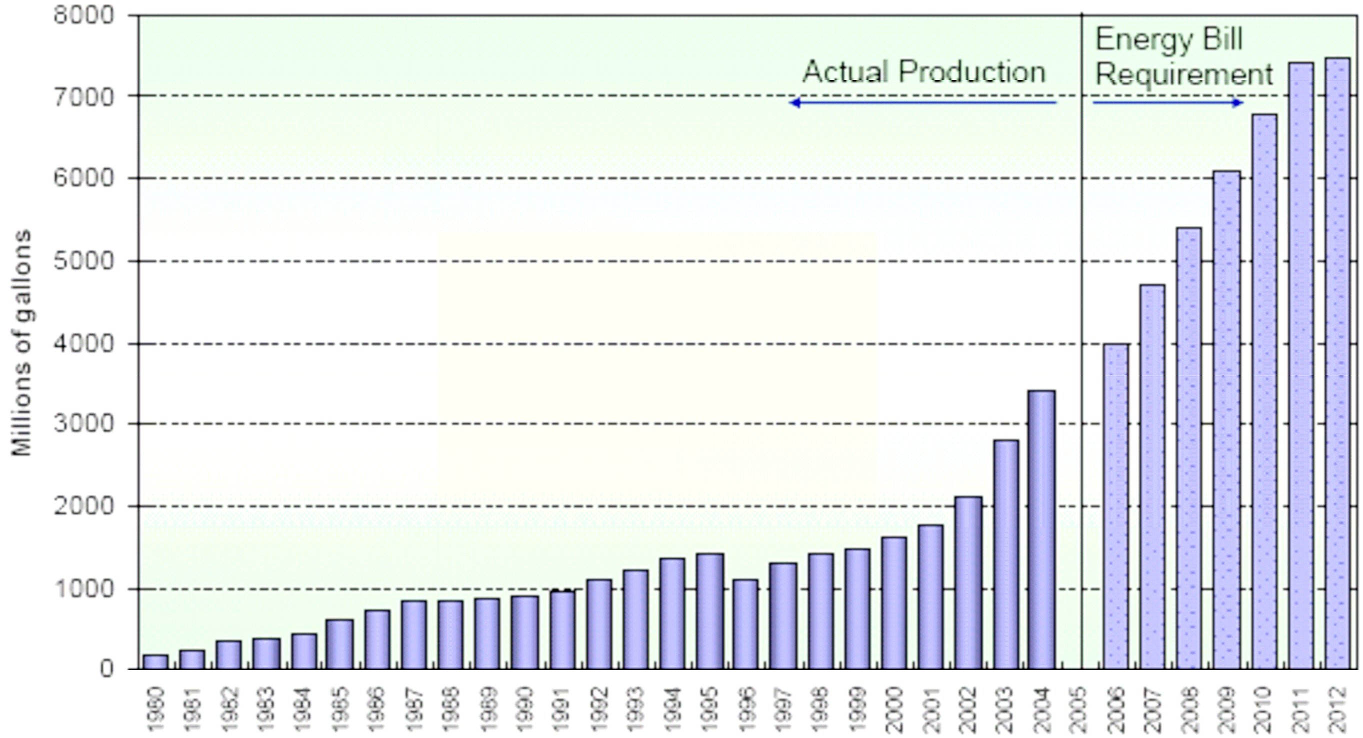
http://www.transportation.anl.gov

ARGONNE NATIONAL LABORATORY

A Recent Study by Pimentel&Patzek Conclude Increases in Fossil Energy Use by Biofuels

- Pimentel&Patzek conclude that
  - Corn ethanol *increases* fossil energy use by 29%
  - Cellulosic biomass-based ethanol by 50-57%
  - Biodiesel by 27-118%
- Other studies have very different conclusions
  - Argonne has shown
    - Corn ethanol *reduces* fossil energy use by 26%
    - Cellulosic biomass-based ethanol *reduces* by 90%
  - National Renewable Energy Laboratory has shown that biodiesel *reduces* fossil energy use by 69%
- Differences between Pimentel&Patzek and others lie in
  - Corn farming energy use
  - Energy use for producing nitrogen fertilizer
  - Ethanol plant energy use
  - Credits for co-products from biofuel plants

U.S. Fuel Ethanol Production Has Experienced Large Increases, and The Trend Will Continue

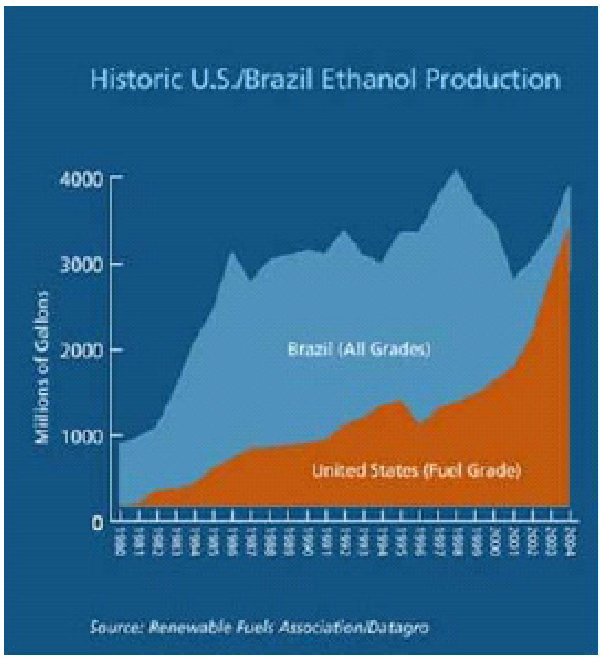


Source: Renewable Fuels Association

2

ARGONNE NATIONAL LABORATORY

Brazil and The U.S. Lead Fuel Ethanol Use



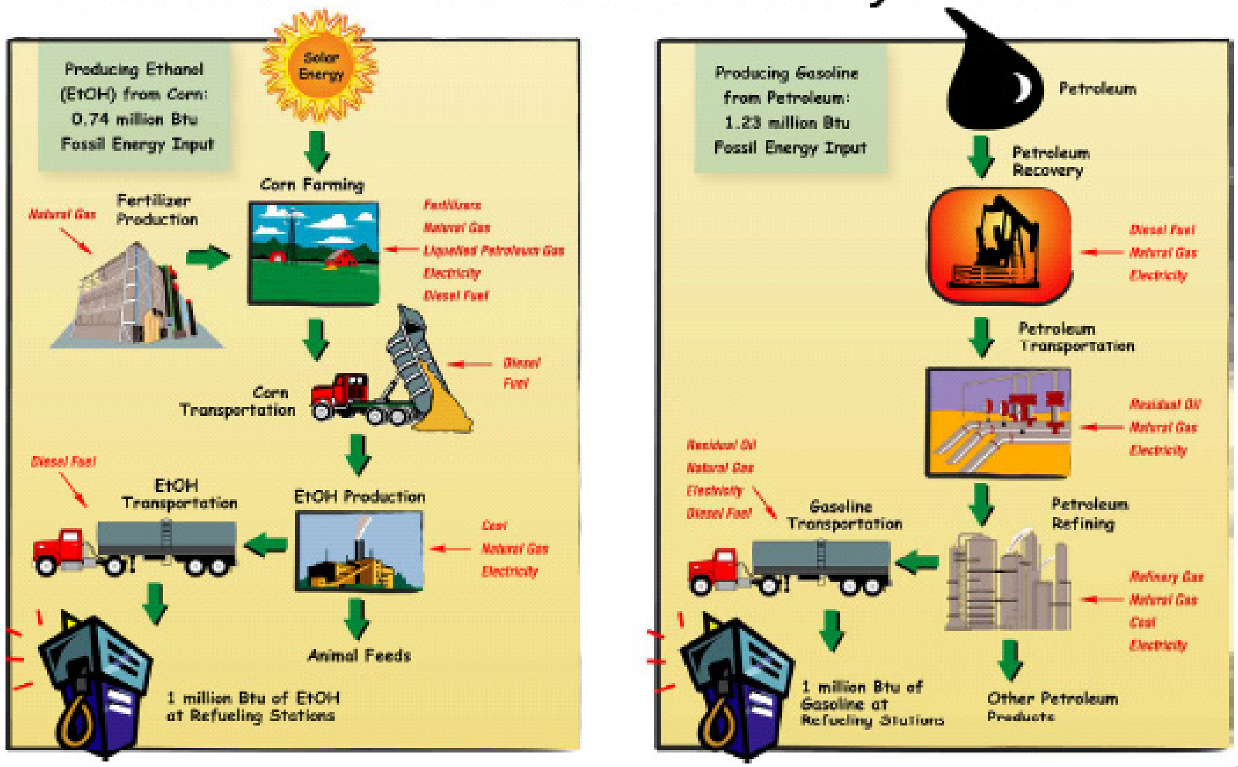
2004 World Ethanol Production

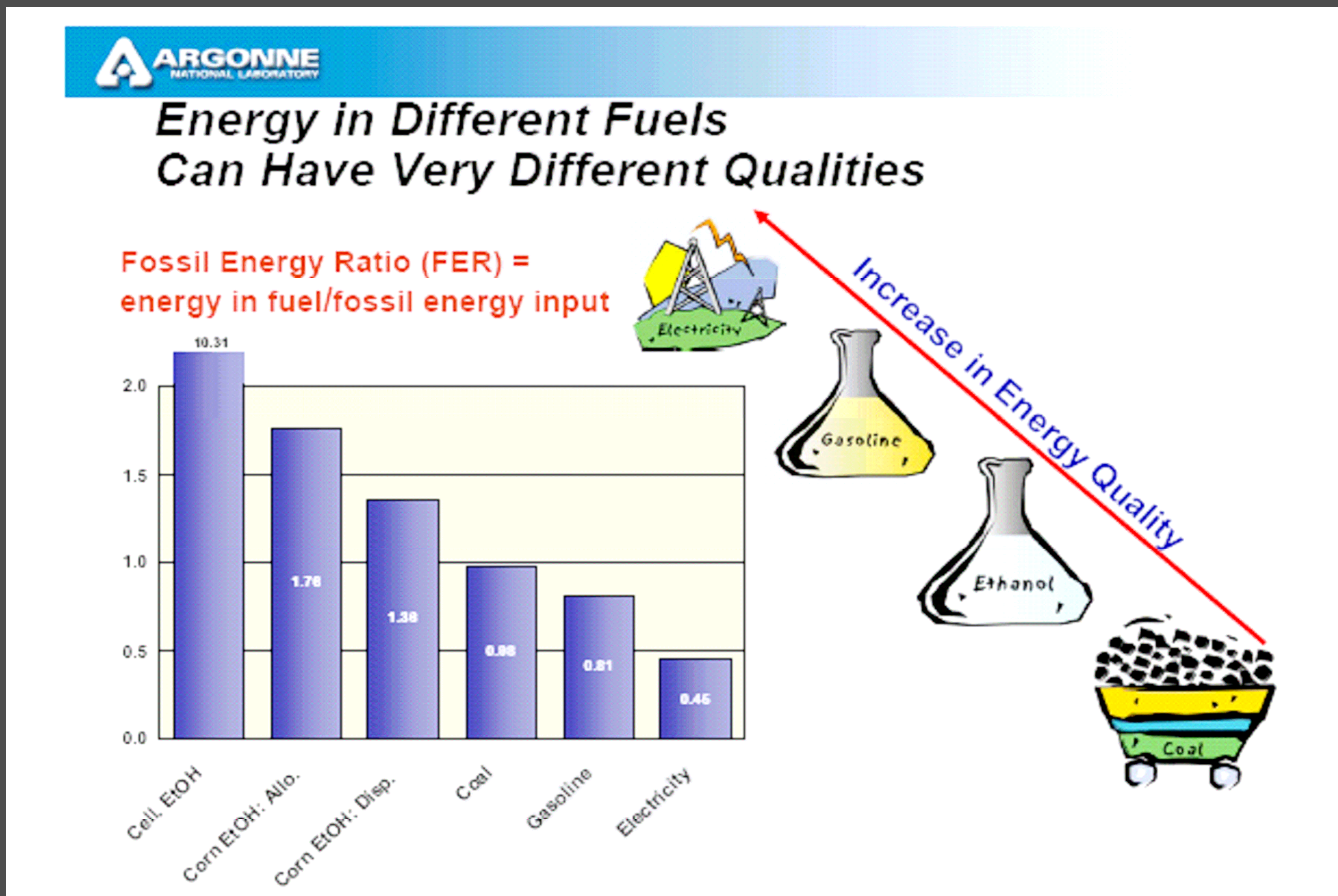
(All grades, million gallons, from F.O. Licht)

