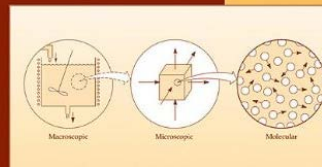


# Bob Bird's 90th Birthday Symposium



## Transport Phenomena

Revised  
Second Edition



R. Byron Bird • Warren E. Stewart  
Edwin N. Lightfoot



Chemical Industry  
Dynamics:  
Innovation is Not Enough



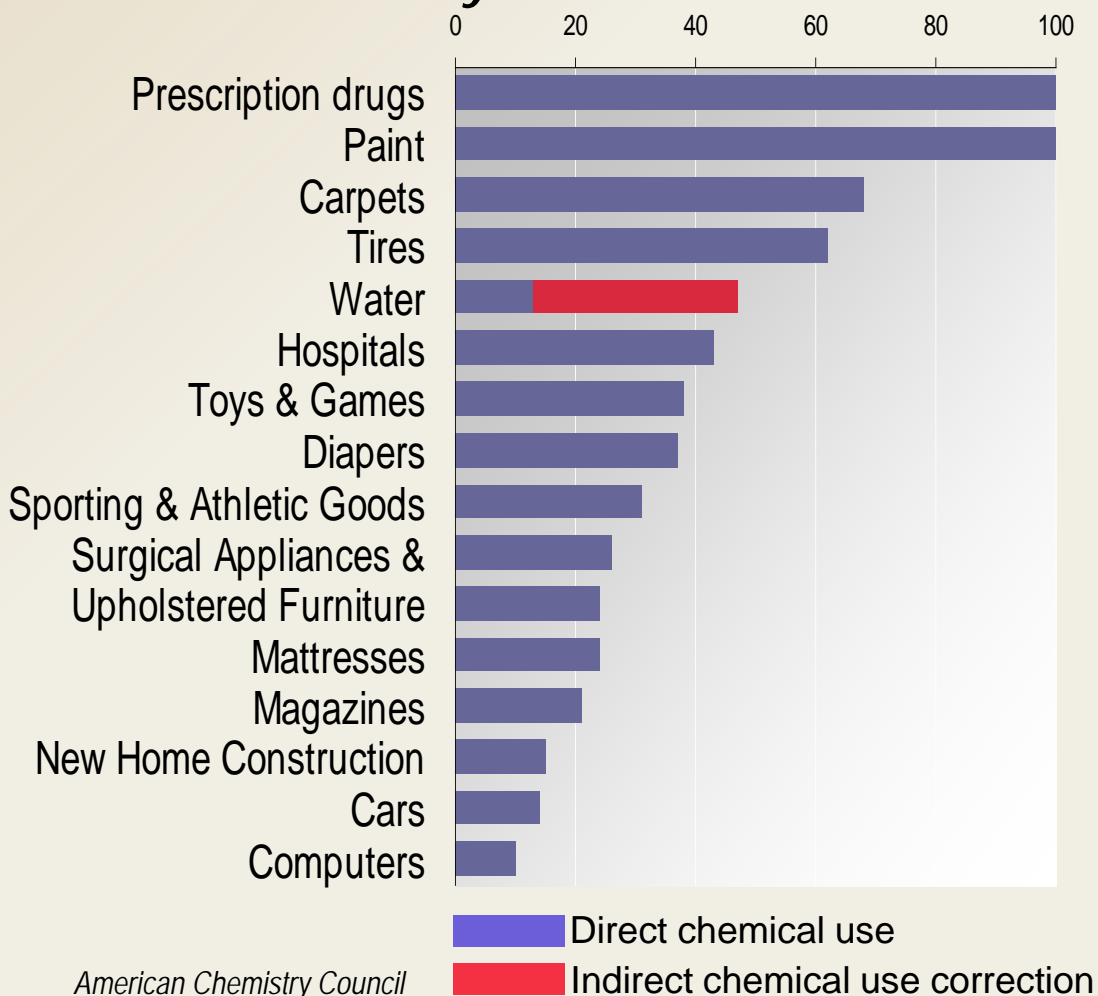
**WISCONSIN**  
UNIVERSITY OF WISCONSIN-MADISON

