Dr. William F. Banholzer
Executive VP and CTO
The Dow Chemical Company

The Future of Fuels and Alternative Feedstocks – Recognizing Hype vs. Practical Limitations

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Business Success vs. SCIENCE

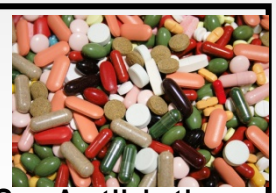
Impact to Society = Business Success

High

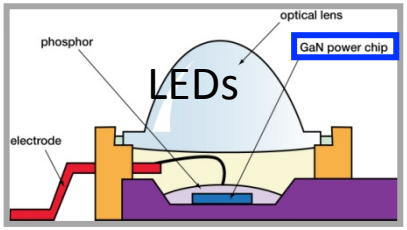
Low

Man Made Diamonds

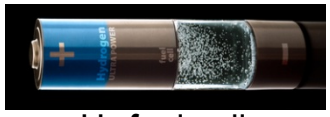
Transistors



Antibiotics



Ethylene Styrene Interpolymers



H_2 fuel cells

SkyMine®

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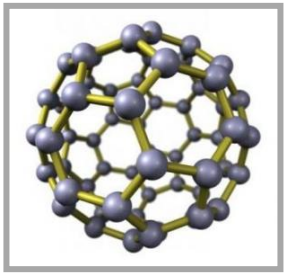
Green Cement for a Blue Planet



Low

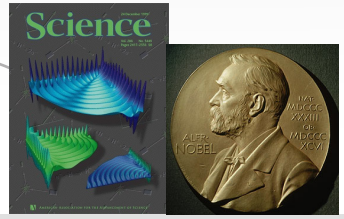
Quality of Science

High

Business vs. Academic Success

Challenges to Society

Invention



Academic Success

Impact to Society

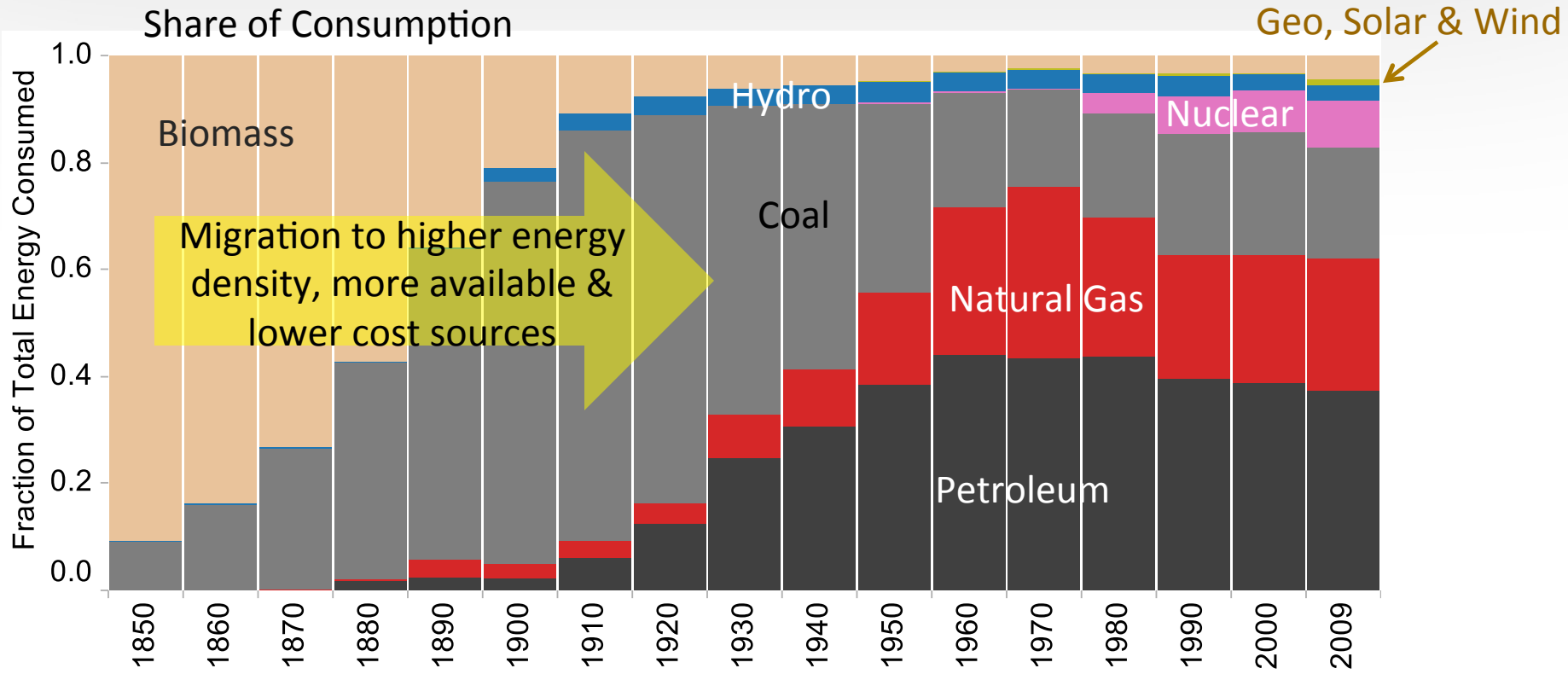
What people want ≠ what they will pay for
What they will pay for impacts society

Economic viability

Business Success

Risk vs Reward

Energy Sources Have Changed



What's Changed?

- Oil Price Rise
- CO2 awareness

Is that enough?

Source: IEA. EIA

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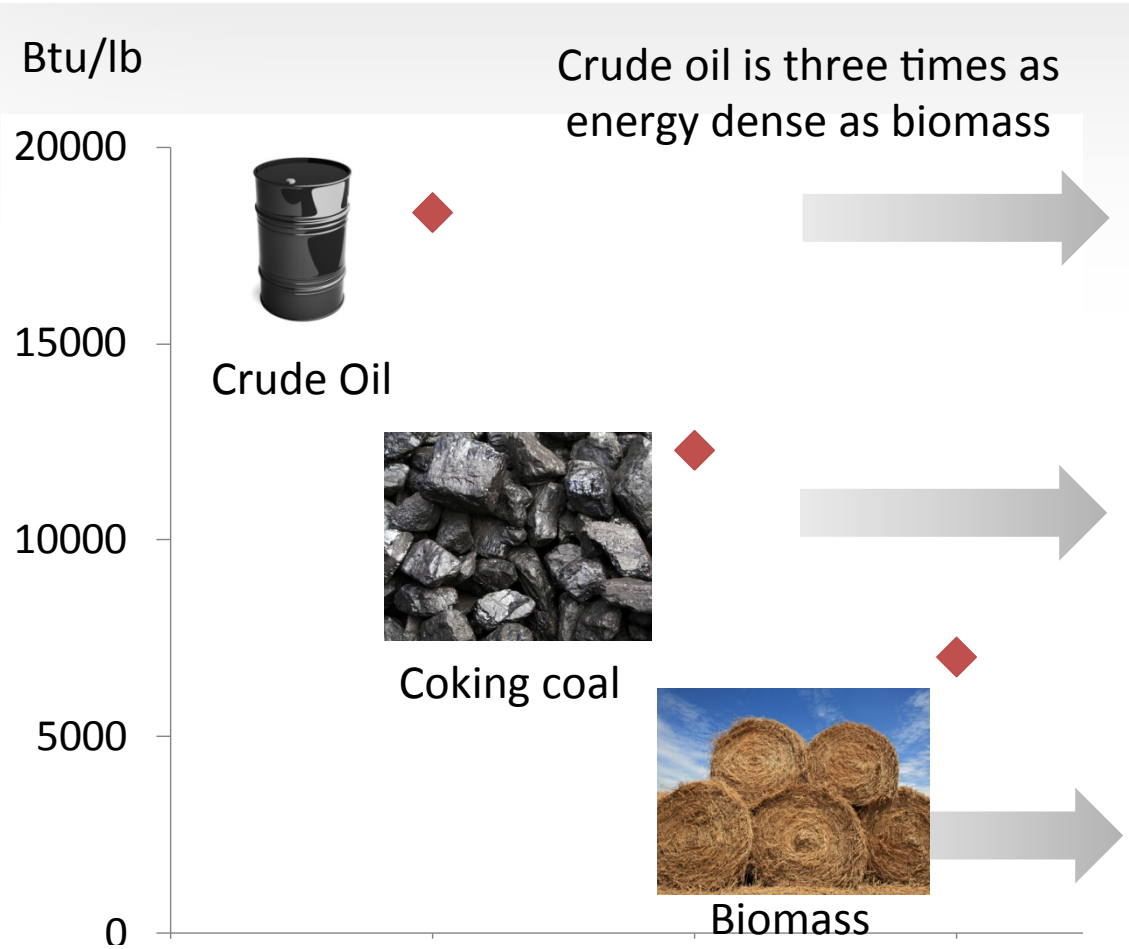
Migration to Higher Energy Density Sources



Energy Equivalency	$ Capital / Usable MM Btu
1 oil refinery	$164
27 power plants	$167
60 Ethanol refineries	$321*

*land & water penalty not included

Energy from fossil infrastructure built over 80-100 years defines our current standard of living

Sources: Heating values from GREET, Argonne National Lab, May 2008; Refinery size and economics by Oil & Gas Journal construction update, Dec 2010; Coal fired plant economics and size from Congressional Research Service report 2008; Ethanol plant of 100 MM gal/yr from DOE targets and economics estimated internally

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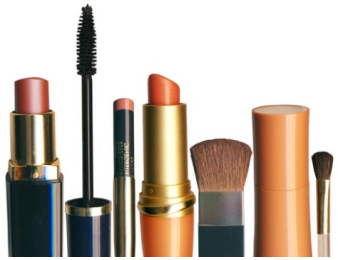
Chemical Feedstocks Have Changed

then

then

then



Why?