Brazil	3,989	Italy	40
U.S.	3,535	Australia	33
China	964	Japan	31
India	462	Pakistan	26
France	219	Sweden	26
Russia	198	Philippines	22
South Africa	110	South Korea	22
U.K.	106	Guatemala	17
Saudi Arabia	79	Cuba	16
Spain	79	Ecuador	12
Thailand	74	Mexico	9
Germany	71	Nicaragua	8
Ukraine	66	Mauritius	6
Canada	61	Zimbabwe	6
Poland	53	Kenya	3
Indonesia	44	Swaziland	3
Argentina	42	Others	338

ARGONNE NATIONAL LABORATORY

Comparative Results Between Ethanol and Gasoline Are More Relevant to Policy Debate



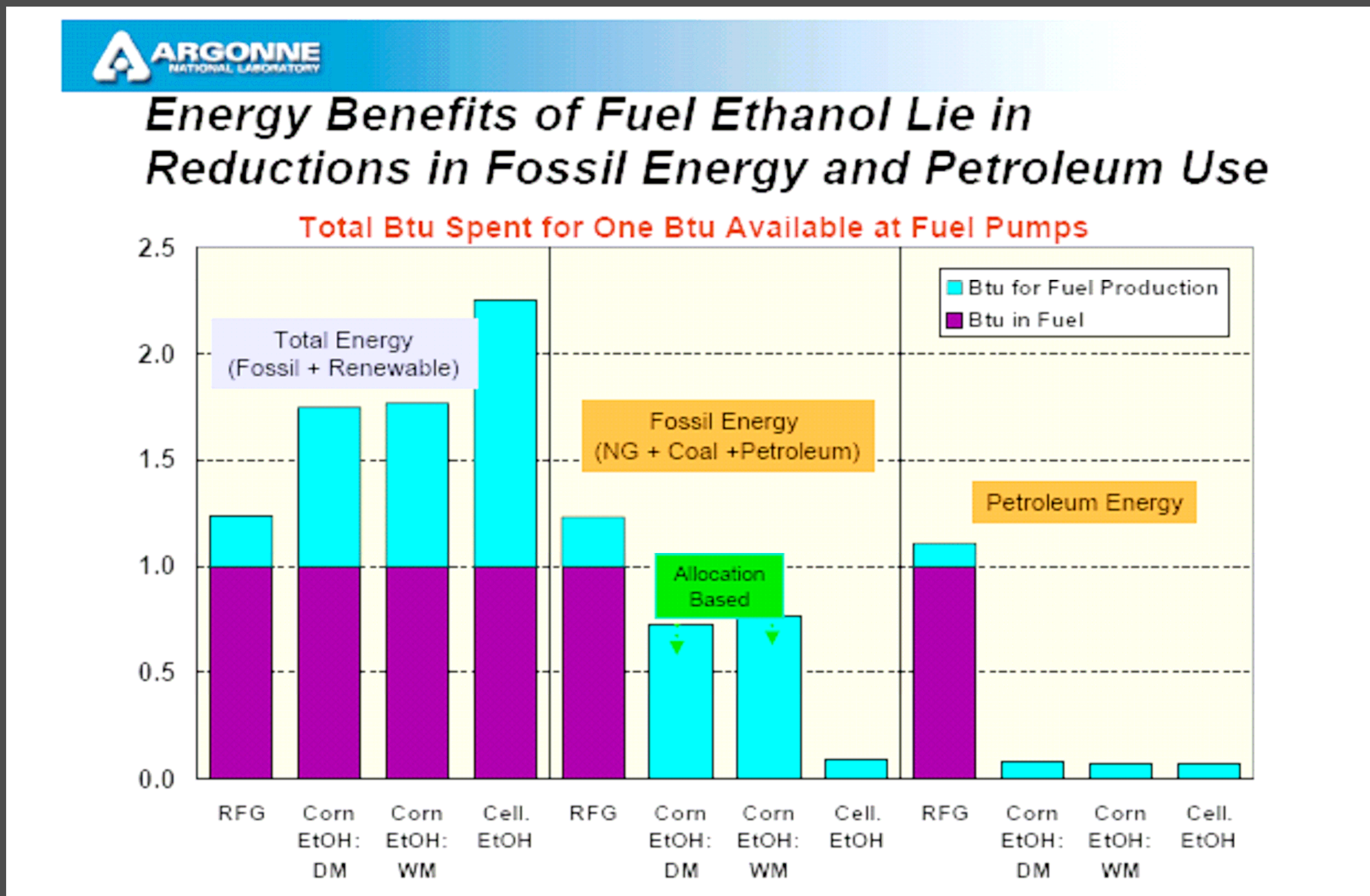

ARGONNE
NATIONAL LABORATORY
Energy in Different Fuels
Can Have Very Different Qualities
Fossil Energy Ratio (FER) =
energy in fuel/fossil energy input
10.31
2.0
1.5
1.0
0.5
0.0
1.76
1.36
0.98
0.81
0.45
Cell. EtOH
Corn EtOH: Allo.
Corn EtOH: Disp.
Coal
Gasoline
Electricity
Electricity
Gasoline
Ethanol
Coal
Increase in Energy Quality

ARGONNE NATIONAL LABORATORY

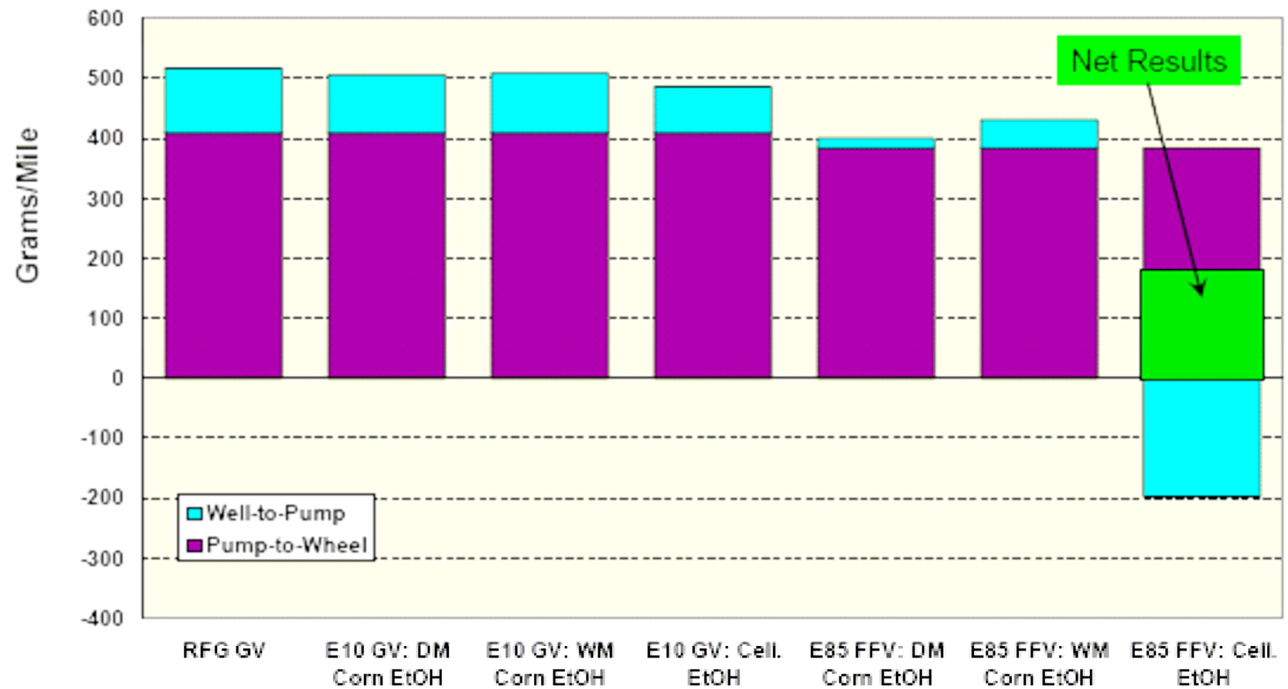
Allocation Method for Animal Feed Is a Critical Factor in Determining Ethanol's Energy and Emission Results

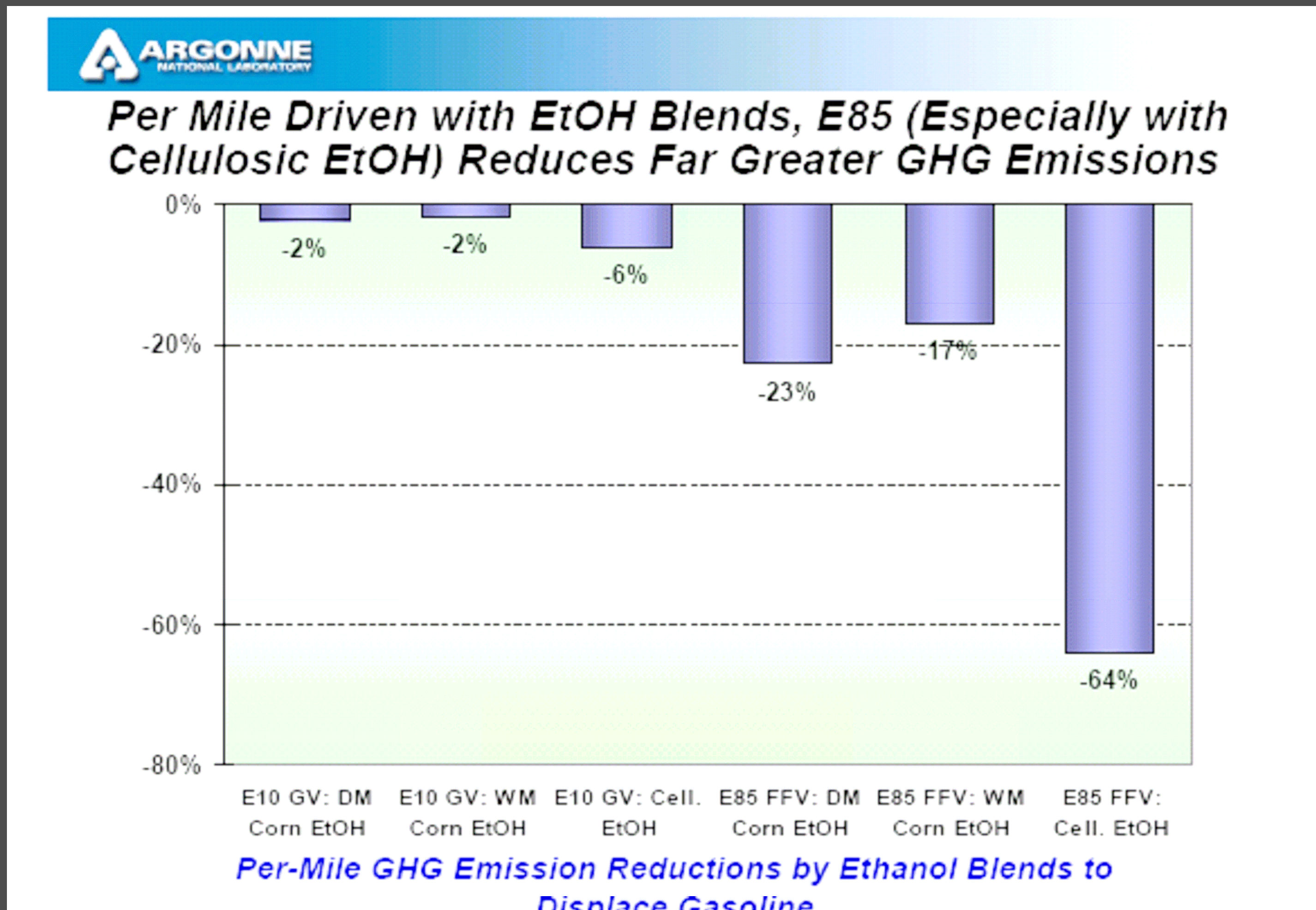
Allocation Method	Wet milling	Dry milling
Weight	52%	51%
Energy content	43%	39%
Process energy	36%	41%
Market value	30%	24%
Displacement	~16%	~20%