Bill Banholzer  
Jan 30, 2014

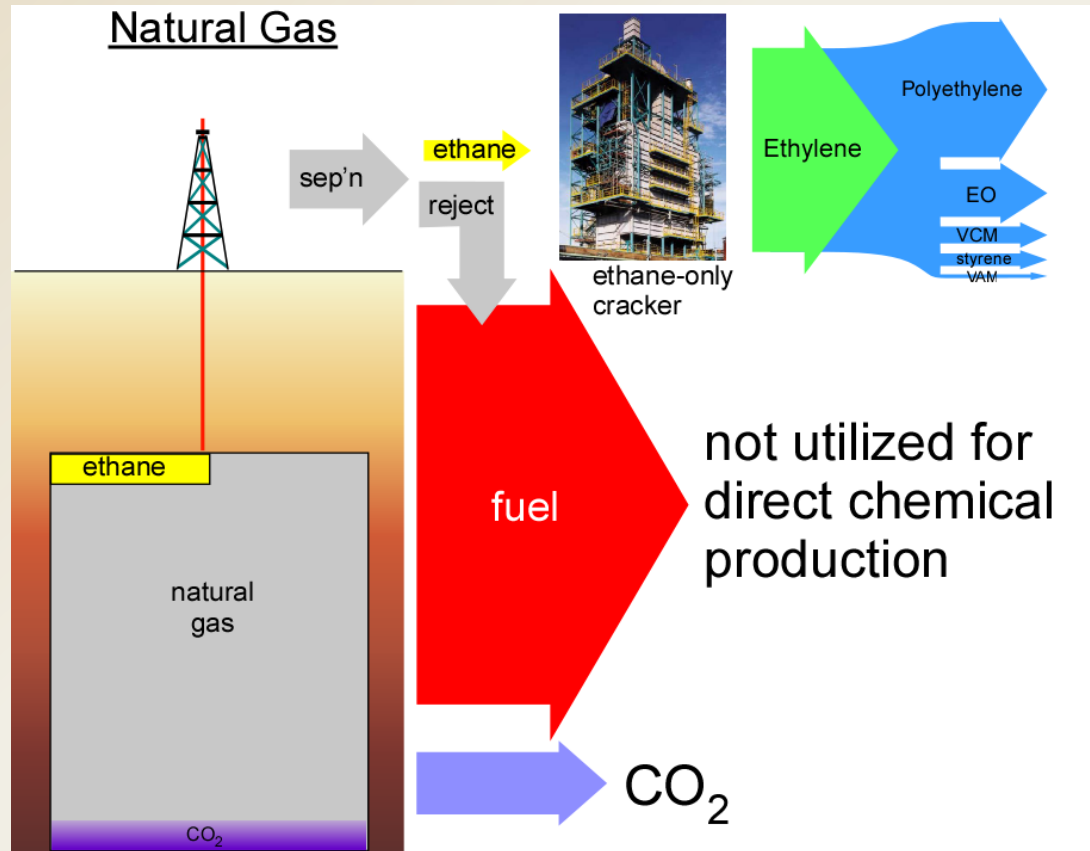
# The World Needs Chemistry



## Value of chemistry as % of all materials



# Light Gas Cracking



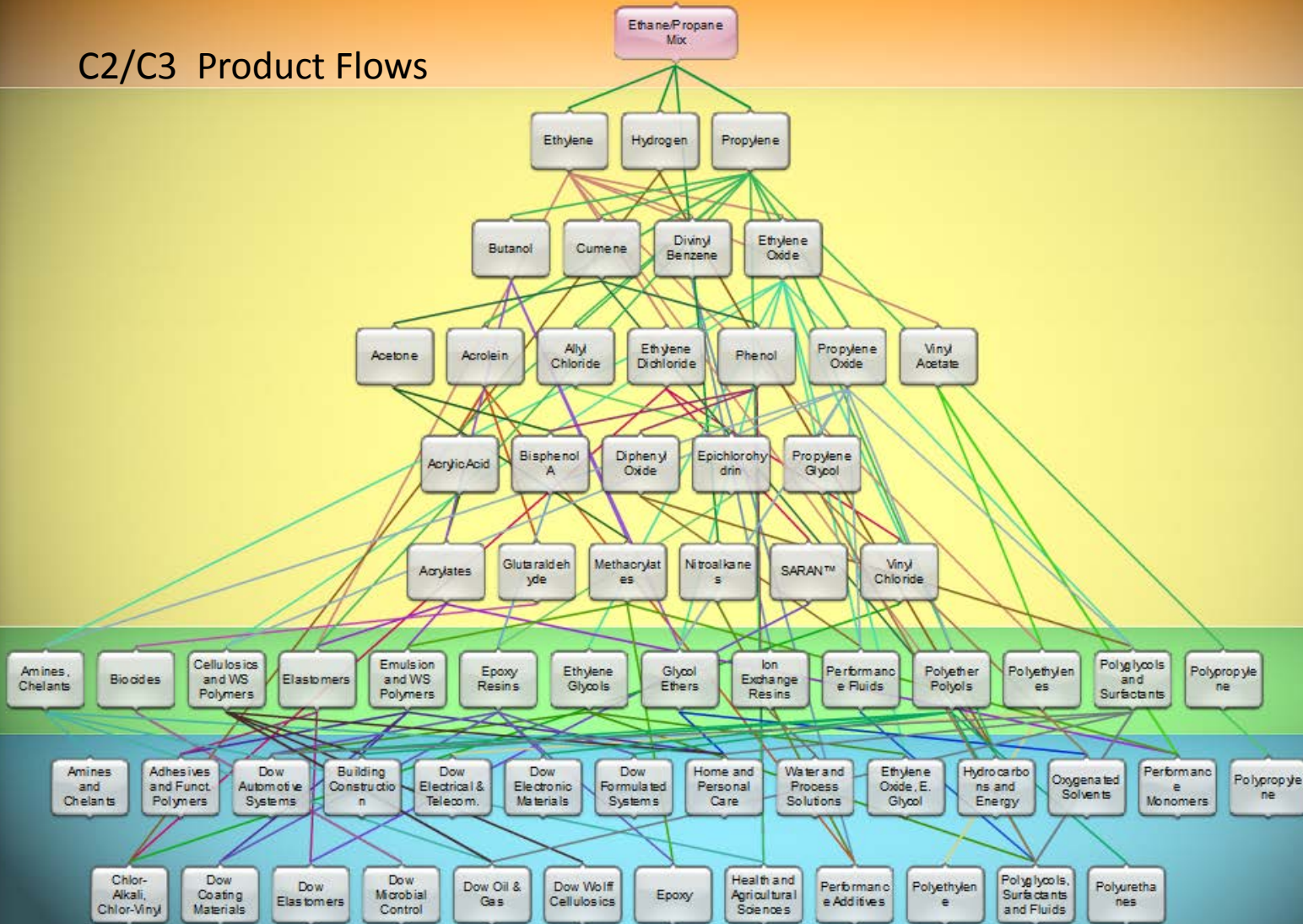
material	per capita consumption (lb/yr)
olefins	271
polyolefins	171
petroleum	6619
natural gas	8037
coal	6439
sand and gravel	13923
cement	512
iron ore	340
salt	403
beef	54.3
chicken	55.7