now

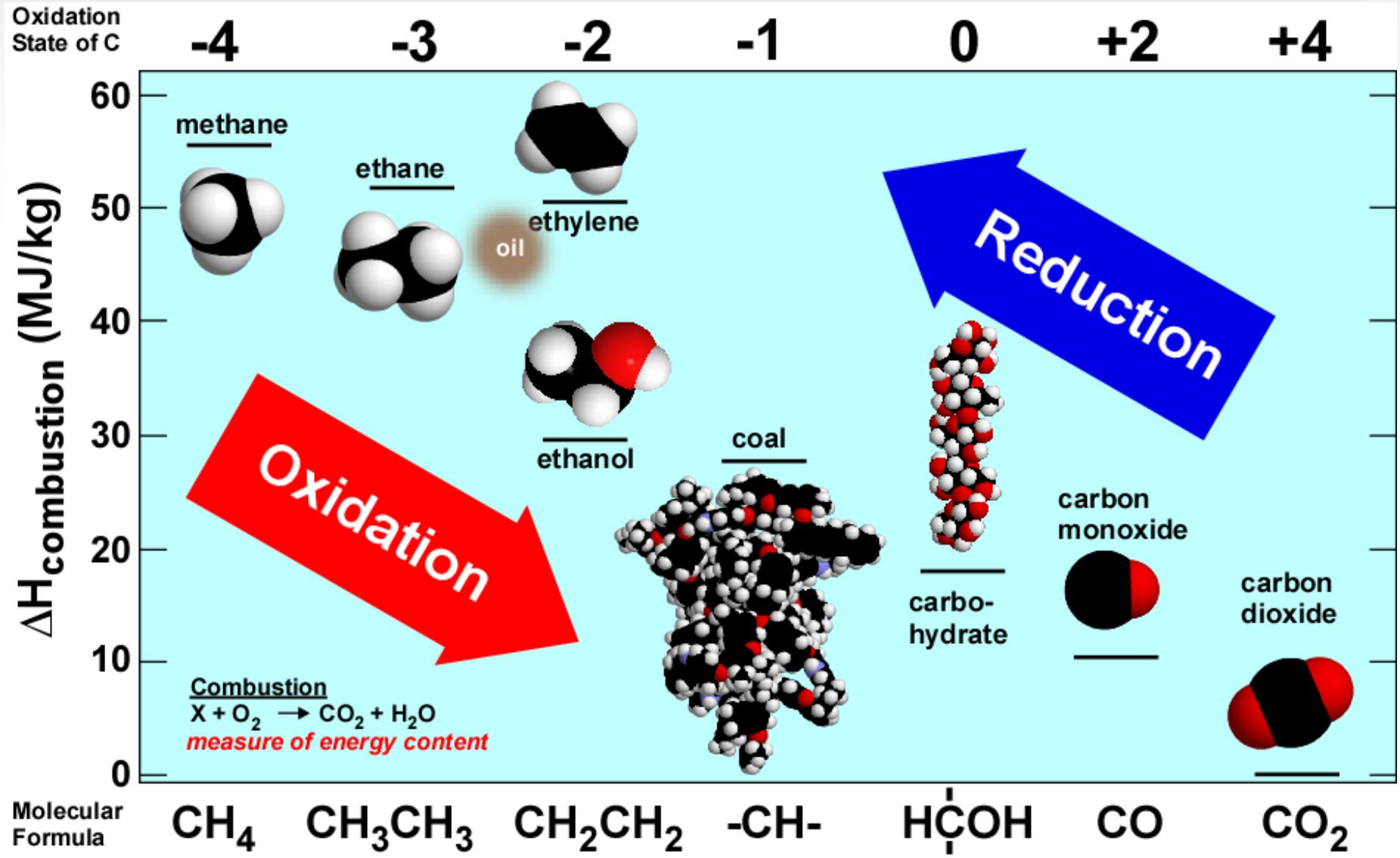
- Higher purity
- More availability
- Lower cost

What's Changed?

- Oil Price Rise
- CO2 awareness

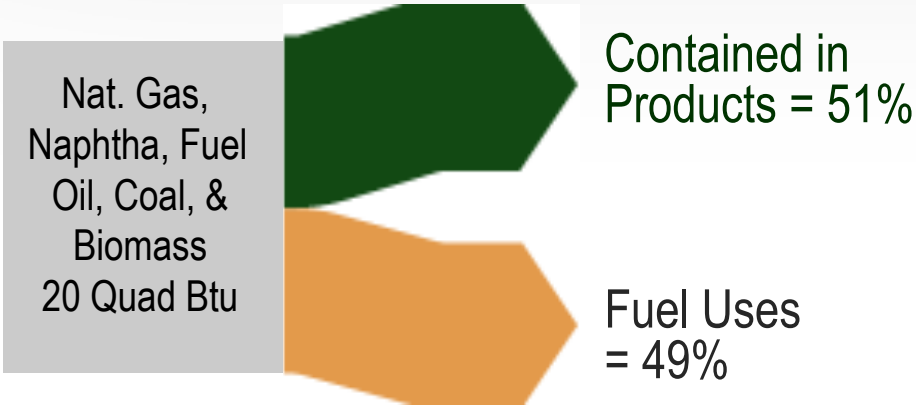
Is that enough?

Feedstock Oxidation States

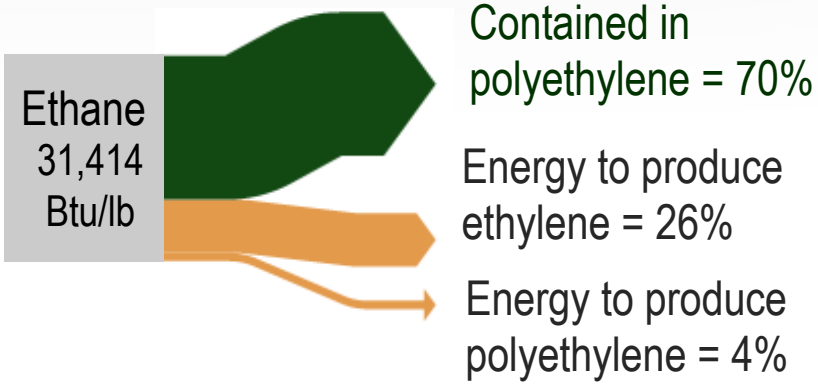


Carbon Stewardship

Chemical Industry



Ethane to Polyethylene



Transportation, *Other Industrial, Commercial, Residential

**Excludes Petrochemical industry*

Source: IEA 2008 Energy Balance for World, Energy and Environmental Profile of the U.S. Chemical Industry, May 2000, Energetics Inc.

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Limits to Photosynthesis

Photosynthesis is a highly under optimized energy conversion process

Solar Capture Process	W/m^2	Efficiency
Sugar Cane to Ethanol	0.60	0.30%
Energy Crop - Fermentation	0.70	0.32%
US Corn to Ethanol (gross)	0.32	0.16%

Problems with Biofuels & feedstocks

Poor quantum efficiencies	Less than1% for plants, max 3% for algae
Oxidized intermediates	Carbohydrates vs. products
Massive land & water	1 acre of US corn = 244 gallons of gasoline
Dilute feedstock & product	Capital costs are extreme
Food v fuel debates	Food needs expected to increase 2-5x by 2050
Cost prohibitive	Ethanol must be less than 15 cents/gal to compete with Middle east oil

Conclusion: Opportunistic plays but not massively scalable

Carbon Dioxide – An Opportunity

Skyonic

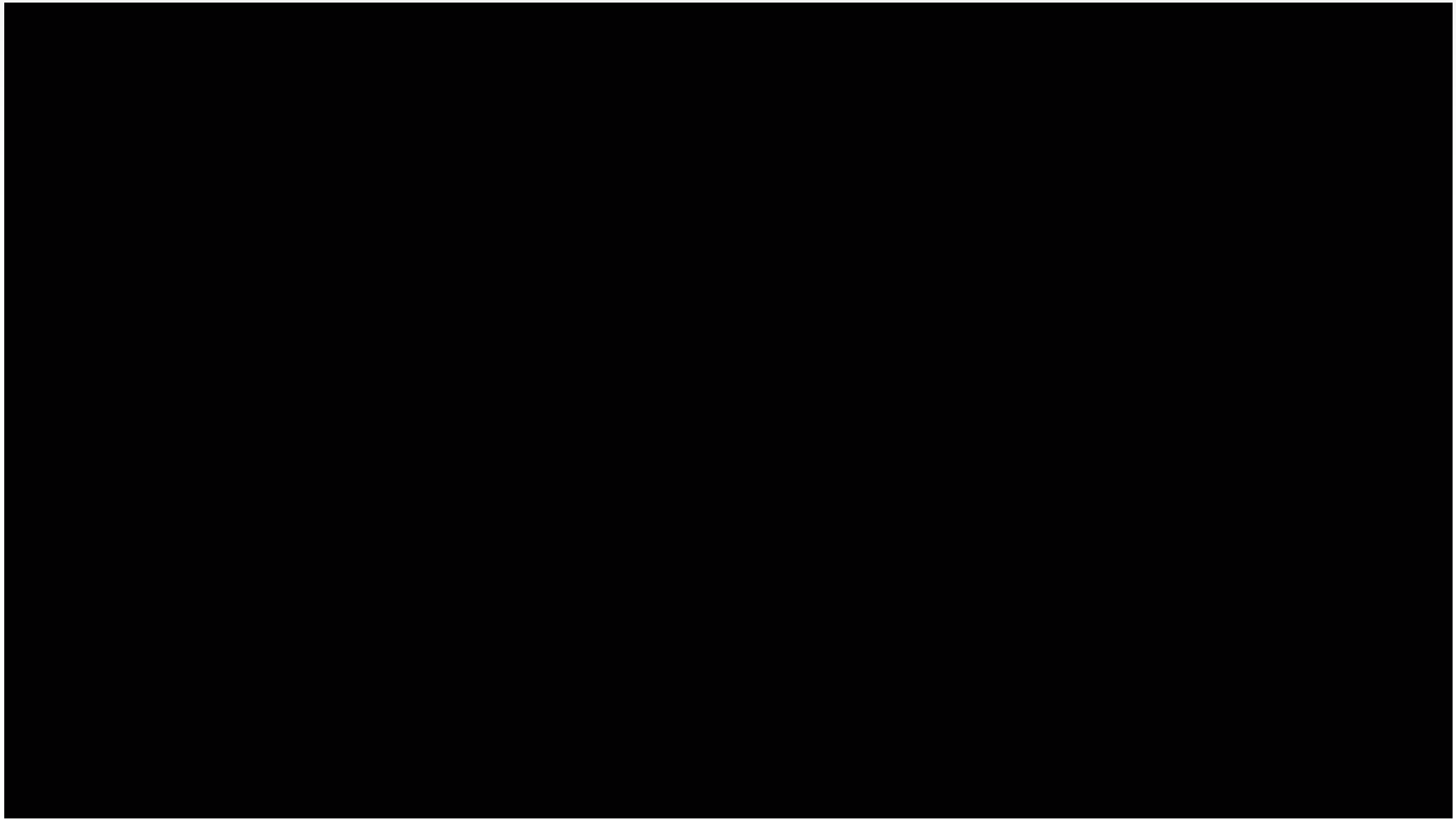
Founded in 2005. Has raised $4.5MM from 15 investors including TXU Corp (NYSE: TXU). Received $28M in US federal support as of 8/2011.