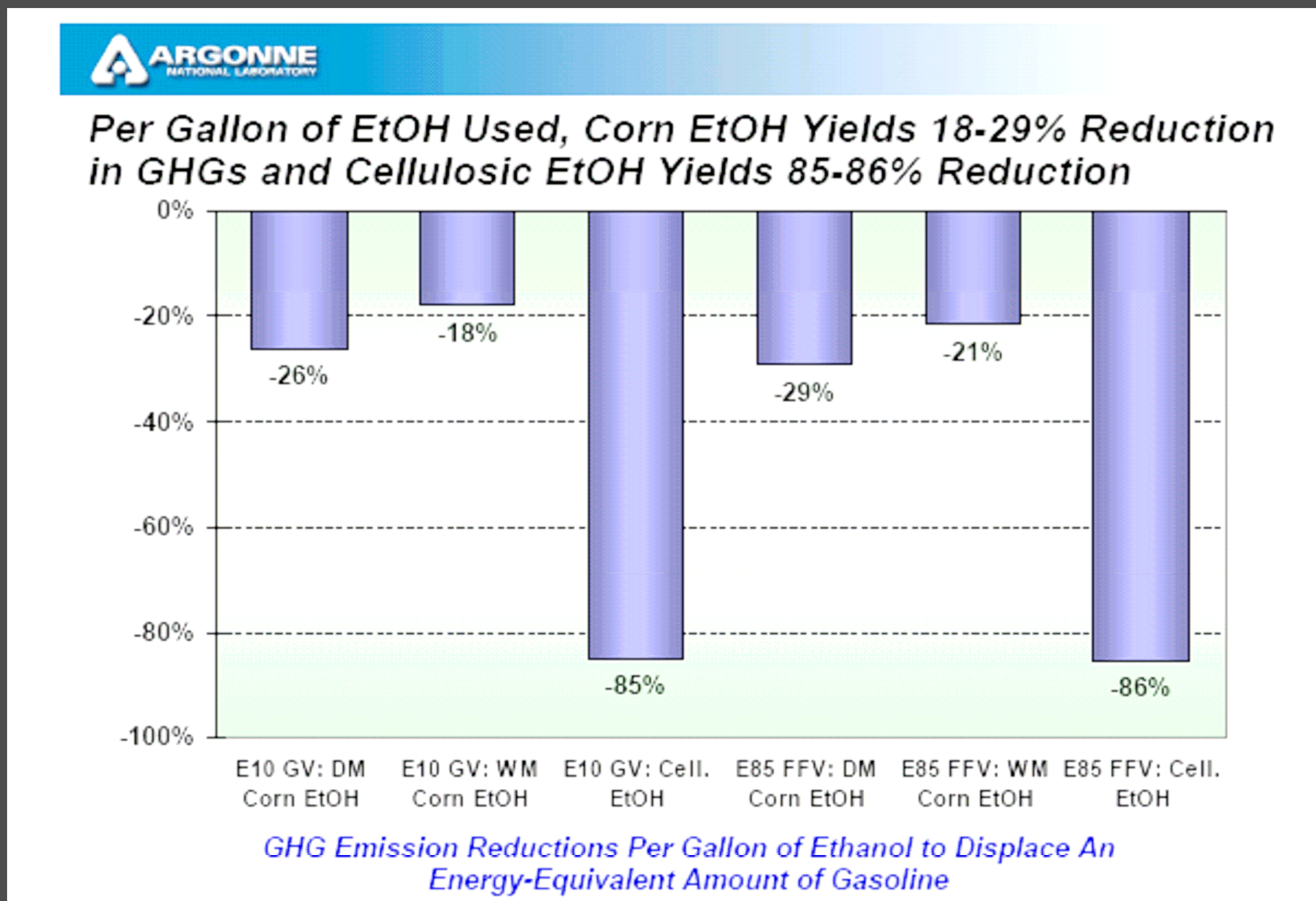
- Weight and energy methods no longer used
- Process energy allocation values are from USDA 2004
- Some studies did not consider co-products at all

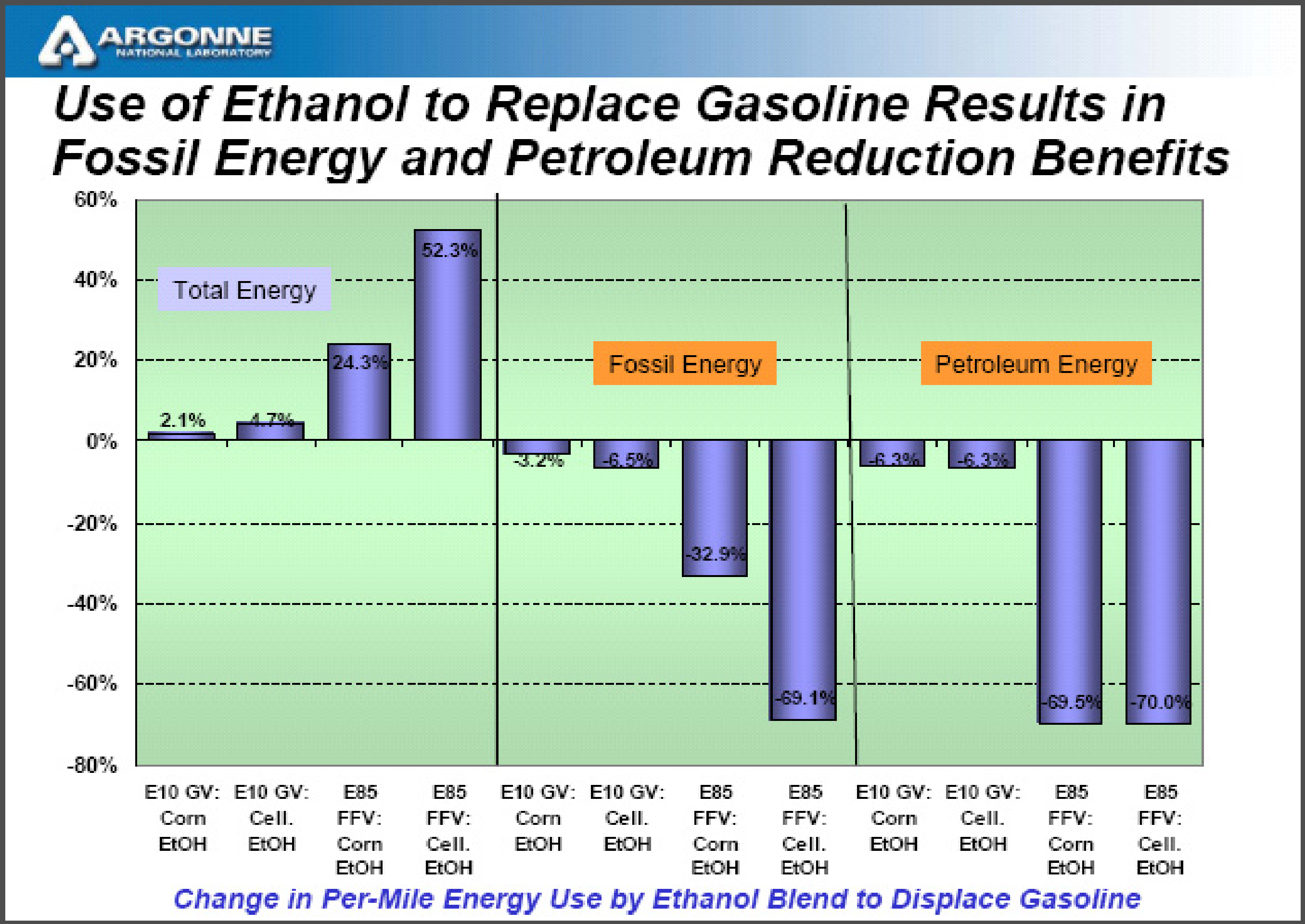

ARGONNE
NATIONAL LABORATORY
Energy Benefits of Fuel Ethanol Lie in Reductions in Fossil Energy and Petroleum Use
Total Btu Spent for One Btu Available at Fuel Pumps
Btu for Fuel Production
Btu in Fuel
Total Energy (Fossil + Renewable)
Fossil Energy (NG + Coal +Petroleum)
Petroleum Energy
Allocation Based
2.5
2.0
1.5
1.0
0.5
0.0
RFG
Corn EtOH: DM
Corn EtOH: WM
Cell. EtOH

Per-Mile GHG Emission Results Show Larger Benefits of E85 Blend and Cellulosic Ethanol