# Product Integration at Dow

## C2/C3 Product Flows





# The Chemical Industry - Technology Waves

## Inorganic

- mined materials
- electrochemical
- active reagents allow transformations

## Functionalization

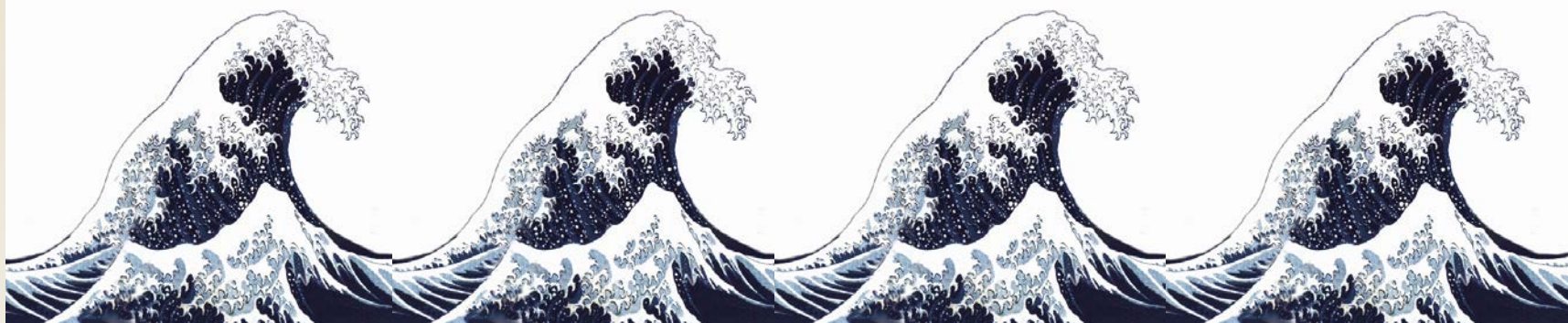
- use inorganics to transform organic substrates
- make dyes, solvents and drugs