SkyMine® Technology

$NaOH$ **Caustic** + CO_2 **Carbon Dioxide** → $NaHCO_3$ **Baking Soda**

This technology appears to be a natural fit for Dow, the world's leading manufacturer of caustic soda.

Cookies from Coal



Technology Evaluation

How much electricity is required to make this NaOH?

Byproducts: Chlorine: 2.7 million ton/yr - (50% of Dow global capacity)
Bicarbonate: 6.3 million ton/yr

Capital to build NaOH capacity $4 billion

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Recognizing Fads

The art of being wise is the art of knowing what to overlook - William James

Hydrogen Car

"We asked ourselves, **'Is it likely in the next 10 or 15, 20 years that we will convert to a hydrogen car economy?**' The answer, we felt, was 'no,'""

Steve Chum, Energy Secretary, May 2009

Corn Ethanol

"…Using land to grow fuel leads to the destruction of forests, wetlands and grasslands that store enormous amounts of carbon."

Michael Grunwald, TIME April 2007

Biodiesel

"Biofuels are contributing to higher prices and tighter markets."

Timothy Searchinger, Princeton University April 2011

Cellulosic Ethanol

"…the need for trucks, machinery and manpower would come during harvest, already the busiest time of the year on the farm. And that's where **a massive federal initiative into cellulosic ethanol may find its biggest bottleneck – on the farm."**

Robert Rapier

Bio Plastics

Dow launched the JV with Cargill in 1997 to develop and market PLA from corn, exited the JV in 2004.

THE WALL STREET JOURNAL.

"Sun Chips Bag to Lose Its Crunch"

Photo: Associated Press

Bio based packaging launched in 2009 but discontinued by late 2010, due to performance perception issues

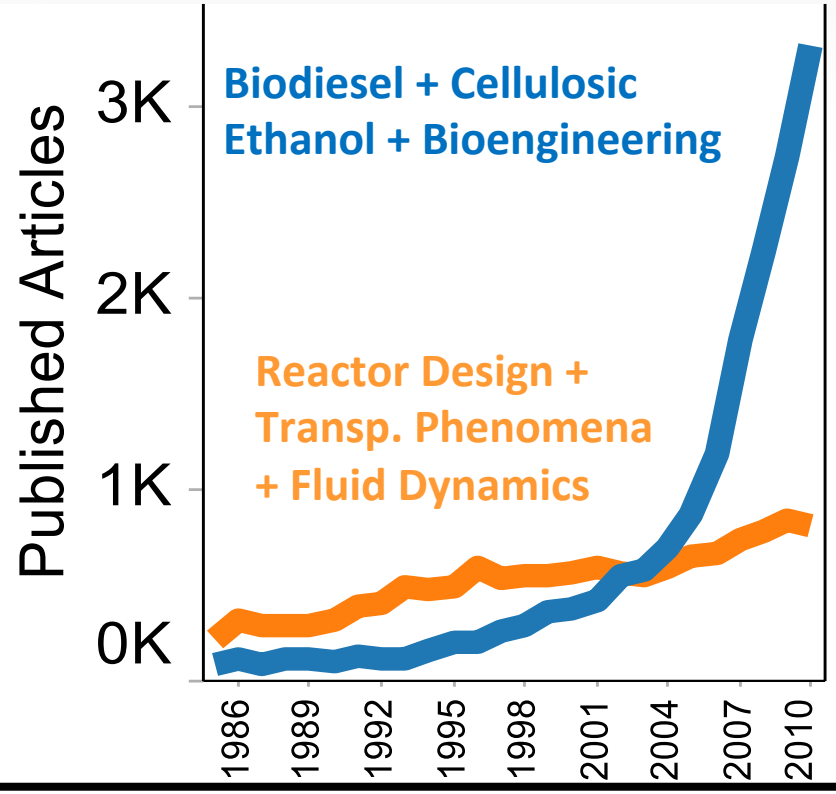
Natural oil Polyols

RENUVA™

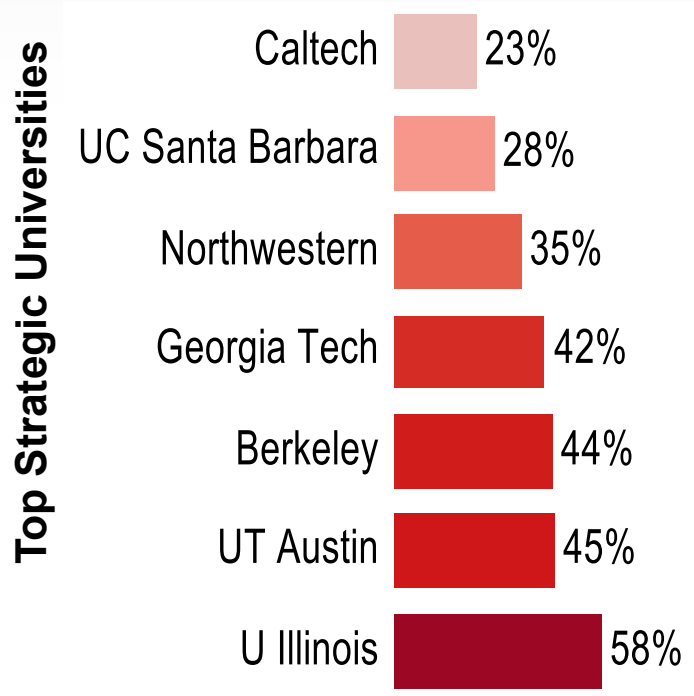
Dow Launched in 2007, exited in 2010.

Funding Follows the Hype

Published Articles Reflect the Focus on "Bio" Related Research:



Percentage of Faculty with "Bio" Related Research Interests:



Dynamic range of the discipline is threatened by decreasing support of the traditional core research areas.