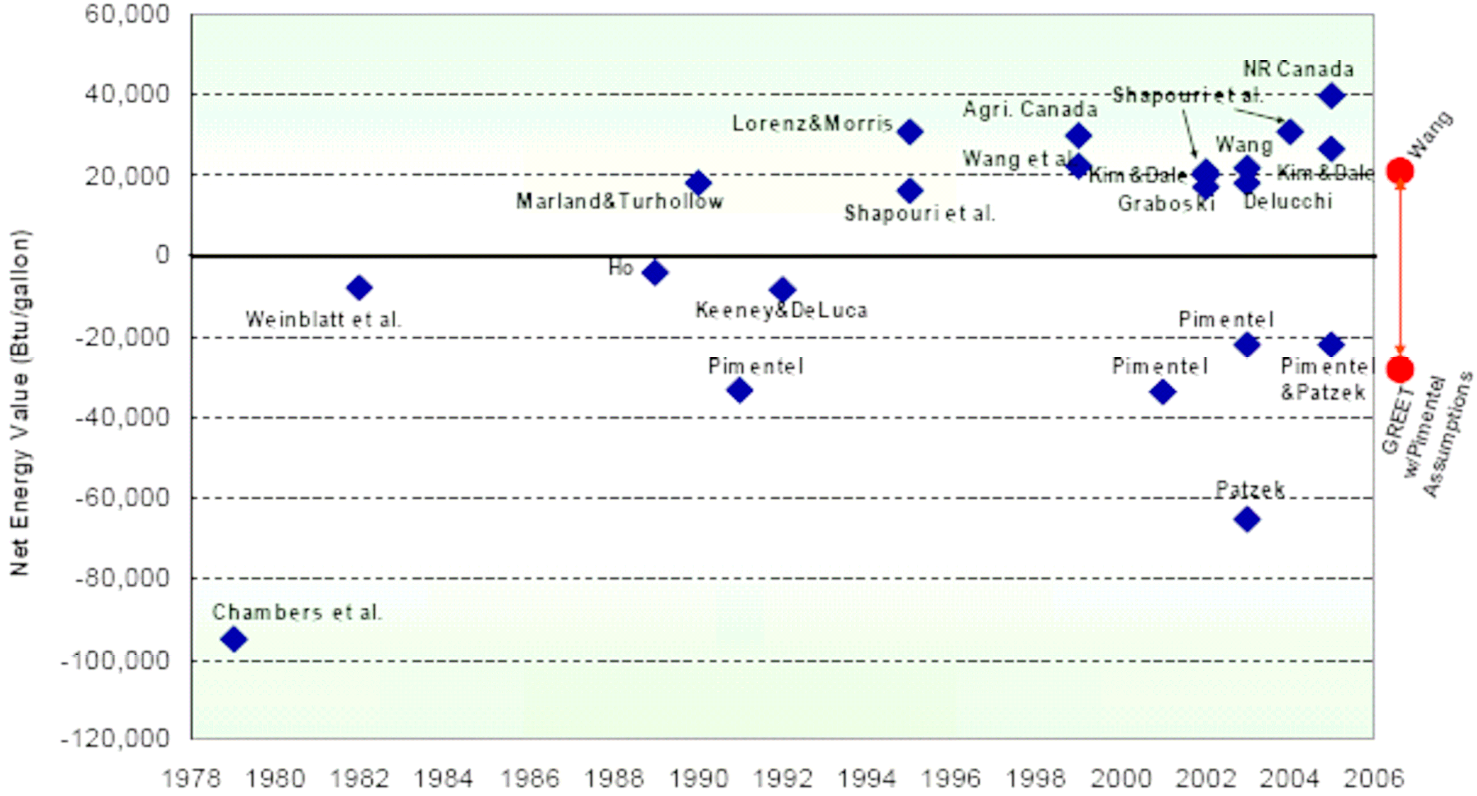



ARGONNE
NATIONAL LABORATORY
Per Mile Driven with EtOH Blends, E85 (Especially with Cellulosic EtOH) Reduces Far Greater GHG Emissions
0%
-20%
-40%
-60%
-80%
-2%
-2%
-6%
-23%
-17%
-64%
E10 GV: DM Corn EtOH
E10 GV: WM Corn EtOH
E10 GV: Cell. EtOH
E85 FFV: DM Corn EtOH
E85 FFV: WM Corn EtOH
E85 FFV: Cell. EtOH
Per-Mile GHG Emission Reductions by Ethanol Blends to Displace Gasoline


ARGONNE
NATIONAL LABORATORY
Per Gallon of EtOH Used, Corn EtOH Yields 18-29% Reduction in GHGs and Cellulosic EtOH Yields 85-86% Reduction
0%
-20%
-40%
-60%
-80%
-100%
-26%
-18%
-85%
-29%
-21%
-86%
E10 GV: DM Corn EtOH
E10 GV: WM Corn EtOH
E10 GV: Cell. EtOH
E85 FFV: DM Corn EtOH
E85 FFV: WM Corn EtOH
E85 FFV: Cell. EtOH
GHG Emission Reductions Per Gallon of Ethanol to Displace An Energy-Equivalent Amount of Gasoline


ARGONNE
NATIONAL LABORATORY
Use of Ethanol to Replace Gasoline Results in Fossil Energy and Petroleum Reduction Benefits
60%
40%
20%
0%
-20%
-40%
-60%
-80%
Total Energy
Fossil Energy
Petroleum Energy
2.1%
4.7%
24.3%
52.3%
-3.2%
-6.5%
-32.9%
-69.1%
-6.3%
-6.3%
-69.5%
-70.0%
E10 GV: Corn EtOH
E10 GV: Cell. EtOH
E85 FFV: Corn EtOH
E85 FFV: Cell. EtOH
E10 GV: Corn EtOH
E10 GV: Cell. EtOH
E85 FFV: Corn EtOH
E85 FFV: Cell. EtOH
E10 GV: Corn EtOH
E10 GV: Cell. EtOH
E85 FFV: Corn EtOH
E85 FFV: Cell. EtOH
Change in Per-Mile Energy Use by Ethanol Blend to Displace Gasoline

Most of the Recent Corn EtOH Studies Show a Positive Net Energy Balance



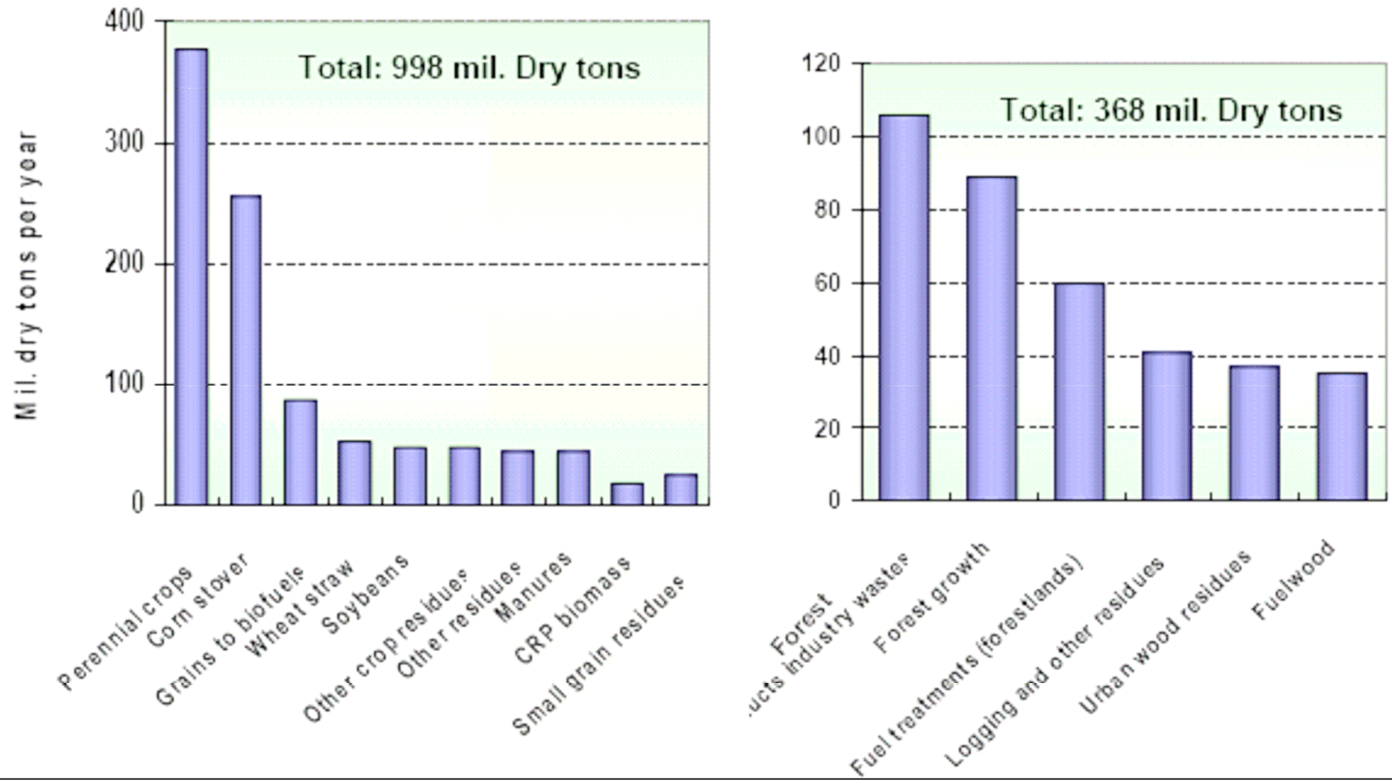
Energy balance here is defined as Btu content a gallon of ethanol minus fossil energy used to produce a gallon of ethanol

ARGONNE NATIONAL LABORATORY

Debate on Energy Balance Itself May Have Little Practical Meaning

- Though self evaluation of a fuel's energy balance is easy to understand, to do so for a fuel in isolation could be arbitrary
- All Btus are not created equal. The energy sector has been converting low-value Btus into high-value Btus, *with energy losses*
- Society has not made energy choice decisions on the basis of energy balance values of individual energy products
- Issues of concern, such as petroleum consumption and GHG emissions, should be analyzed directly for fuels
- A complete, robust way of evaluating a fuel's effects is to compare the fuel (e.g., ethanol) with those to be displaced (e.g., gasoline)

A Recent Study by Oak Ridge National Laboratory Concludes 1.3 Billion Tons of Biomass Available in U.S. Per Year



The Energy Bill Encourages Production of Cellulosic Ethanol

- Creates a credit-trading program where 1 gallon of cellulosic ethanol is equal to 2.5 gallons of renewable fuel
- Creates a program for production of 250 million gallons of cellulosic ethanol in 2013
- Creates a Loan Guarantee Program of $250 million per facility
- Creates a $650 million Grant Program for cellulosic ethanol
- Creates an Advanced Biofuels Technologies Program of $550 million

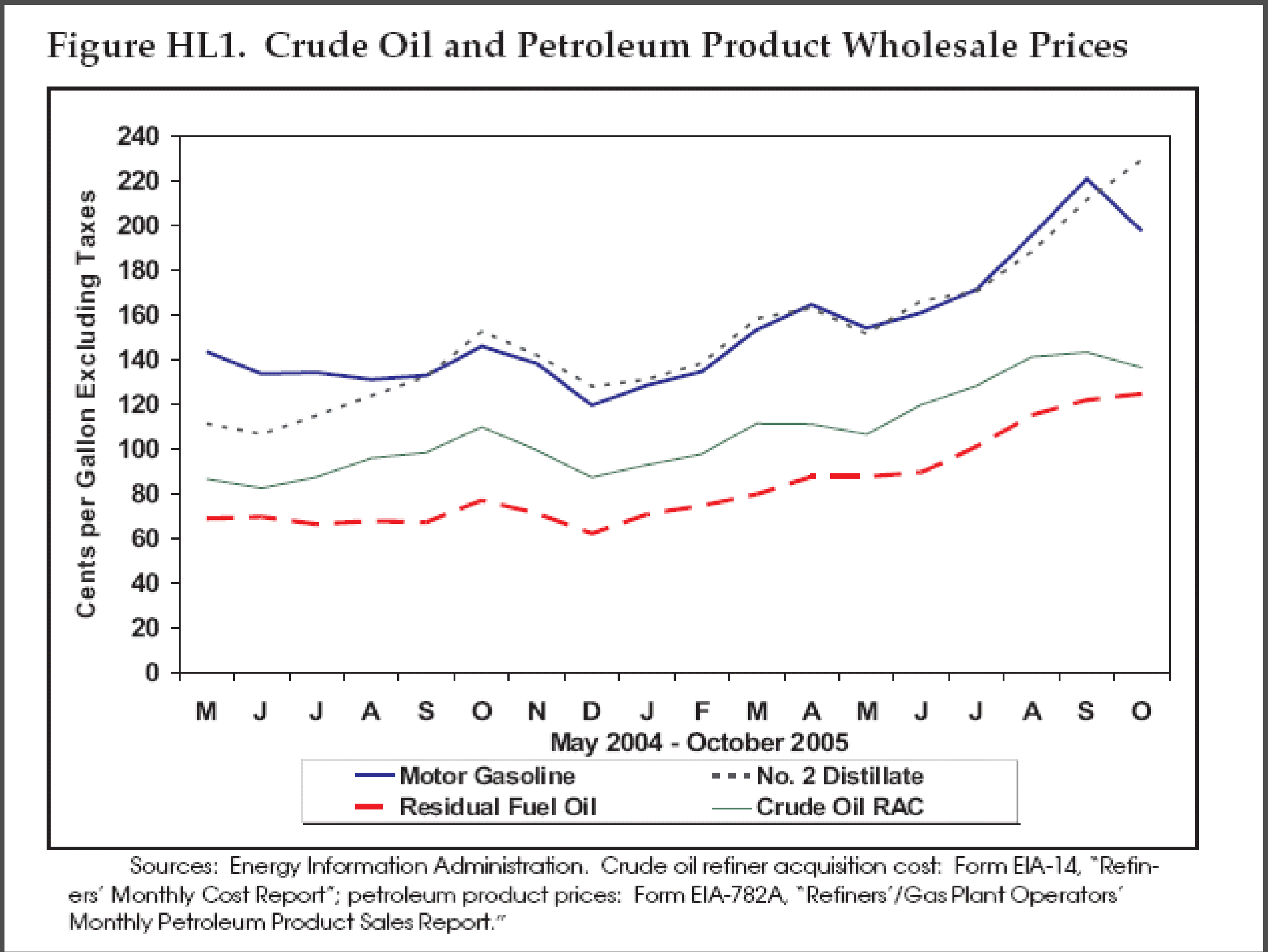
ARGONNE NATIONAL LABORATORY

Conclusions

- Energy balance value for a given energy product alone is not meaningful in evaluating its benefit
- Any type of fuel ethanol helps substantially reduce transportation's fossil energy and petroleum use, relative to petroleum gasoline
- Corn-based fuel ethanol achieves moderate reductions in GHG emissions
- Cellulosic ethanol can achieve much greater energy and GHG benefits