## Cellulosics

- use inorganics to transform natural materials
- partially synthetic polymers

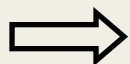
## Polymers

- took off with synthetic rubber
- continues today



1760-1910

rocks



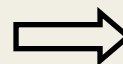
1870-1930

coal



1895-1935

biomass

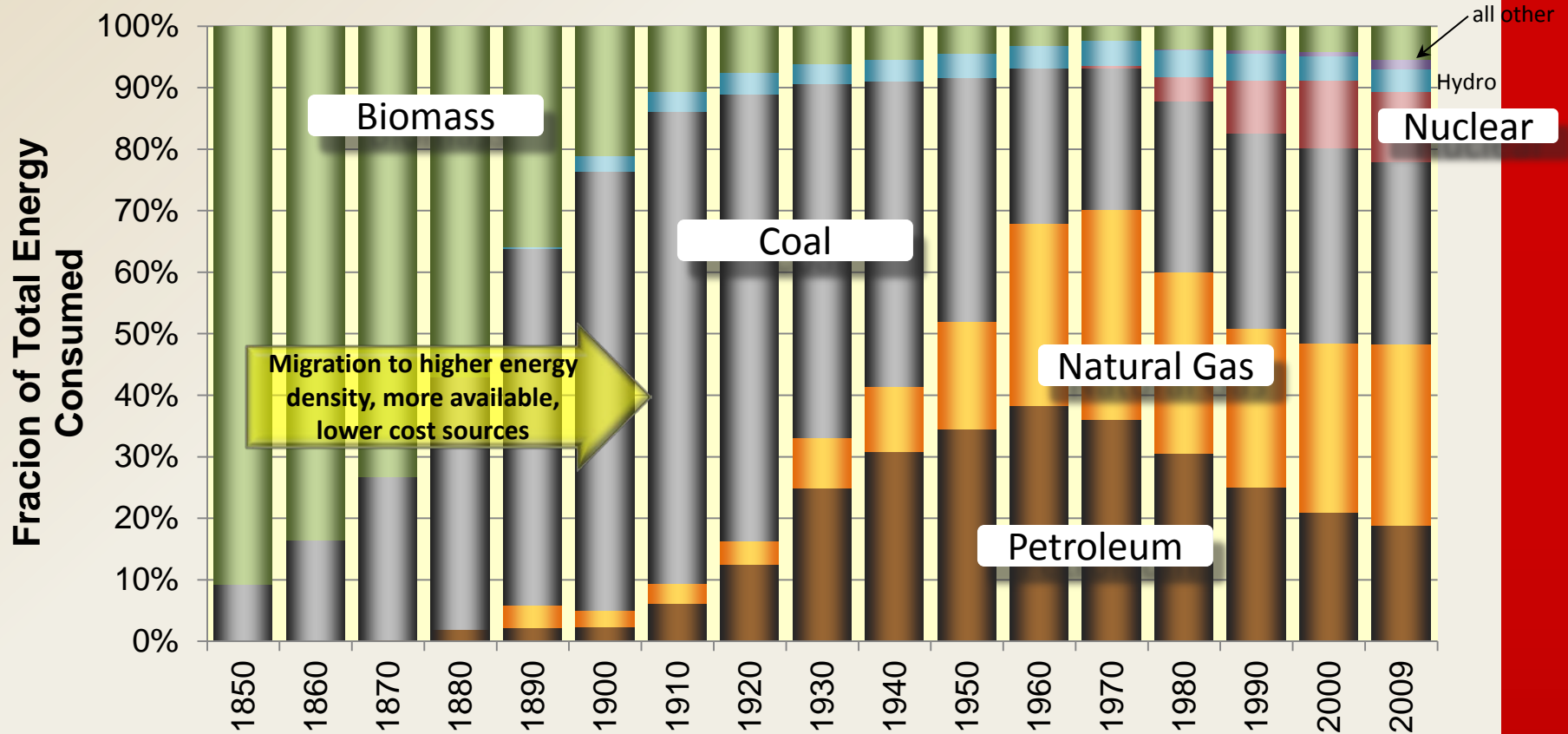


1925-present

petroleum  
NGL



# Energy Sources Have Changed



What's Changed?