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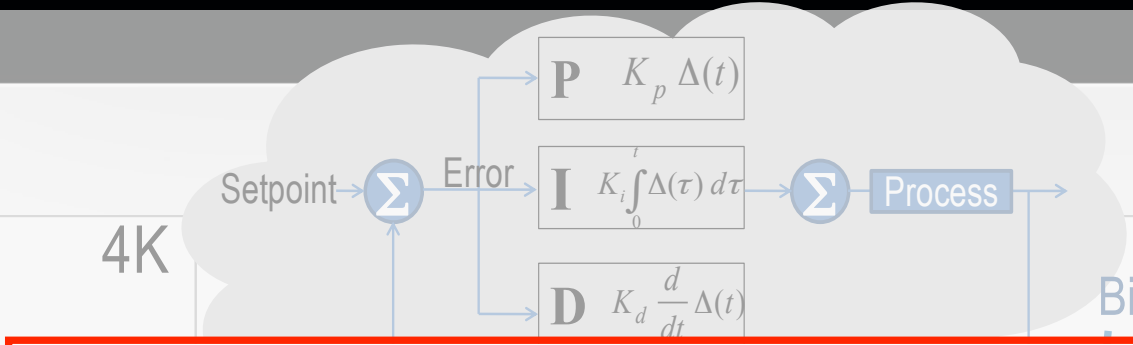
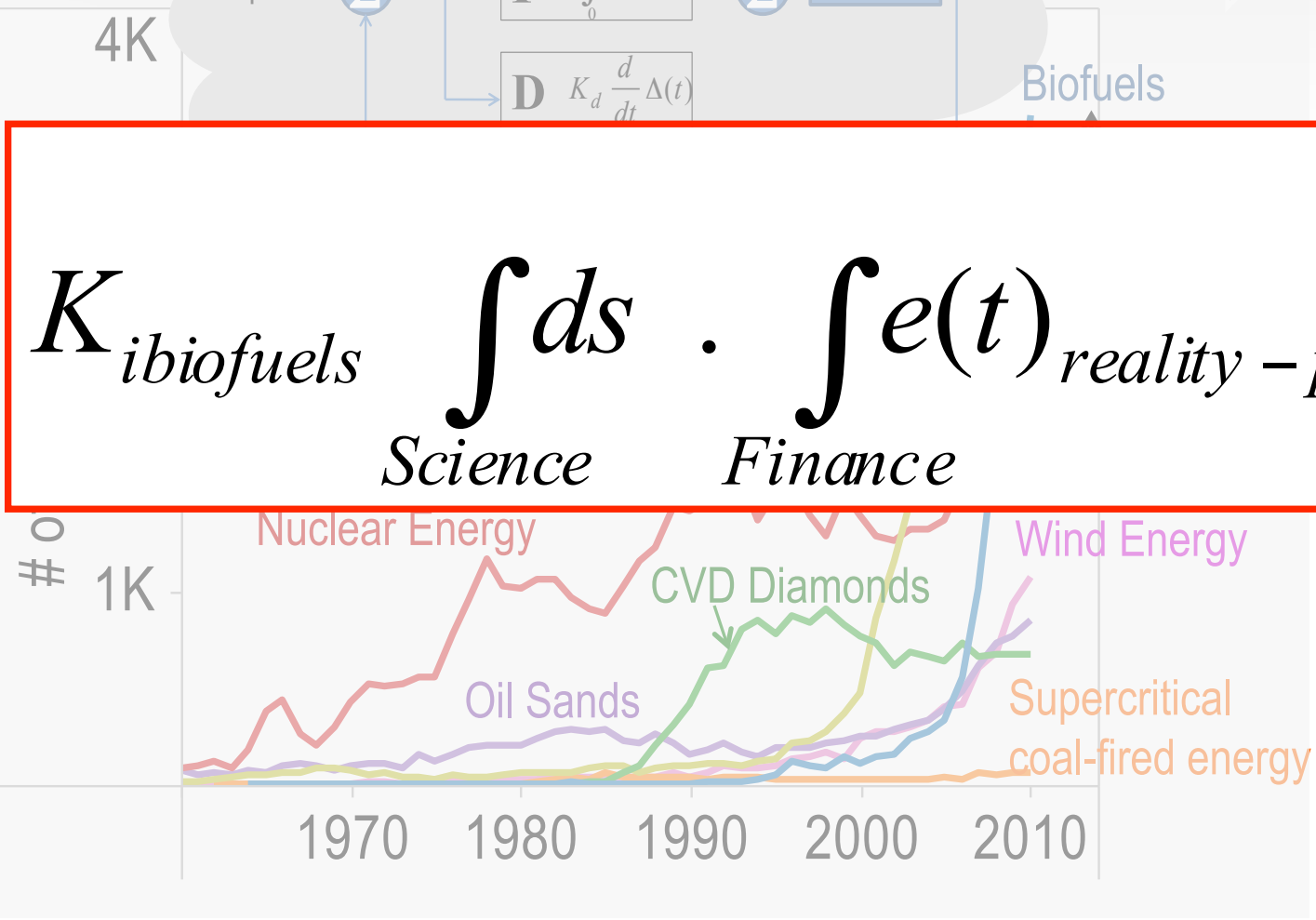
Control Loop Feedback for Fads

R&D gets wasted on a lot of things that have little significance to society



A large proportional response to public opinion

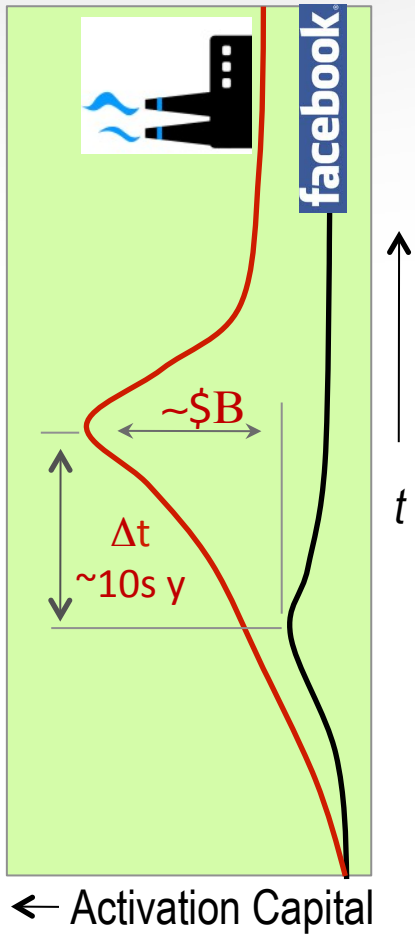
$$K_{ibiofuels} \int_{Science} ds \cdot \int_{Finance} e(t)_{reality-perception}\, de$$



Requires an integral function of good science and economic analysis to separate fads from what is practical.

Scale of Industry Makes it Harder

	Original Inv.	Capital for Single Plant	
facebook	$41MM		Largest Social Community on Internet
Nuclear Power Plar (1350MW)		$4,971MM	0.05% of Global Electricity Generation Revenue $1051MM/y
Pulverized Coal: C((600MW)		$2,372MM	0.02% of Global Electricity Generation Revenue $441MM/y
EG (400 KT/Yr)		$326MM	2% of Global MEG Consumption
MTO (277 kiloton/Y		$321MM	0.3% of Global Ethylene consumption

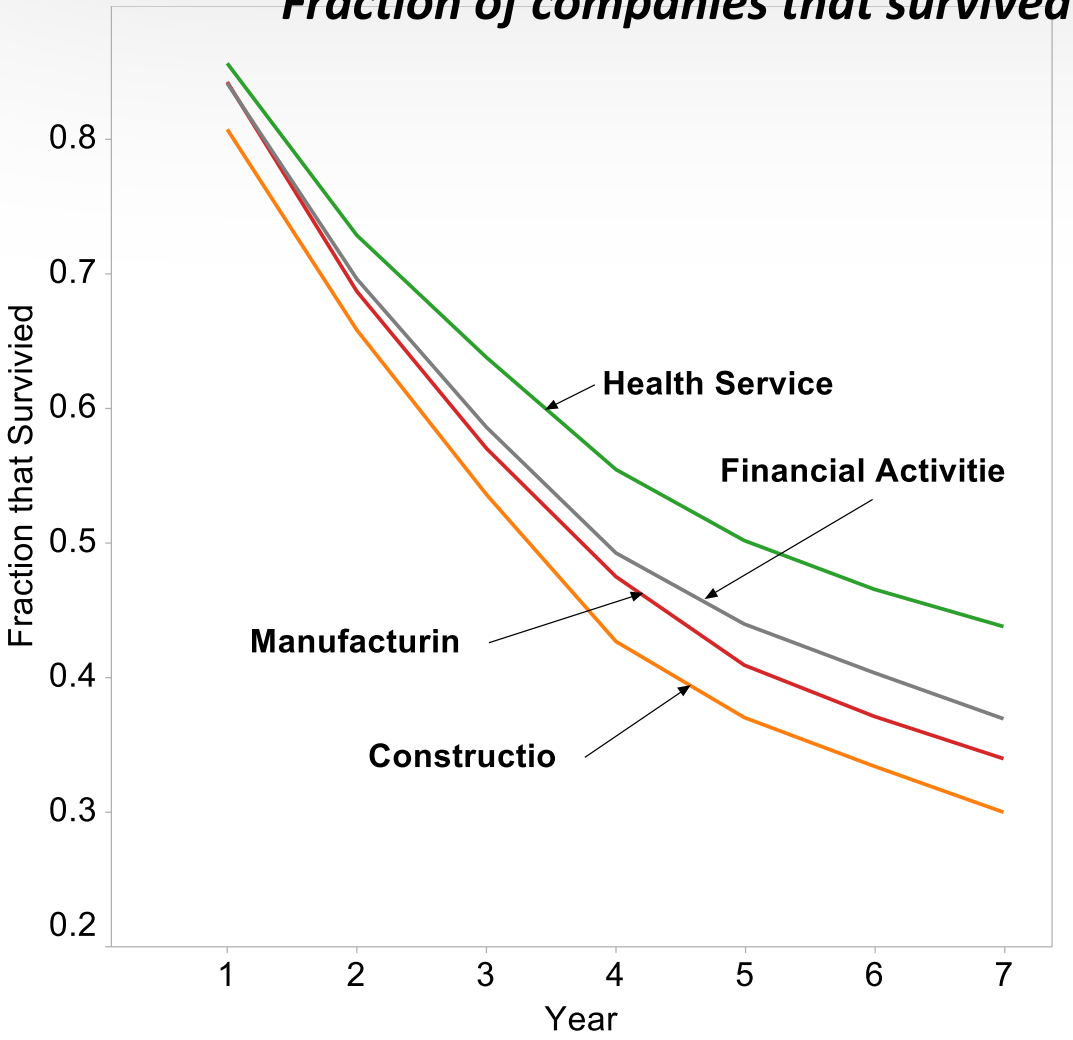


Sources: facebook original investment showing combined amounts from Peter Thiel (PayPal cofounder), Accel Partners and Greylock Partners as described in the History of facebook on wikipedia; Power Plants: RL34746 report - Stan Kaplan - Congressional Research Service; MTO: PEP Report 261 – SRI and EG: PEP Repor 2I – SRI; **Revenues** for Power Plants calculated using 2010 electricity average retail prices (all sectors) 9.88 cents/kWh (data from DOE)

The Truth – Companies Fail

Especially Small Companies

Fraction of companies that survived after launch



Energy & chemical industries require very high reliability

Energy & chemical industries are extremely capital intensive

Failure has massive financial and social consequences

Source: Knaup, Amy E., May 2005,, "Survival and longevity in the Business Employment Dynamics data," *Monthly Labor Review*, pp. 50–56; Knaup, Amy E. and MC. Piazza, September 2007, Business Employment Dynamics Data: Survival and Longevity, Monthly Labor Review, pp 3-10.