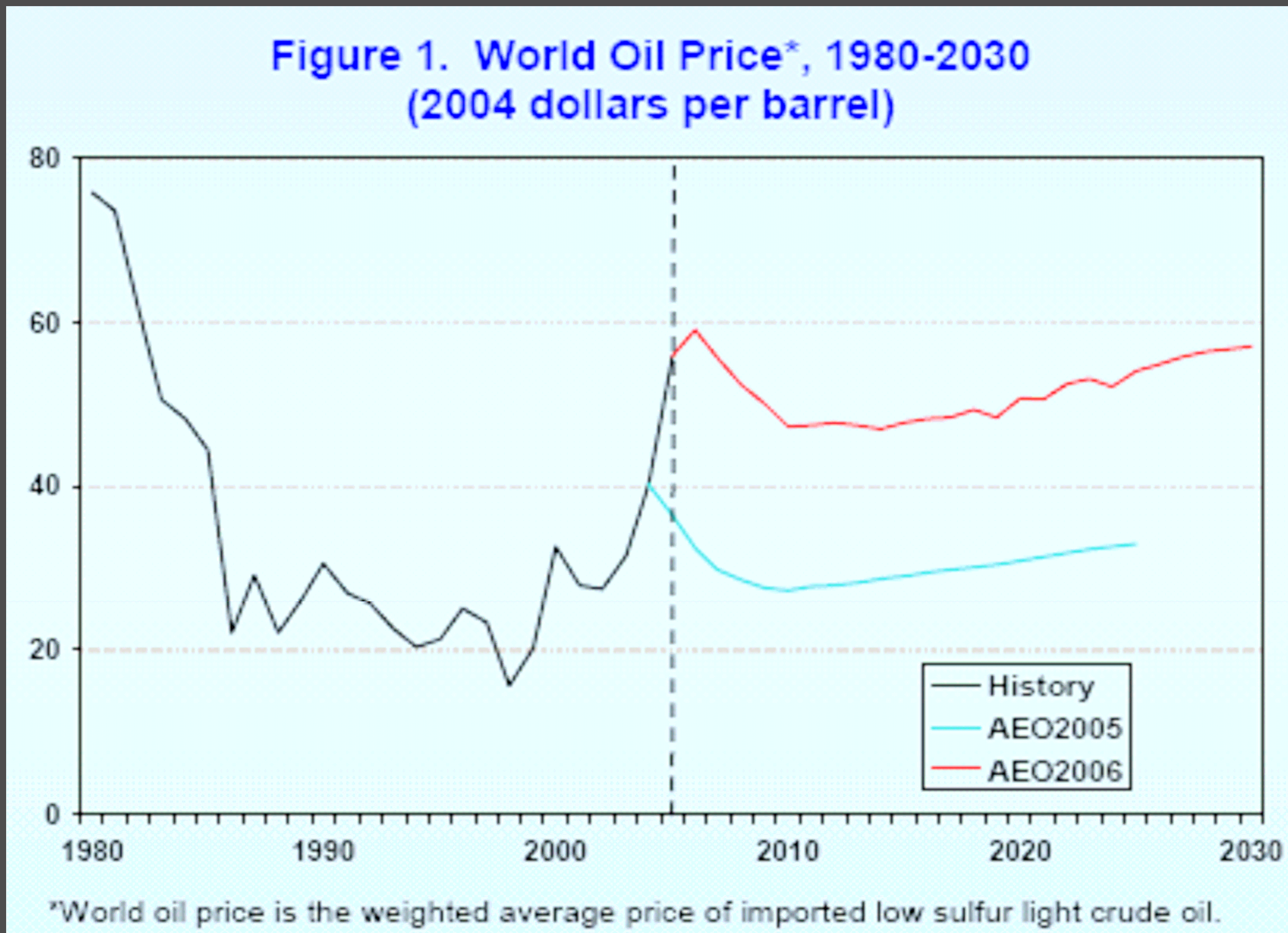
(For more information, please visit the GREET model website at http://greet.anl.gov)

Wholesale Prices



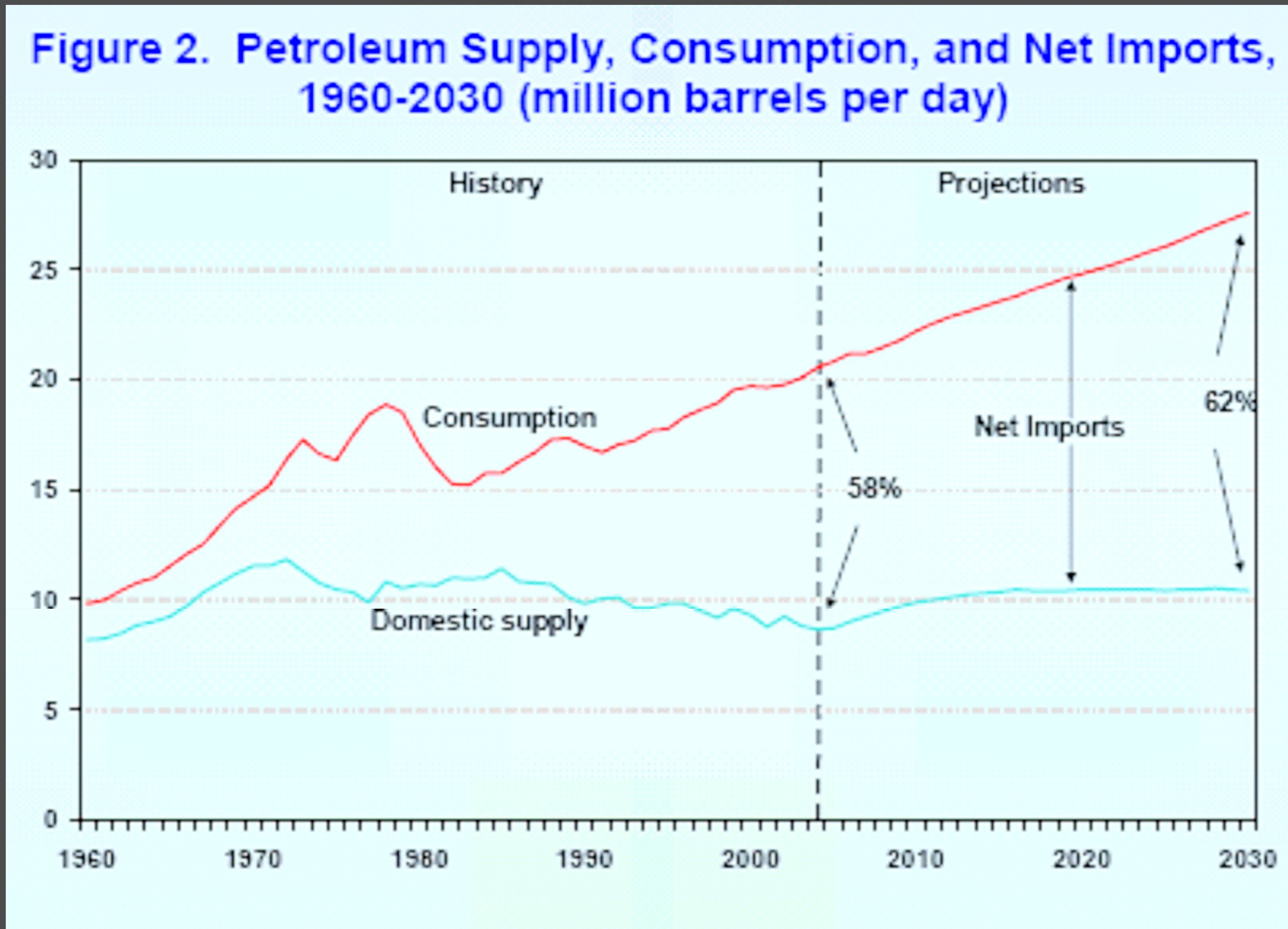
Source: http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_marketing_monthly/current/pdf/pmmall.pdf

Projected World Oil Prices (EIA)



Source: EIA Reports

US Domestic Oil Consumption & Supply



Source: EIA Reports

Prices of Selected Petroleum Products

(Crude Oil in Dollars per Barrel, Products in Cents per Gallon Excluding Taxes) — Continued

Products Sales Type Geographic area	2005											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov[a]	Dec
Crude Oil												
Refiner Acquisition Cost												
Domestic	41.82	43.80	48.87	49.64	47.81	52.13	55.78	60.57	62.84	60.78	**56.71**	
Imported	37.55	39.72	45.71	45.18	43.12	49.28	52.88	58.66	58.79	55.41	**51.60**	
Composite	39.01	41.05	46.77	46.67	44.74	50.30	53.88	59.29	60.18	57.26	**54.13**	
Motor Gasoline												
Sales to End Users Through Retail Outlets												
Regular												
U.S.	137.6	145.0	161.9	177.5	167.4	169.8	182.1	206.3	241.7	224.2	**180.0**	
PADD 1	137.3	143.0	157.7	173.9	166.0	167.8	180.9	203.2	246.5	226.2	**176.6**	
PADD 2	137.4	144.9	162.7	173.8	160.5	167.9	179.2	207.1	238.2	216.6	**173.0**	
PADD 3	133.6	139.4	157.2	172.9	162.2	165.3	176.9	203.6	235.2	227.5	**186.5**	
PADD 5	143.2	156.8	175.5	199.5	191.6	183.7	197.7	216.3	245.0	232.9	**199.1**	
Sales for Resale												
Regular												
U.S.	127.4	133.2	151.8	162.6	152.5	159.6	169.9	194.3	220.1	196.1	**157.8**	
PADD 1	127.6	130.8	148.8	158.5	149.8	158.3	169.2	191.5	222.9	193.0	**154.7**	
PADD 2	127.9	134.1	153.4	159.5	149.3	158.9	167.8	197.7	218.0	192.5	**153.3**	
PADD 3	124.7	128.3	146.6	158.0	148.1	155.3	164.2	188.0	213.2	198.4	**153.5**	
PADD 5	131.1	146.0	164.5	184.7	170.0	170.0	184.1	204.5	226.5	206.5	**175.8**	

Source: http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/petroleum_marketing_monthly/current/pdf/pmmall.pdf

Characteristics of an Ideal Crop: Miscanthus

Characteristics of an ideal biomass energy crop present (+) in corn, short rotation coppice and *Miscanthus*, developed in part from Long (1994).

Crop characteristic	Corn	Short-rotation coppice	*Miscanthus*
C_4 photosynthesis	+		+
Long canopy duration		+	+
Perennial (no need for annual tillage or planting)		+	+
No known pests or diseases			+
Rapid growth in spring to out compete weeds		+	+
Sterile; prevent 'escape'			+
Stores carbon in soil (soil restoration and carbon sequestration tool)		+	+
Partitions nutrients back to roots in fall (low fertilizer requirement).			+
Low nutrient content i.e. < 200 mg MJ^{-1} nitrogen and sulphur (clean burning)		+	+
High water use efficiency	+		+
Dry down in field (zero drying costs)			+
Good winter standing (harvest when needed; zero storage costs)		+	+
Utilizes existing farm equipment	+		+
Alternative markets (high quality paper, building materials and fermentation)	+	+	+

Source :http://www.aces.uiuc.edu/DSI/MASGC.pdf

Economics of Miscanthus Farming

Annual and extended projected costs and profits for two cropping systems in Central Illinois over a 10 year period.