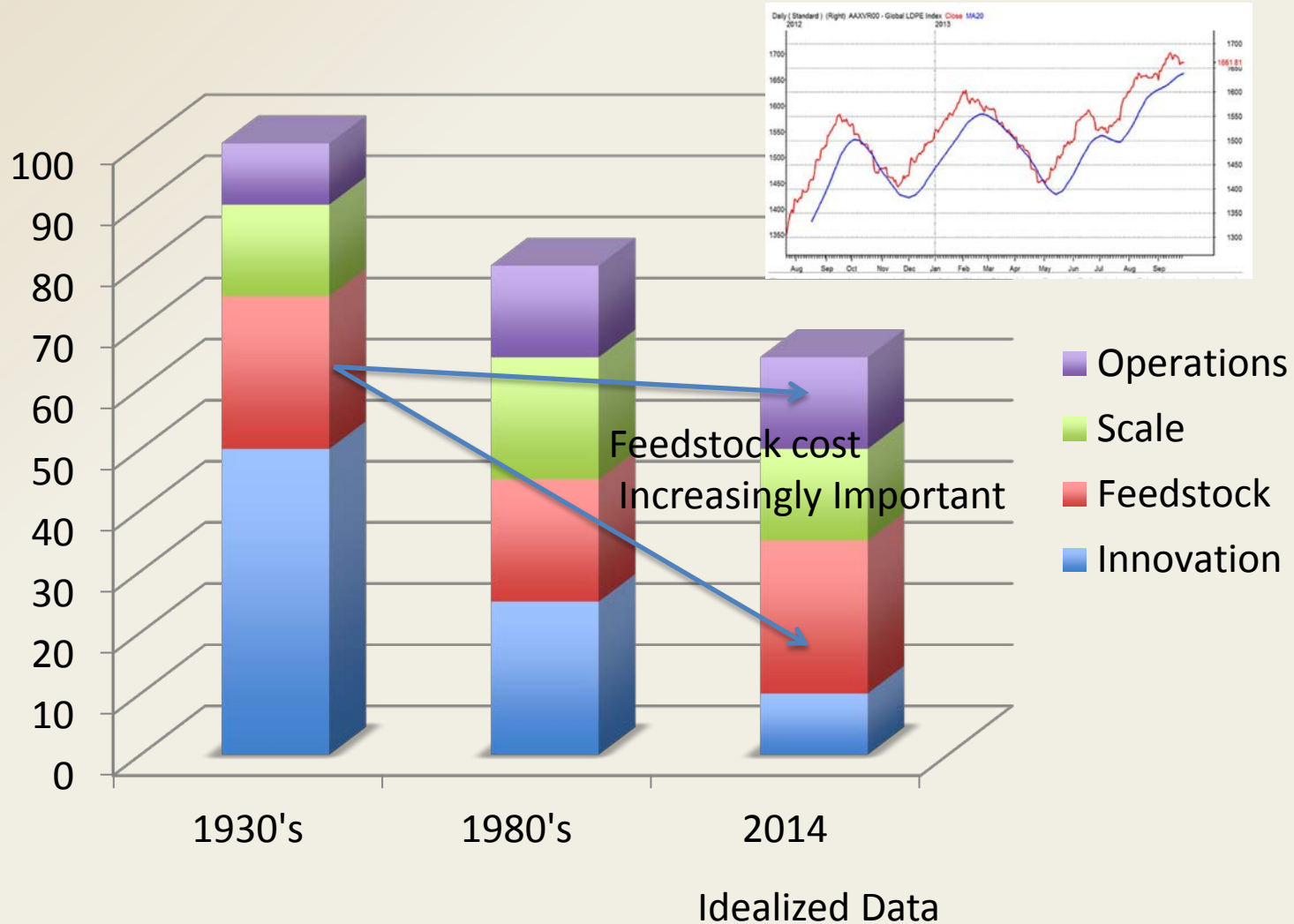
- Oil Price Rise
- CO2 awareness



Is that enough?