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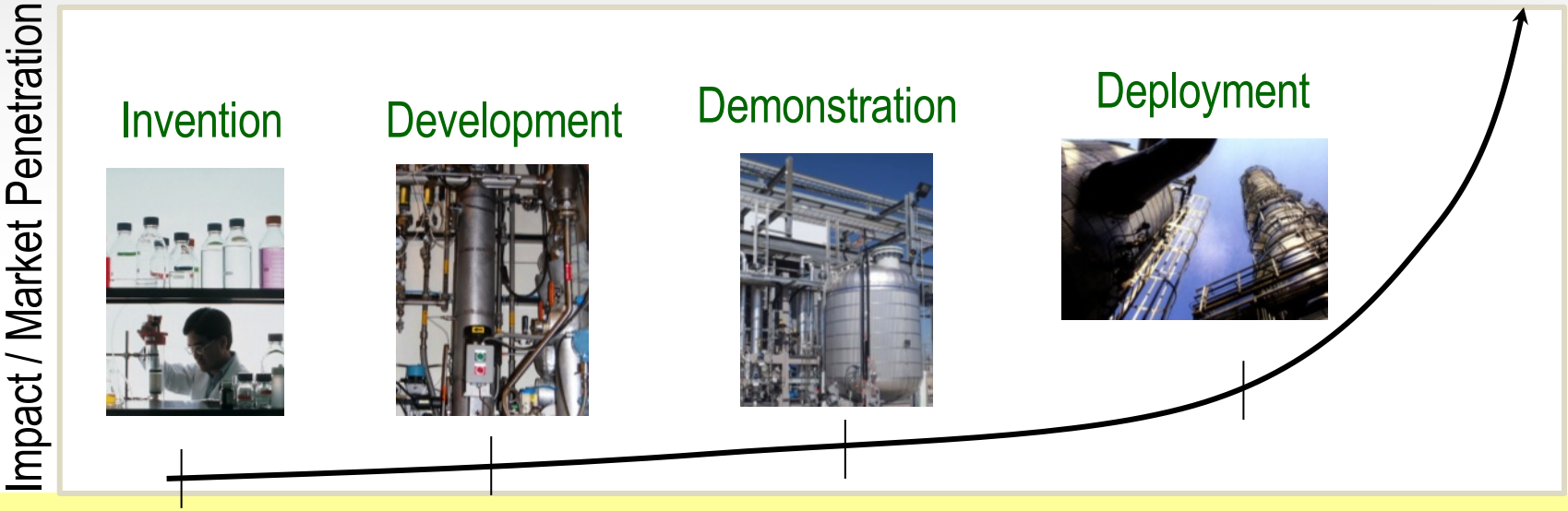
Timeline for Impact

It takes decade(s) to commercialize new products or technology



Single Site Catalysis

$ ~$10s MM ~$50 MM ~$150 MM*

t 1957, 80 1980-90 1989 1991 **Σ ~12 yrs**

Super Critical Coal Power

$ ~$100s MM ~$500+ MM ~$2 B**

t 1920 1930 -50s 1957 1970s **Σ ~50 yrs**

Sources: SRI PEP LLDPE 36E 2008, SRI PEP 153B 2001 Single site catalysts for PE Production, AEP Power Co, World Bank, EIA 2011 Energy Outlook, Electricity Market Module

*400 mT LLDPE plant, 2008$ **600 MW plant, 2009$

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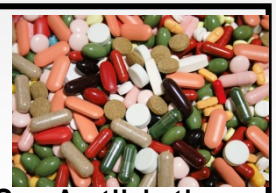
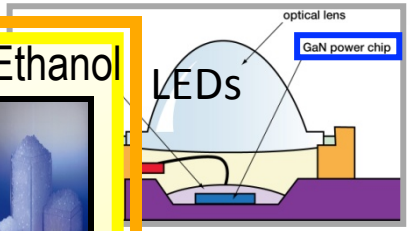


Antibiotics

Bio Based PET

Cellulosic Fuels

PE from Ethanol



LEDs

Styrene
olymers

H_2 fuel cells

SkyMine®

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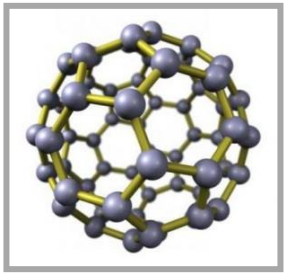
Green Cement for a Blue Planet



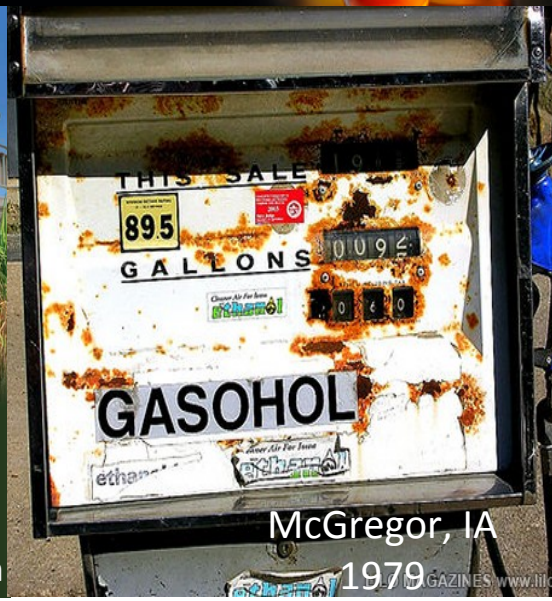
Low

Quality of Science

High

Ethanol – Its not a new idea

Lincoln NE
1933



McGregor, IA
1979

Ford Model T 1908

"Does the average citizen understand what this means? In from 10 to 20 years this country will be dependent entirely upon outside sources for a supply of liquid fuels … paying out vast sums yearly in order to obtain supplies of crude oil from Mexico, Russia, and Persia."

Yale Professor Harold Hibbert - Ethanol promoter, 1925

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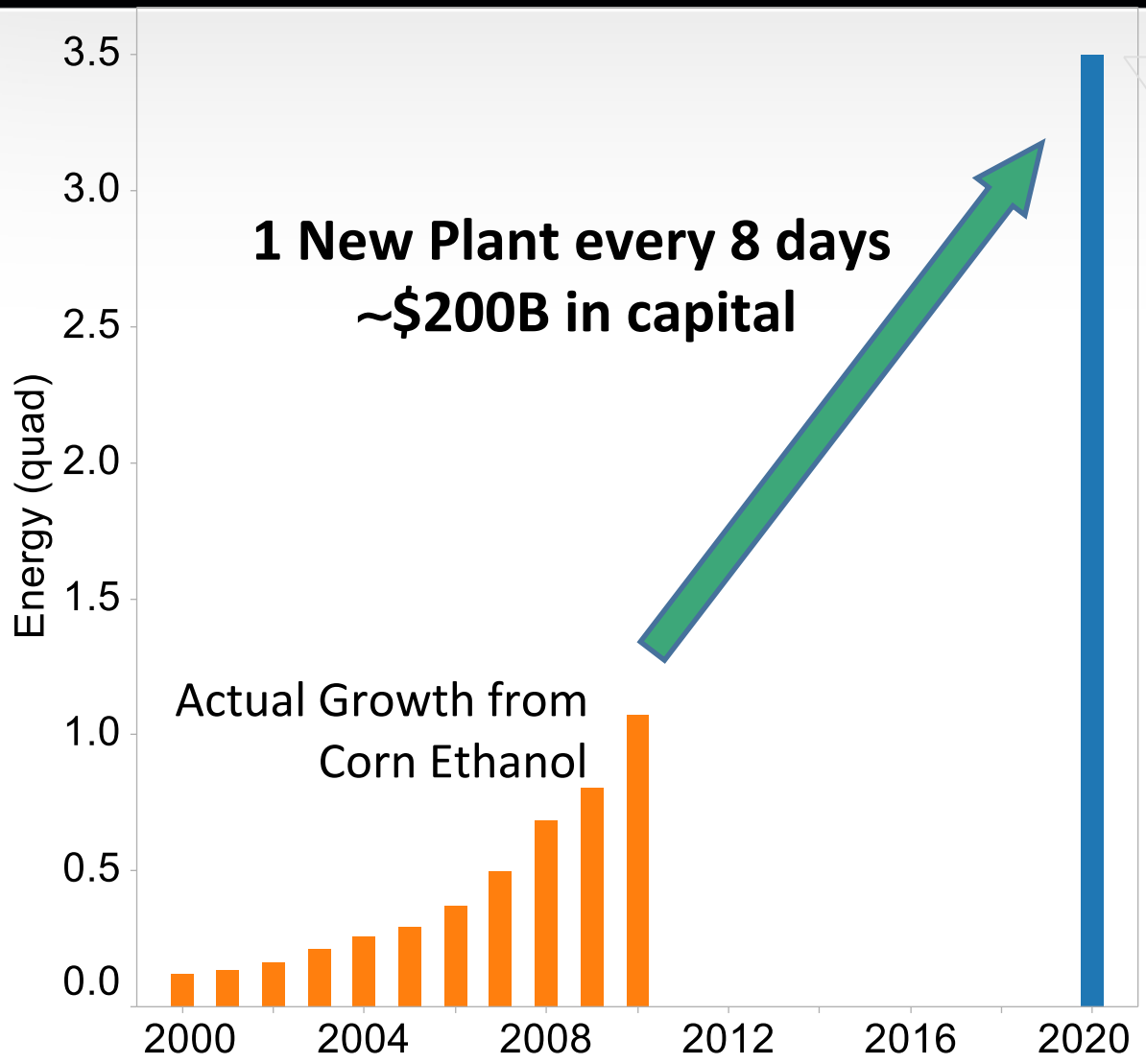
The Cellulosic Ethanol Fad