Costs ($ ha^{-1})	Corn/Soybean[1] rotation			*Miscanthus*[2] energy crop			
	Corn	*Soy*	**10 years**[3]	*1st year*	*2nd year*	*3rd–10th*	**10 years**
Fertilizer	131	47	**621**	62	60	23	**242**
Pesticides	77	79	**520**	15	0	0	**15**
Seed	84	47	**445**	316	0	0	**316**
Crop Drying	17	5	**77**	0	0	0	**0**
Machinery repair, fuel, hire	67	59	**423**	45	101	95	**635**
Labor	89	84	**580**	84	82	77	**562**
TOTAL VARIABLE COSTS	464	321	**2657**	521	242	195	**1770**
Machinery overhead, housing, depreciation, non-land interest	257	198	**1533**	22	58	54	**360**
Land	373	373	**2496**	373	362	341	**2496**
TOTAL OTHER COSTS	630	571	**4029**	395	420	396	**2856**
TOTAL ALL COSTS	1094	892	**6686**	916	662	591	**4626**
Yield (tons ha^{-1})	*10.5*	*3.5*					
Yield, (dry tons ha^{-1})				*0*	*17*	*35*	
Value ($ ton^{-1})	*98*	*195*		*40*	*39*	*38*	
GROSS REVENUE ($ ha^{-1})	1020	681	**5783**	0	663	1330	**7527**
NET PROFIT[4] ($ ha^{-1})	–74	–210	**–903**	–916	1	739	**2900**

[1] Corn and soybean costs and average yields for Central Illinois after (Hoeft et al. 2000) and prices based on Chicago Board of Trade Dec. 2002 futures.
[2] Miscanthus seed costs based on (Lewandowski et al. 2000) and harvest costs assuming cutting and baling as for corn silage. Machinery costs from University of Minnesota Extension and Illinois Farm Business Farm Management Association. A predicted yield of 35 t/ha for Central IL is assumed (Figure 1), and a price of $40/t. This compares to $44 /t proposed by (McLaughlin et al. 2002) for US biomass crops and an EU suggested price of $49 /t (Bullard 2001).
[3] Total values over 10 years, discounted annually at 3%.
[4] Farm gate price, excluding subsidies.

Source: http://www.aces.uiuc.edu/DSI/MASGC.pdf

Hydrogen vs. Ethanol Economics

- Raw Material Costs: cost per Giga Joule (gj)
  - Electricity @$0.04/kwh = $11.2/gj (Lower cost than natural gas)
  - Biomass @$40/ton = $2.3/gj (with 70% conversion efficiency)

- Hydrogen from electricity costly vs. Ethanol from Biomass
- Hydrogen from Natural Gas no better than Natural Gas
- Cost multiplier on hydrogen: distribution, delivery, storage
- Higher fuel cell efficiency compared to hybrids not enough!
- Hydrogen cars have fewer moving parts but more sensitive, less tested systems and capital cost disadvantage

Reference: The Future of the Hydrogen Economy (http://www.oilcrash.com/articles/h2_eco.htm#8.2)

Hydrogen vs. Ethanol

- Ethanol: US automakers balance sheets ill-equipped for hydrogen switchover
- Ethanol: No change in infrastructure in liquid fuels vs. gaseous fuels
- Ethanol: Current engine manufacturing/maintenance infrastructure
- Ethanol: switchover requires little capital
- Ethanol: Agricultural Subsidies are leveraged for social good
- Ethanol: Faster switchover- 3-5 years vs 15-25yrs
- Ethanol: Low technology risk
- Ethanol: Incremental introduction of new fuel
- Ethanol: Early carbon emission reductions

Tutorial

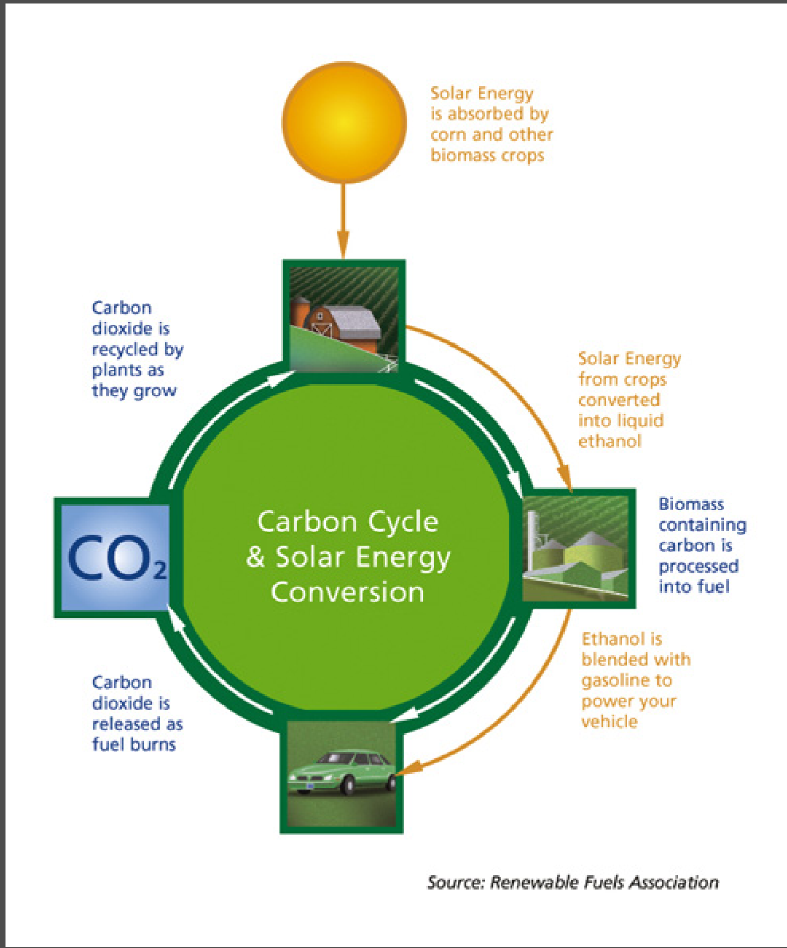
- http://www.eere.energy.gov/biomass/understanding_biomass.html

SAAB BioPower

Gallons Saved: Hybrids vs FFV

Why Does E85 Make Sense?

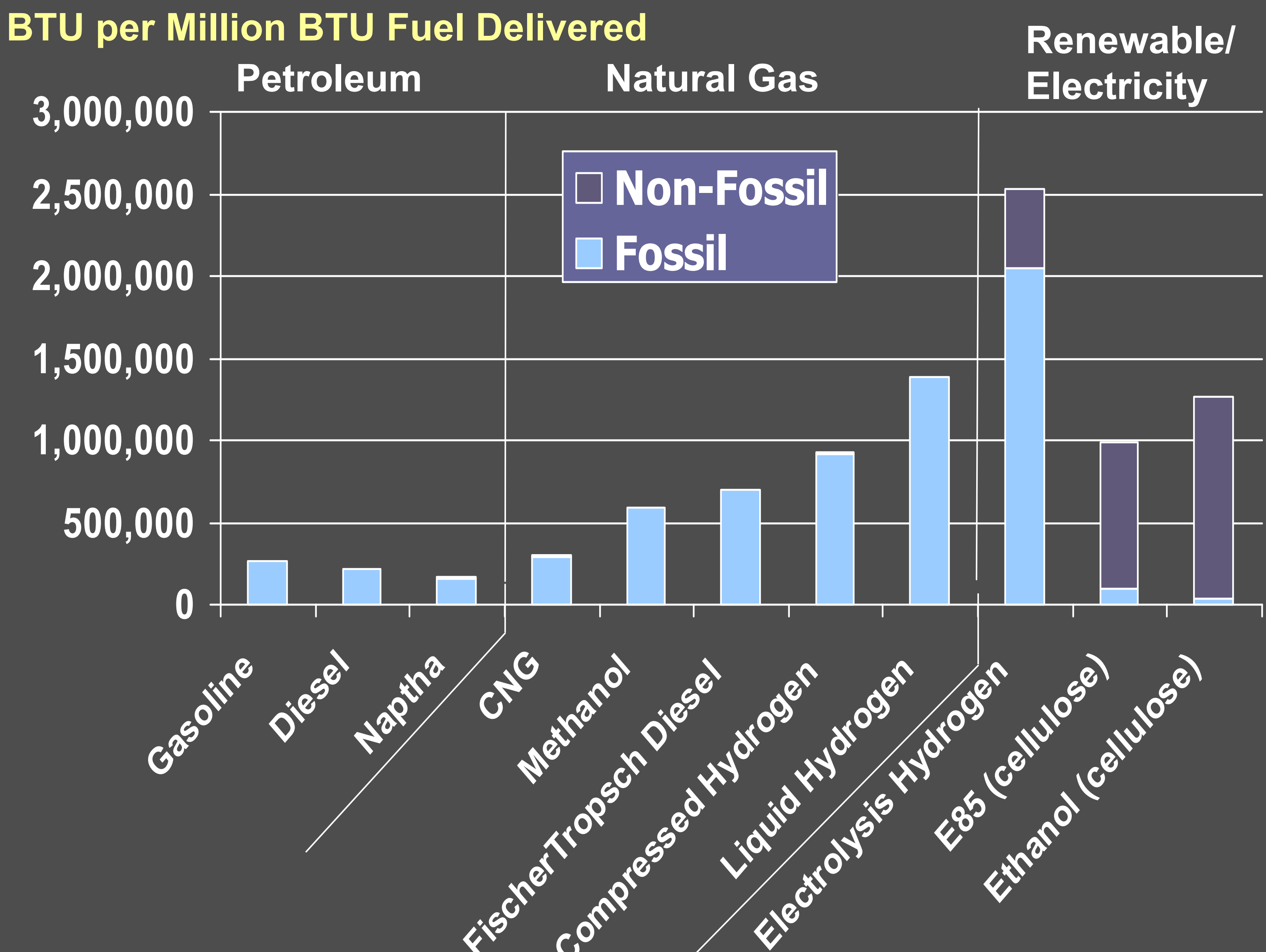
- Environmental Factors
  - Ethanol is renewable, biodegradable, and water soluble
  - Compared to gasoline, E85 reduces ozone-forming volatile organic compounds by 15%, Carbon Monoxide by 40%, NOx by 10%, and sulfate emissions by 80%
  - Ethanol has a positive energy balance
    - Ethanol creates over 40% more energy than it takes to produce it



Why Does E85 Make Sense?

- Health Factors
  - Benzene
    - Gasoline contains Benzene, which has been determined by the Department of Health and Human Services to be a carcinogen
    - Used as a substitute for lead, benzene makes up 1 to 2 percent of every gallon of gasoline and it is released as a by-product of fuel combustion
    - 85% of the Benzene in the air we breathe is from vehicle exhaust
    - Long-term exposure to benzene in the air can cause cancer of the blood-forming organs – a condition called leukemia
    - The four major types of leukemia related to Benzene are:
      - Acute and chronic myelogenous leukemia (AML / CML)
      - Acute and chronic lymphocytic leukemia (ALL / CLL)

Well-to-Tank Energy Consumption



Source: "Well-To-Wheel Energy Consumption and Greenhouse Gas Analysis", Norman Brinkman, GM Research & Development

Three of Ten Important Sources

Stovers: 250m tons

- Production of corn stover and stalks from other grains (wheats, oats) totals well over 250 million dry tons. A combination of different crop rotations and agricultural practices (e.g. reduced tillage) would appear to have potential for a large fraction of these residues to be removed. For example, although complete removal of corn stover would result in a loss of about 0.26 tons of soil carbon per year, cultivation of perennial crops (e.g. switchgrass, Miscanthus) adds soil carbon at a substantial rate. Thus a rotation of switchgrass and corn might maintain or even increase soil fertility even with 100% stover removal. This, however, brings up questions about the length of time land might be grown in each crop, since switchgrass would benefit from longer times to distribute the cost of establishment while corn would benefit from short times to maintain productivity and decrease losses due to pests. It is likely that some crop other than switchgrass as it exists today would be best for incorporation into a relatively high frequency rotation with corn. Targets for crop development could be identified and their feasibility evaluated.