# Relative Source of Profit



# LDPE Cost Trend

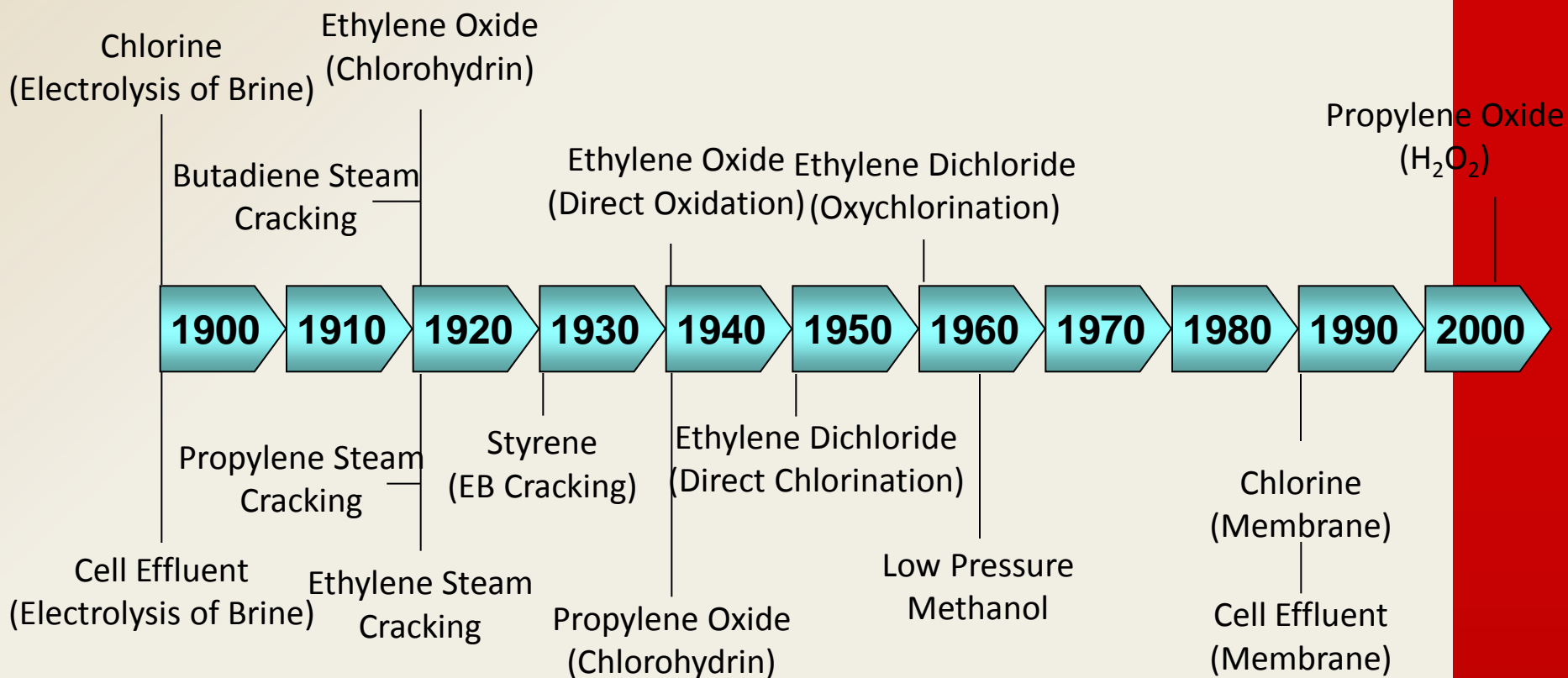




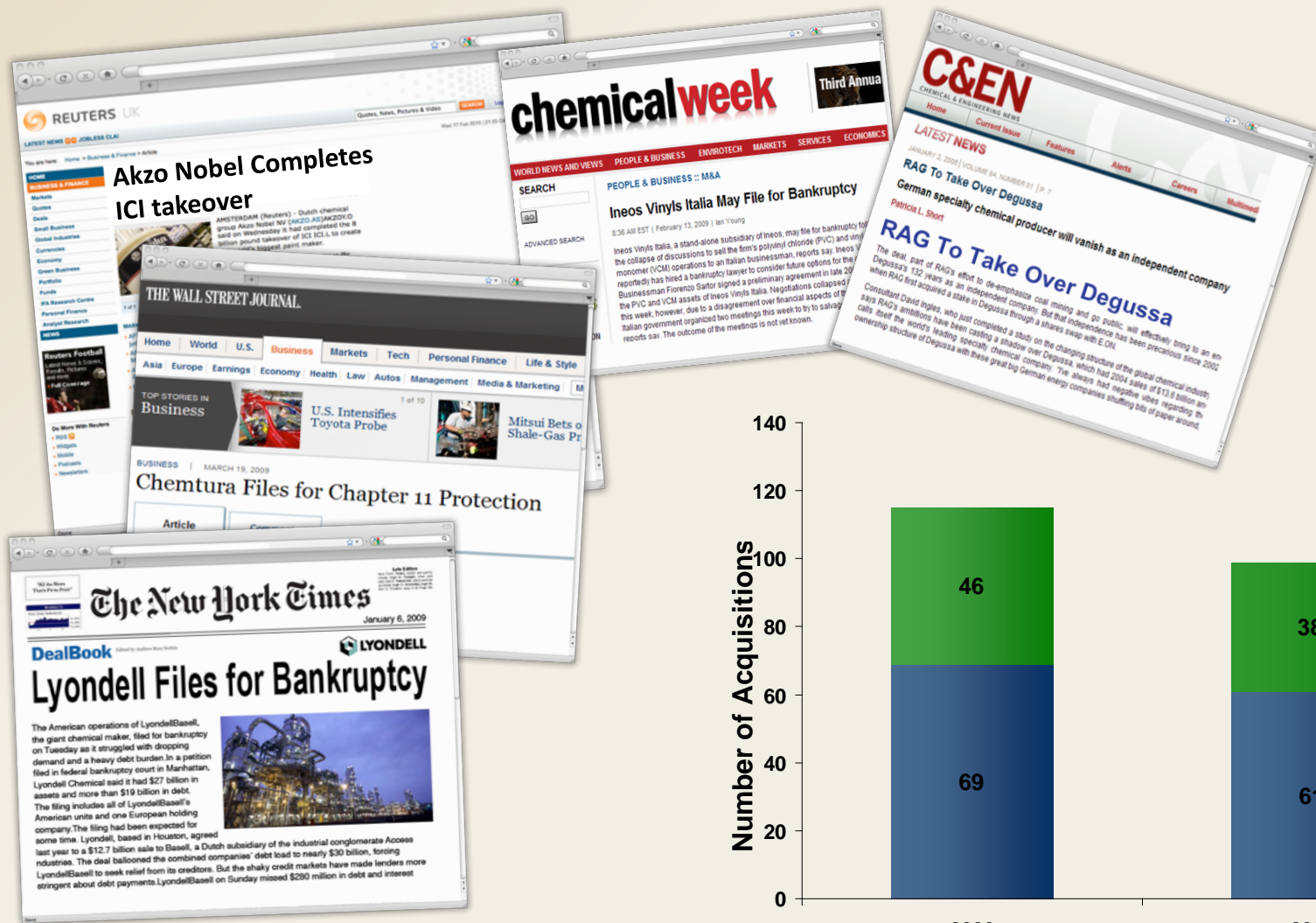
# Basic Raw Material Transformations



## Technology is Decades Old



# There is NO Entitlement....



# Top US Chemical Companies 1970



Rank '69 '68	Company	Chemical sales (Millions of dollars)	Total revenues <sup>a</sup> (Millions of dollars)	Chemical sales as per cent of total revenues	Company SIC class. <sup>b</sup>	After-tax earnings <sup>c</sup> (Millions of dollars)	Profit margin <sup>d</sup>	Rank '69 '68	Return on invest- ment <sup>e</sup>	Rank '69 '68
TOTAL COMPANIES										
1 1	Du Pont <sup>f</sup>	\$3220	\$3,655	88%	281	\$343.5	9.4%	4 3	5.6%	7 4
2 3	Union Carbide	1815	2,933	62	281	186.2	6.4	18 24	3.2	36 42
3 2	Monsanto	1735	1,939	89	281	109.4	5.6	26 22	3.3	34 33
4 4	Dow Chemical	1570	1,876	84	281	148.7	7.9	10 12	4.7	15 19
5 7	Celanese	1028	1,250	82	281	76.3	6.1	22 34	3.8	29 45
6 5	W. R. Grace	1015	1,812	56	281	51.0	2.8	45 45	2.8	40 41
7 6	Standard Oil (N.J.)	1004	16,900	6	291	1243	7.4	12 9	5.1	11 9
8 8	Allied Chemical	895	1,316	68	281	68.0	5.2	30 46	2.7	41 48
9 9	Hercules	642	746	86	281	43.9	5.9	24 14	4.1	26 12
10 11	Occidental Petroleum	625	2,059	30	509	174.8	8.5	7 14	7.3	3 3
11 10	FMC	620	1,409	44	281	67.3	4.8	32 29	5.0	13 6