Long time and high cost to implement



9% of US Liquid Fuel Consumption in 2020

3% of US total Energy Consumption in 2020

National Academy of Sciences Projected Biomass (550MM ton) with Thermochemical Process

Data shown in 2020 includes only the energy generated by the 550 MM ton of biomass (Nat. Academy of Sciences) with performance of 2012 DOE target

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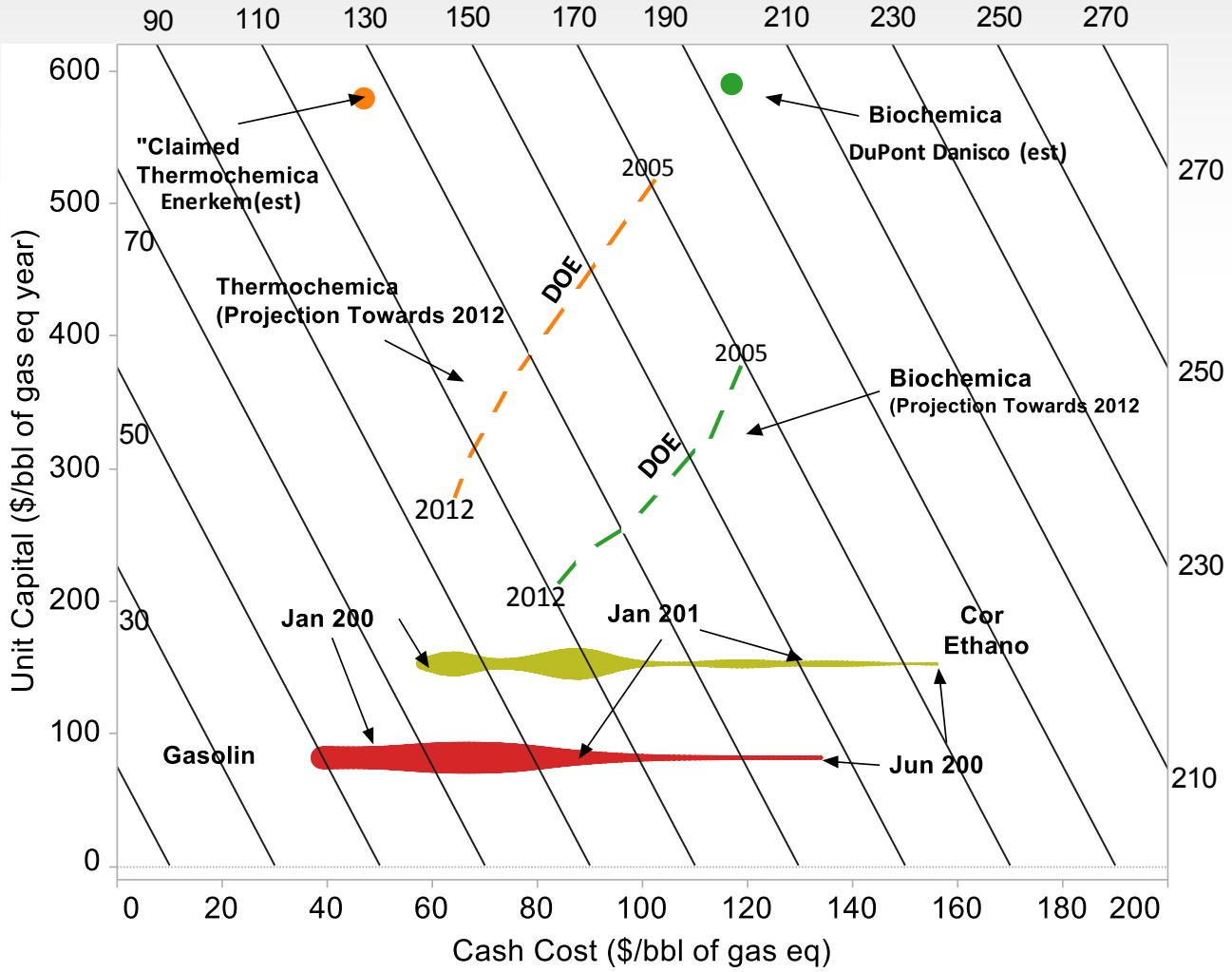
The Cellulosic Ethanol Fad

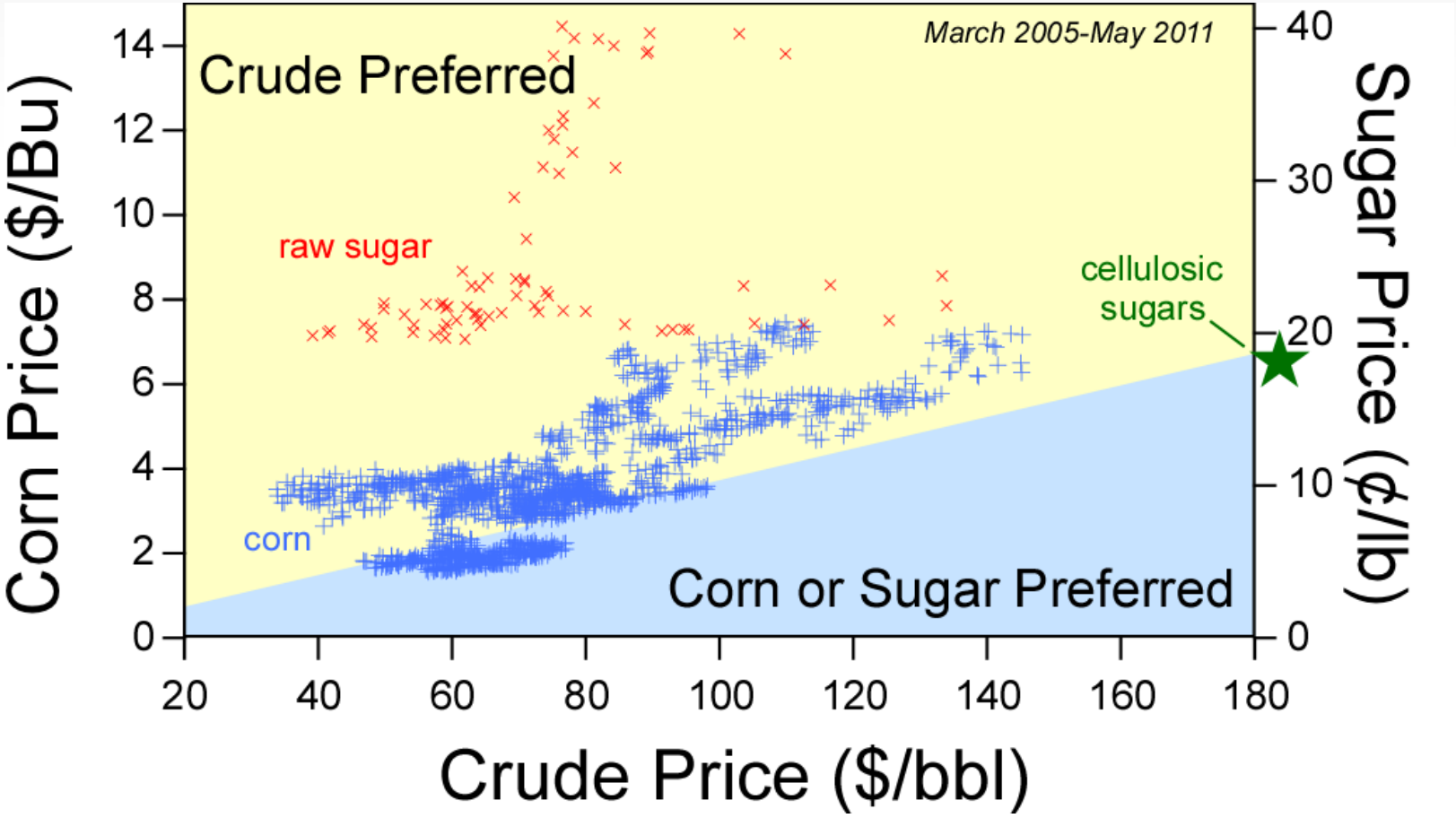
Large cash and capital cost to implement



Sources: Crude Oil price, CMAI, Spot Average FOB price; monthly average prices from Jan 2005 to Jan 2011 Targets from DOE for Biochemical and Thermochemical routes; Capital from Biomass Multi Year Program 201 report from DOE (revisited by DOE on Nov 2010) Corn Ethanol from the Center of Agricultural and Rural Development from Jan 2005 to Jan 2011
Reality today: based on announced Verenium Capital Intensity and assuming: yield of 70 gal EtOH/ton of biomass, enzyme cost at $0.50/gal EtOH and biomass at $75/ton