Winter Crops: 300m tons

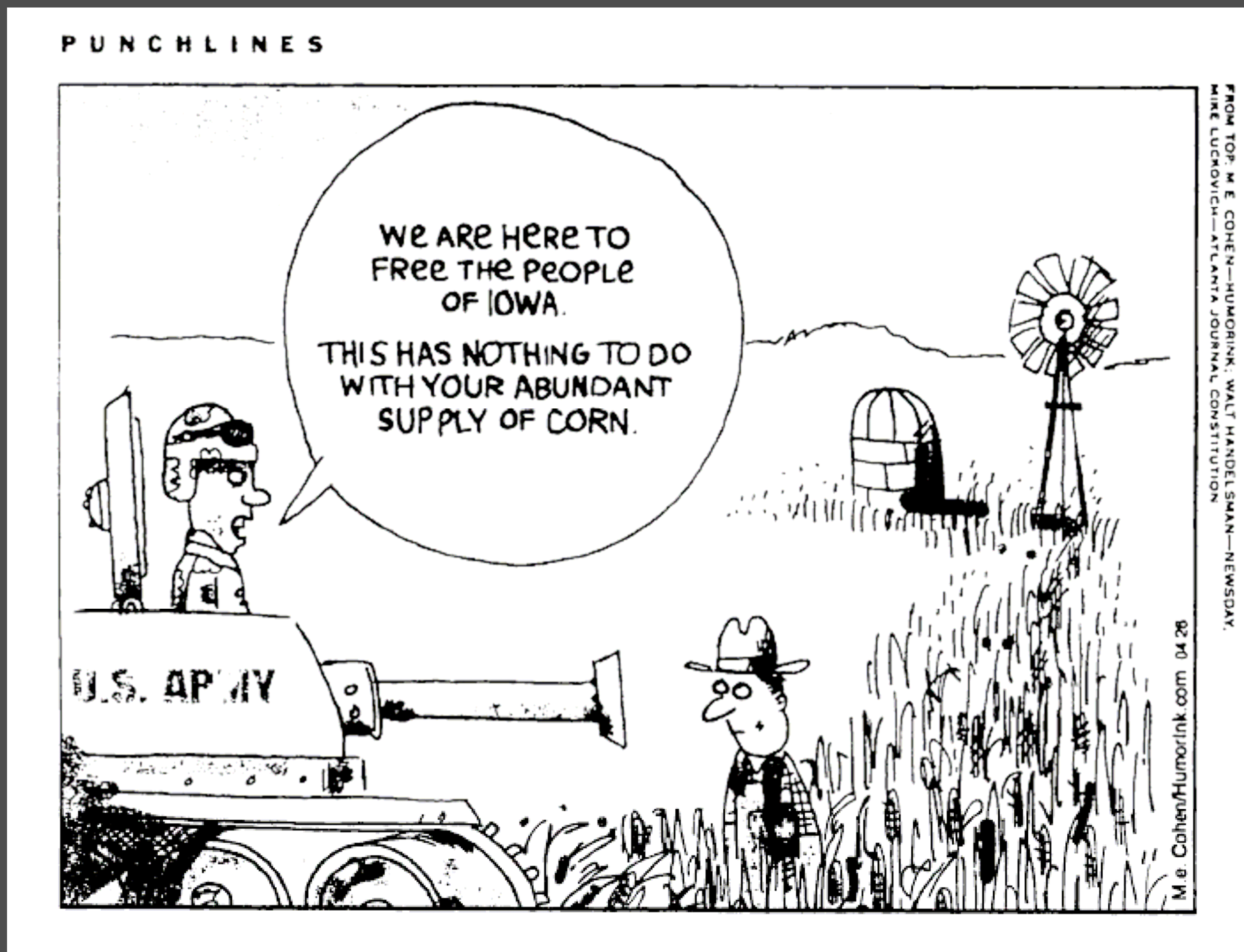
- Winter cover crops grown on 150 million acres (2.0 tons/acre) = 300 million tons of cellulosic biomass.

Soybeans: 350m tons

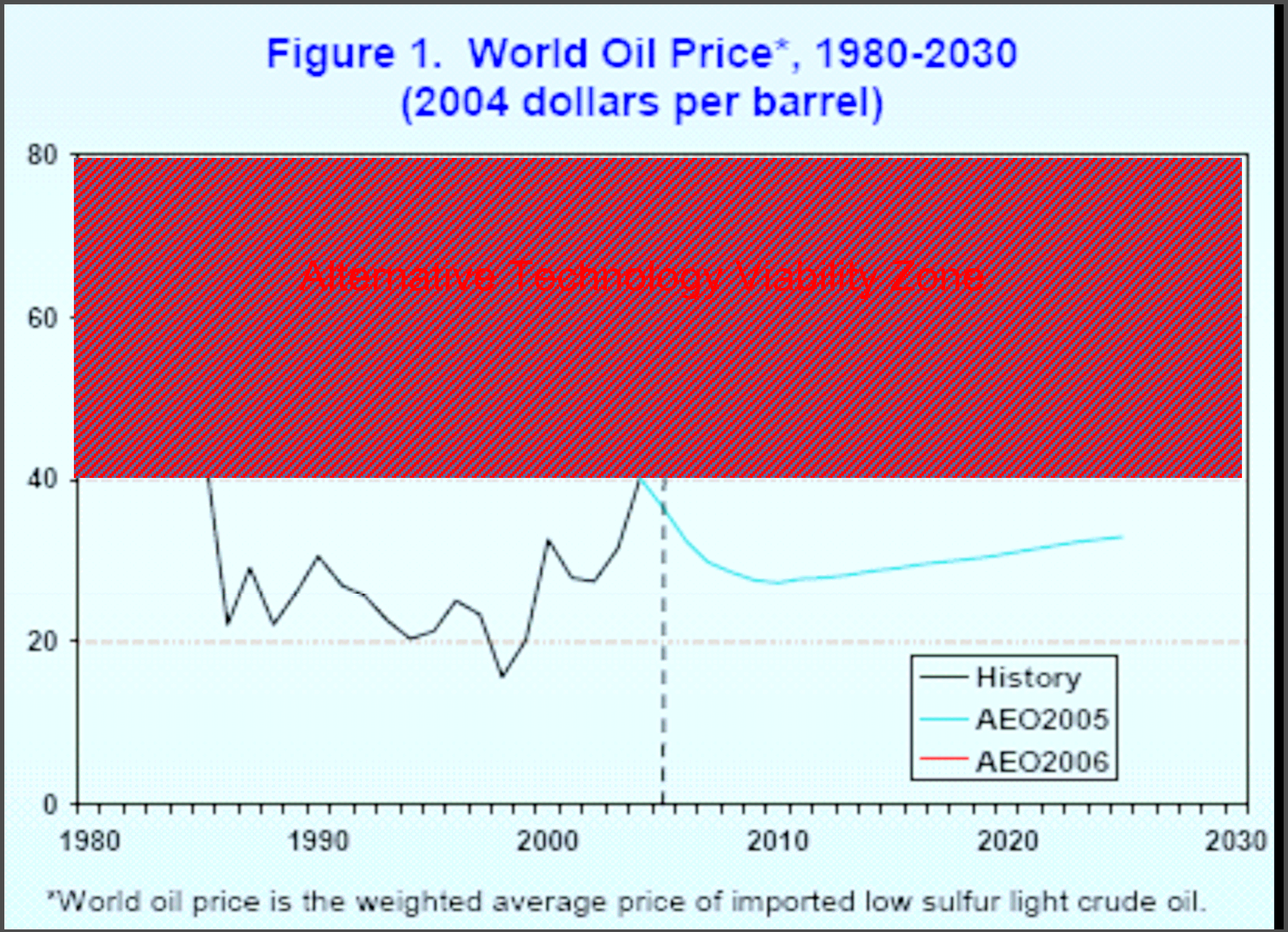
- In recent years, U.S. soybean production has averaged about 1.2 tons of dry beans per acre annually. Given an average bean protein mass fraction of about 0.4, the annual protein productivity of soybean production is about 0.5 tons protein per acre. Perennial grass (e.g. switchgrass) could likely achieve comparable protein productivity on land used to grow soybeans while producing lignocellulosic biomass at about a rate of about 7 dry tons per acre annually. The limited data available suggest that the quality of switchgrass protein is comparable to soy protein, and technology for protein extraction from leafy plants is relatively well-established. The 74 million acres currently planted in soybeans in the U.S. could, in principle, produce the same amount of feed protein we obtain from this land now while also producing over 520 million tons of lignocellulosic biomass. Alternatively, if new soy varieties were developed with increased above-ground biomass (option 4, Table 1), this could provide on the order of 350 million tons of lignocellulosic biomass – although soil carbon implications would have to be addressed.

Source: Lee R. Lynd, “Producing Cellulosic Bioenergy Feedstocks from Currnently Managed Lands,”

A Different World



Projected World Oil Prices (EIA)



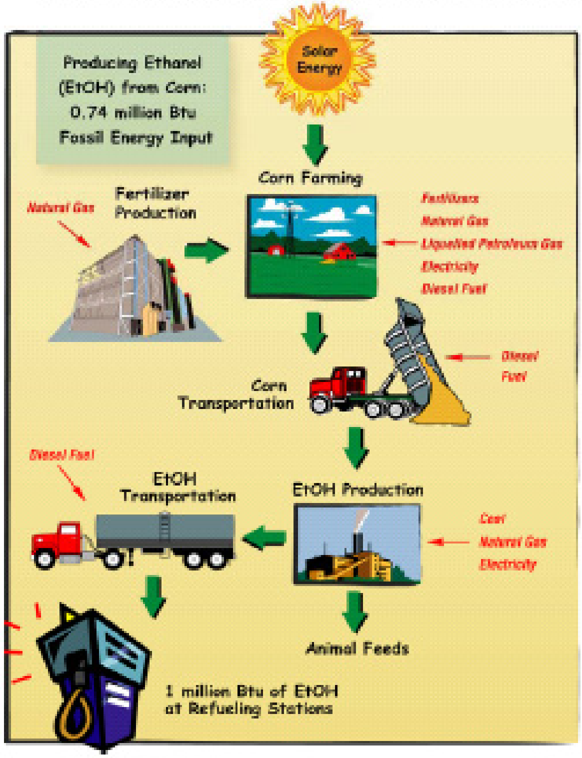
Source: EIA Reports

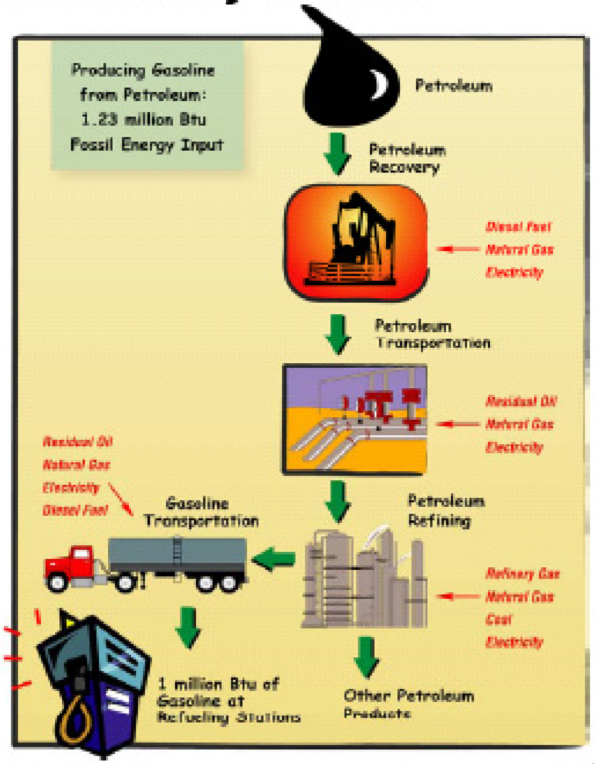
A Recent Study by Pimentel&Patzek Conclude Increases in Fossil Energy Use by Biofuels