Cost Advantage of Petro feedstocks*

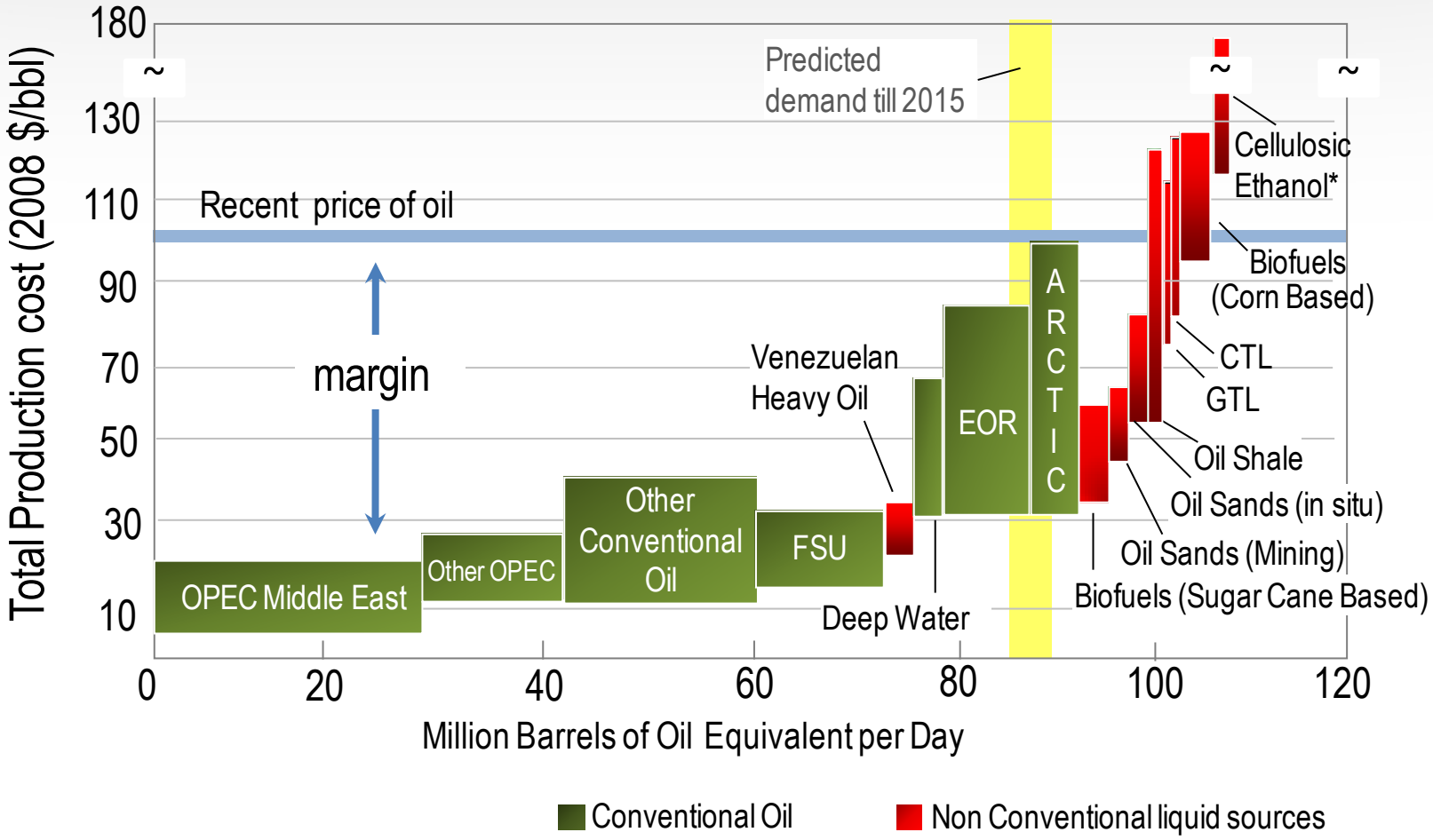
Cash cost *indifference analysis for ethylene from crude oil and bio feedstocks*



***Excludes Capital**

Energy Industry Dynamics

As oil price rises, new capital will flow to EOR, Arctic, Oil sands, GTL, CTL before biofuels.



Source: IEA, EIA, Booz Allen Hamilton, DOE Biomass Multiyear Program Plan April 2011, Dow Analysis

*Based on DOE volume projections for US in 2022. DOE price target is ~$113/bbl

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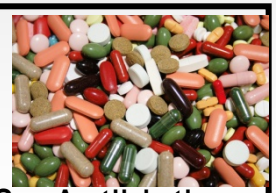

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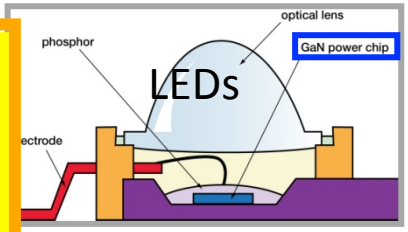
PE from Ethanol



Ethylene Styrene Interpolymers

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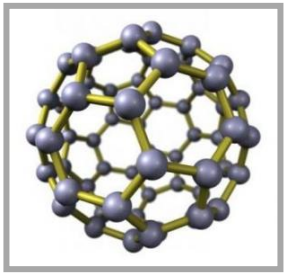

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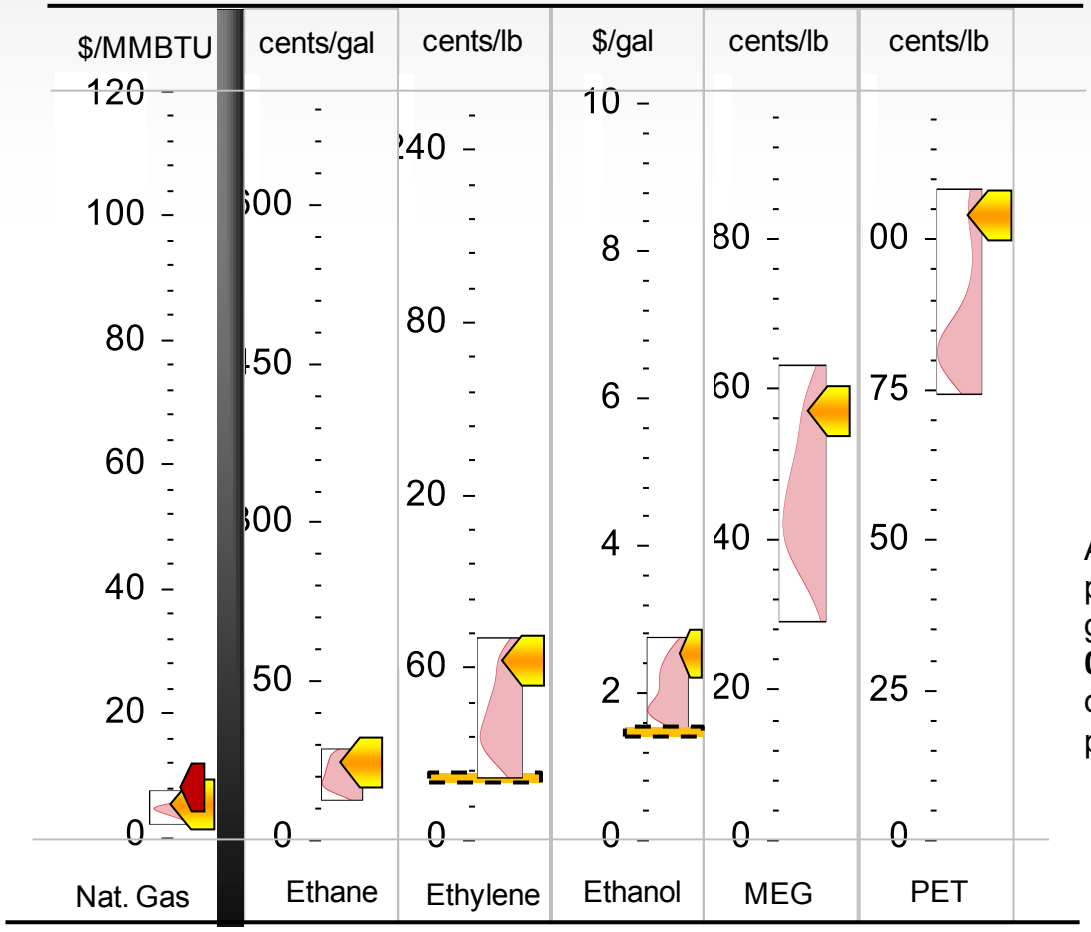
Green PET

Market prices and selected costs on energy equivalent basis



Area required for produce ethanol to meet global PET production ~ **0.4x of Illinois** based on 2010 US avg productivity of corn.

Costs*
USA

Market Prices
USA 2020 US Prj.

Sources: Prices: Natural Gas, Naphtha, p-xylene, ethane, ethylene, MEG, PET: **CMAI;** Ethanol US. **ICIS**, Ethanol Br: **ESALQ;** Prices shown as of June 2011 2 years price variation. *Costs: 2009 US cash cost Ethylene CMAI; Ethanol cost to Blender: SRI 2011

LCA of Polymers

Biopolymers rank in the middle of LCA rankings

POLYMER	Material	Green Design Rank	LCA Rank
Polylactic Acid – NatureWorks	Sugar/cornstarch	1	6
Polyhydroxyalkanoate-Stover	Cornstalks	2	4
Polyhydroxyalkanoate-General	Corn kernels	2	8
Polylactic Acid -General	Sugar/cornstarch	4	9
HD Polyethylene	Petroleum	5	2
PET	Petroleum	6	10
LD Polyethylene	Petroleum	7	3
Bio-PET	Petroleum /plants	8	12
Polypropylene	Fossil fuels	9	1
General Purpose Polystyrene	Petroleum	10	5
PVC	Chlorine/petroleum	11	7
Polycarbonate	Petroleum	12	11

Tabone, MD; Cregg, JJ; Beckman, EJ; Landis, AE. Environ. Sci. Technol. 2010, *44*, 8264-9.

Will Consumers Pay for “GREEN?”

Only if they get “GREEN” in return…..

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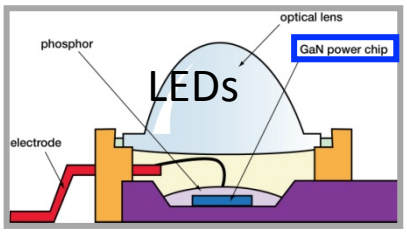

H_2 fuel cells

?