- Pimentel&Patzek conclude that
  - Corn ethanol *increases* fossil energy use by 29%
  - Cellulosic biomass-based ethanol by 50-57%
  - Biodiesel by 27-118%
- Other studies have very different conclusions
  - Argonne has shown
    - Corn ethanol *reduces* fossil energy use by 26%
    - Cellulosic biomass-based ethanol *reduces* by 90%
  - National Renewable Energy Laboratory has shown that biodiesel *reduces* fossil energy use by 69%
- Differences between Pimentel&Patzek and others lie in
  - Corn farming energy use
  - Energy use for producing nitrogen fertilizer
  - Ethanol plant energy use
  - Credits for co-products from biofuel plants

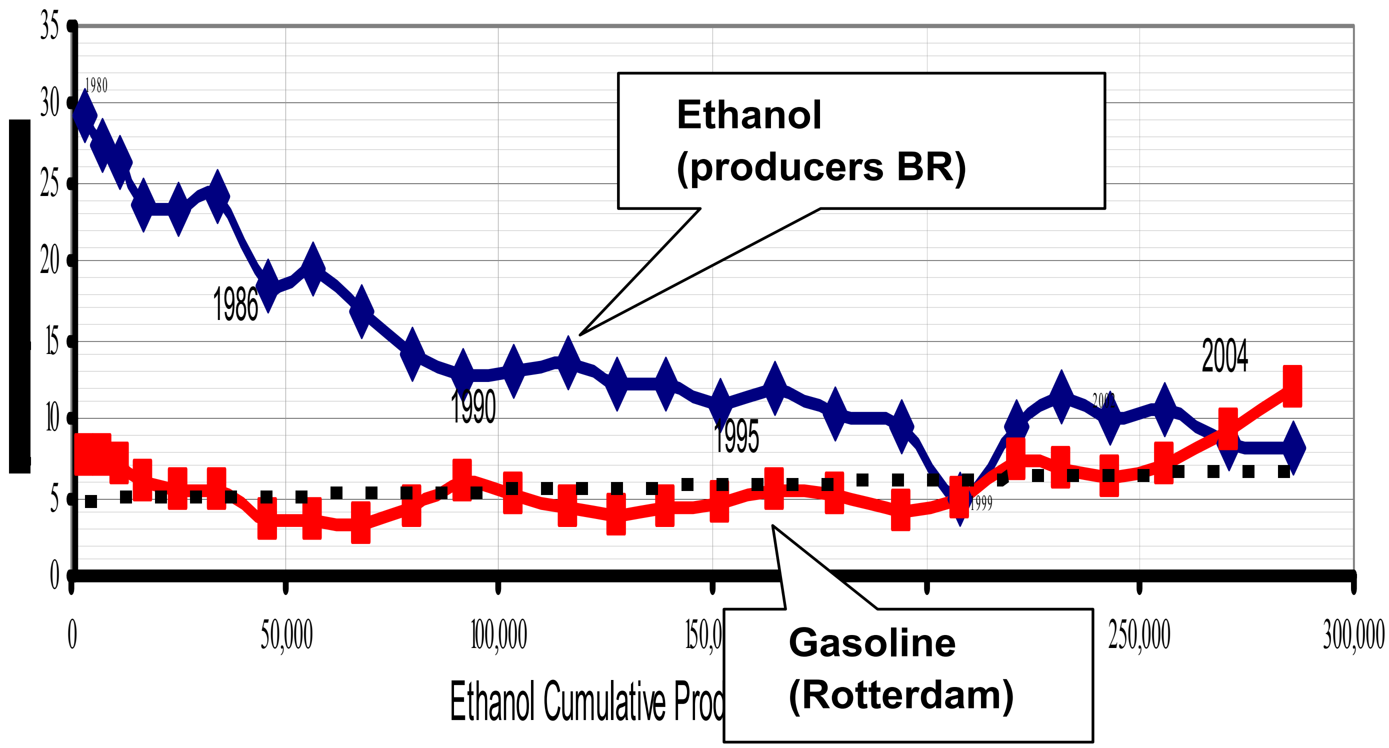
ARGONNE NATIONAL LABORATORY

Comparative Results Between Ethanol and Gasoline Are More Relevant to Policy Debate





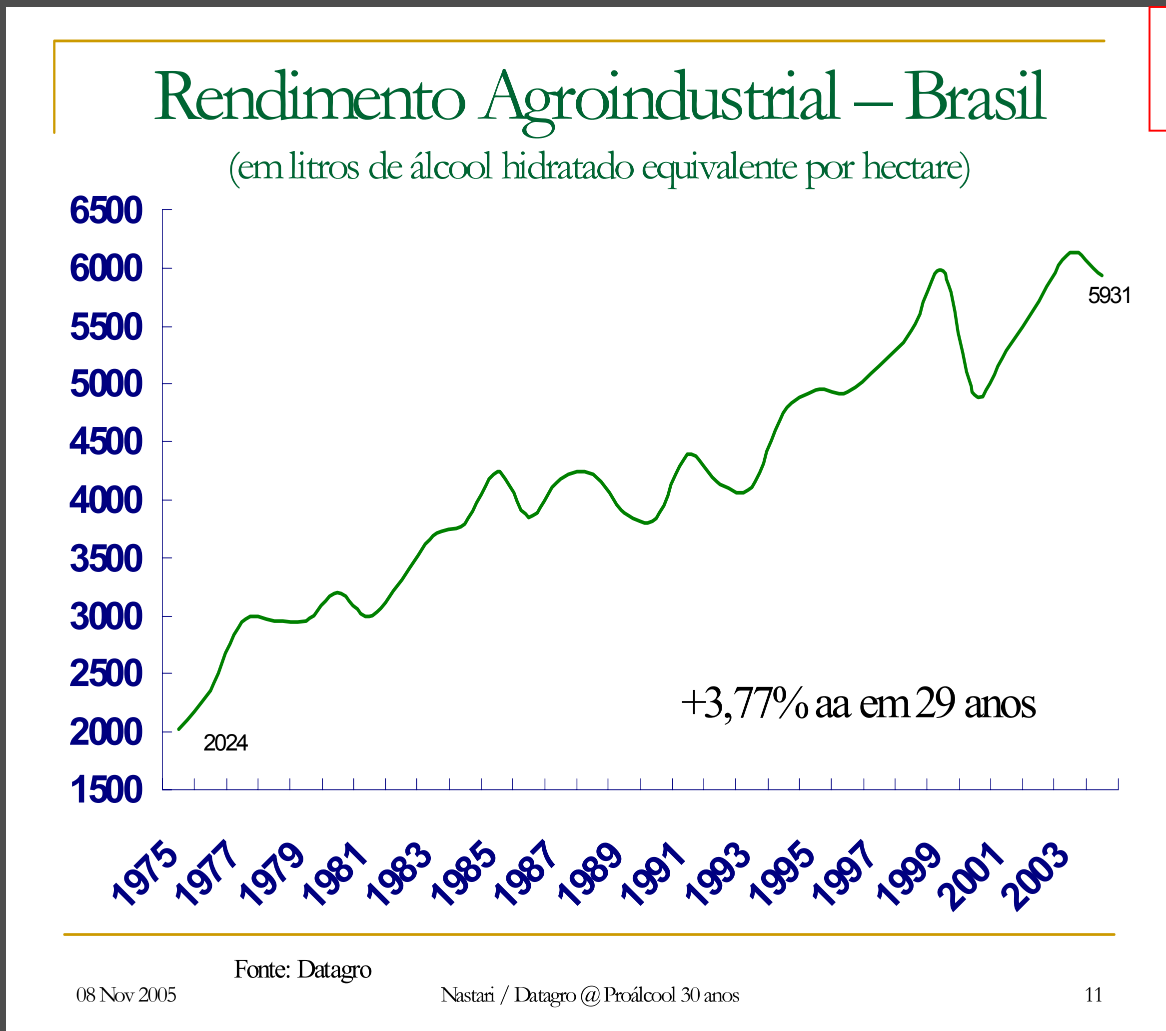
Ethanol: LEARNING CURVE



(J Goldemberg, 2004)

Brazil sugar-cane/ethanol learning curve

Liters of ethanol produced per hectare since between 1975 to 2004



30,000??

U.S. Fuel Ethanol Production Capacity (Dec 2004)

U.S. FUEL ETHANOL PRODUCTION CAPACITY DECEMBER 2004					
Rank	**Company/Producer**	**# of Locations**	**Ownership**	**Capacity (million GPY)**	**% of Existing Capacity**
1	ADM	7	Corp.	1,070	29.9%
2	Aventine Renewable Energy	2	Corp.	140	3.9%
3	Cargill, Inc.	2	Corp.	118	3.3%
4	Abengoa Bioenergy Corp.	3	Corp.	110	3.1%
5	New Energy Corp.	1	Corp.	100	2.8%
6	VeraSun Energy Corporation	1	Corp.	100	2.8%
7	MGP Ingredients, Inc.	2	Corp.	78	2.2%
8	Tate & Lyle	1	Corp.	67	1.9%
9	Chief Ethanol	1	Corp.	62	1.7%
10	AGP	1	Farmer	52	1.5%
11-70	Remaining 60 companies/producers	Only 1 producer has more than 1	36 of the 60 are farmer-owned	Total: 1,694 Range: 50 - 0.7 Mean: 28 Median: 30	47.0%
	Total Existing Capacity	**82**		**3,582**	**100.0%**
	Total Under Construction [1]	**16**		**754**	
	Total Capacity 2005-2006	**98**		**4,336**	

Source: Renewable Fuels Association

U. S. Ethanol Production Capacity Under Construction (Dec 2004)

U.S. ETHANOL PRODUCTION CAPACITY - UNDER CONSTRUCTION DECEMBER 2004				
Rank	**Company/Producer**	**Location**	**Ownership**	**Capacity (million GPY)**
1	VeraSun Energy Corp.	Ft. Dodge, IA	Corp.	110
2	Central Iowa	Goldfield, IA	Farmer	50
3	Illinois River Energy	Rochelle, IL	Corp.	50
4	Lincolnway Energy	Nevada, IA	Farmer	50
5	Northstar Ethanol	Lake Crystal, MN	Corp.	50
6	Voyager Ethanol	Emmetsburg, IA	Farmer	50
7	Granite Falls Energy	Granite Falls, MN	Corp.	45
8	Amaizing Energy	Denison, IA	Corp.	40
9	Bushmills Ethanol	Atwater, MN	Farmer	40
10	Mid-Missouri Energy	Malta Bend, MO	Farmer	40
11	United WI Grain Producers	Friesland, WI	Farmer	40
12	Western Wisconsin	Boyceville, WI	Farmer	40
13	East Kansas Agri-Energy	Garnett, KS	Farmer	35
14	Panhandle Energies	Dumas, TX	Corp.	30
15	Pine Lake Corn Processors	Steamboat Rock, IA	Farmer	20
16	Liquid Resources of Ohio	Medina, OH	Corp.	4
	Total Under Construction			**754**
	Total Existing Capacity			**3,582**
	Total Capacity 2005 - 2006			**4,336**

Source: Renewable Fuels Association

ARGONNE NATIONAL LABORATORY

Comparative Results Between Ethanol and Gasoline Are More Relevant to Policy Debate