Ethylene Styrene Interpolymers

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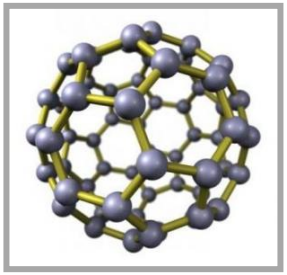

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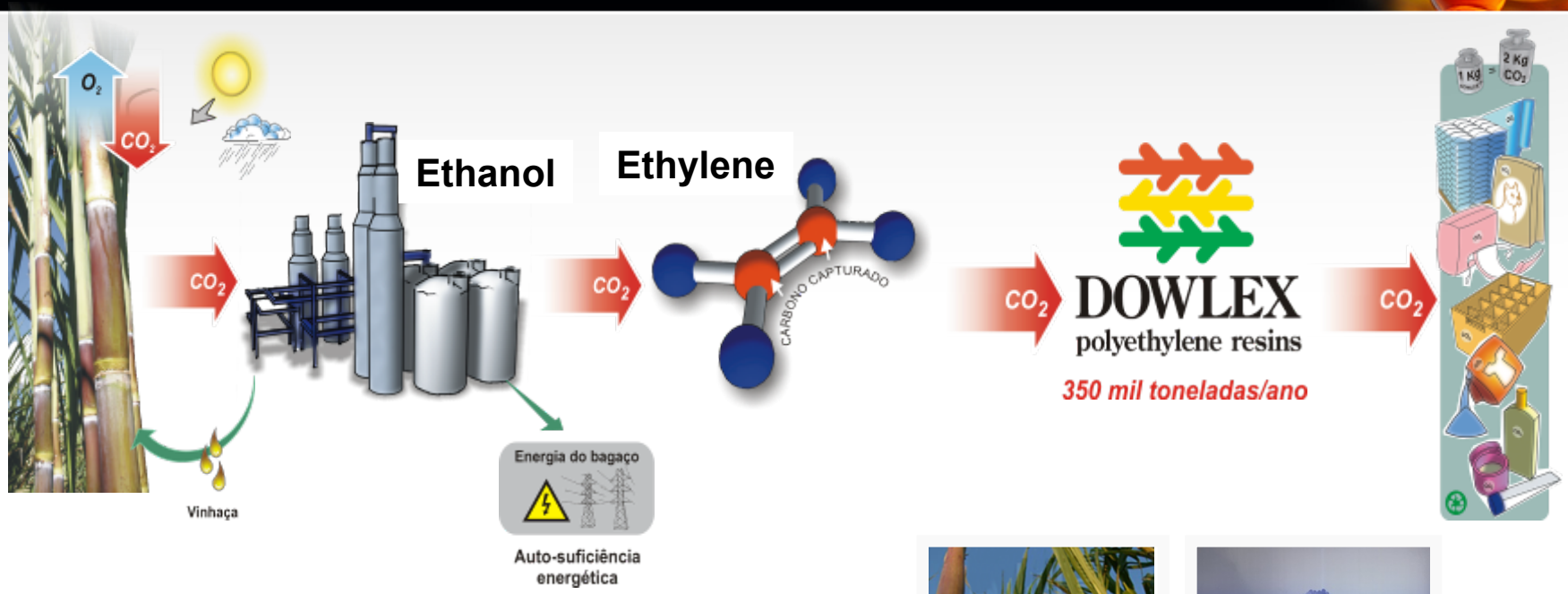
Alternative Feedstock - Cane to LLDPE



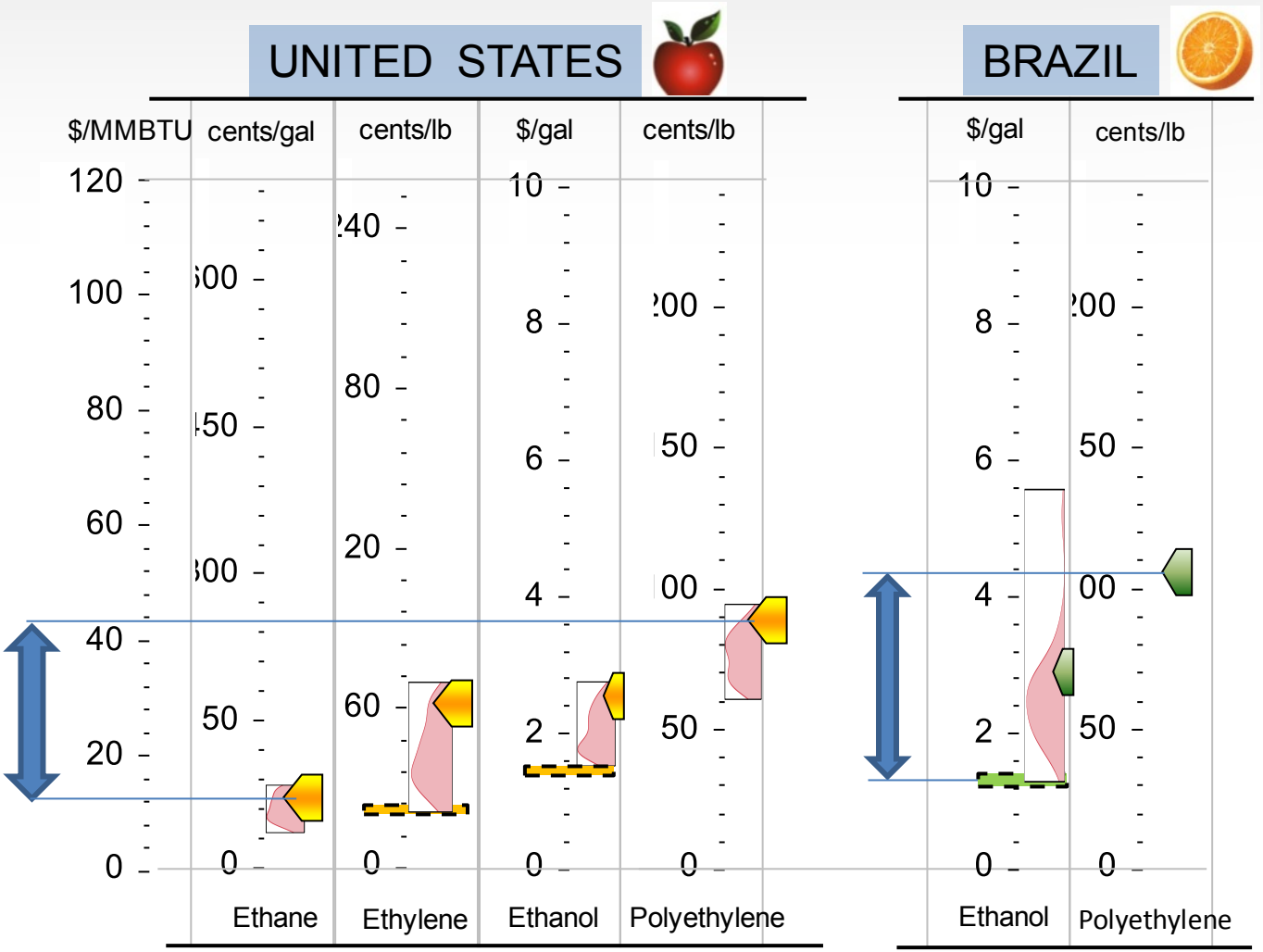
Fully-integrated facility in Brazil
Utilizes state-of-the-art Dow polymerization catalysis

Ethanol to PE – A Niche Opportunity

Market prices and selected costs on energy equivalent basis

- Existing logistics for ethanol in Brazil
- High polyethylene price in Brazil
- Ethanol price fluctuation requires integration

Area required for produce ethanol to meet global PE production ~ **1.6x of Illinois** at Brazil cane productivity



Costs*
USA Brazil

Market Prices
USA Brazil

Sources: Ethane, ethylene, polyethylene (US): **CMAI;** Ethanol US: **ICIS**, Ethanol Br: **ESALQ;** PE Brazil calculated based on market price differential Br to US. Price Densities shown for June 2009 to June 2011; Prices shown from June 2011. *Costs: 2009 US cash cost Ethylene CMAI, US EtOH cost to blender: SRI 2011; Br EtOH: Data Agro 2009 and Estado de S. Paulo 2007 adjusted to 2011 exchange rate

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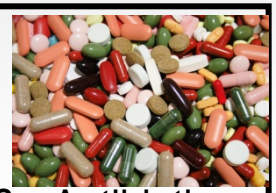

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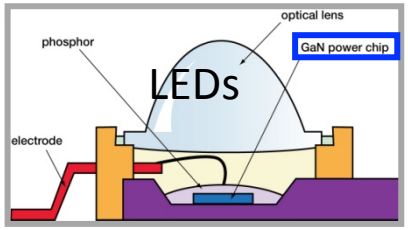
PE from Ethanol



H_2 fuel cells

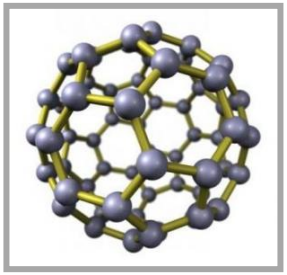
Ethylene Styrene Interpolymers

Cellulosic Fuels

SkyMine®

CALERA

Green Cement for a Blue Planet



Low

Quality of Science

High

W Banholzer

What are we doing?

R&D goal is to extract more earnings per dollar of investment

Dow chooses to operate where
materials science expertise drives success

Energy Storage

Superior Materials:
Cathode
Anode
Electrolytes
Separator

Energy Efficiency

Superior Materials:
Energy efficiency improvements for commercial and industrial products

Energy Generation

Superior Materials:
Efficiency
Yield
Performance
Durability

Final Thoughts

- Incumbent fossil sources set the standard for competition
- Unrecognized truths to transformation
  - It takes decades to deploy a new technology
  - The world is used to the current energy and feedstock infrastructure that was put over a century
- Scale makes small company success challenging
- Fundamental engineering and judgment is crucial to long term innovation
- Can society afford to pay for a different solution?

Facts are the air of scientists. Without them you can never fly.

- Linus Pauling

Thank You