12 12	American Cyanamid	576	1,067	53	281	89.9	8.3	8 5	6.2	6 5
13 13	Shell Oil	544	4,276	13	291	291.2	6.8	15 10	4.2	21 18
14 14	Eastman Kodak	522	2,747	19	383	401.1	14.6	1 1	10.5	1 1
15 16	Uniroyal	513 <sup>g</sup>	1,554	33	301	46.6	3.0	44 40	2.7	41 31
16 15	Stauffer Chemical	499	499	100	281	31.6	6.5	17 17	7.2	4 9
17 17	Phillips Petroleum	471	2,227	21	291	134.3	6.0	23 19	3.2	36 35
18 18	Rohm and Haas	448	453	99	281	33.5	7.4	12 8	4.8	14 9
19 19	Mobil Oil	444	7,573	6	291	434.5	5.7	25 22	4.4	17 22
20 21	Borden	394	1,756	23	202	47.9	2.7	46 47	4.2	21 24
21 26	Ethyl Corp.	382	517	74	281	33.0	6.4	18 20	4.3	20 19
22 20	Cities Service	361	1,595	23	291	127.2	8.0	9 5	4.0	27 26
23 23	Ashland Oil	342	1,151	30	291	52.3	4.5	34 32	4.4	17 15
24 28	Diamond Shamrock	327	555	59	281	30.7	5.5	28 17	3.2	36 30
25 24	Continental Oil	325	2,607	13	291	146.4	5.6	26 21	3.7	30 24

# Evolution of the Chemical Industry

Top 20 companies: 1990 - 2012



## Top 20 Companies in 1990

BASF  
Hoechst  
ICI  
Bayer  
DuPont  
Dow Chemical  
Rhone-Poulenc  
Ciba-Geigy  
Union-Carbide  
Asahi Chemical  
Hüls  
Akzo  
Monsanto  
DSM  
Mitsubishi  
Atochem  
Enichem  
Shell  
Exxon  
BP

## Additions

### Super Regionals

- Sabic
- Sinopec
- LG Chem
- Formosa
- Reliance

### IPOs/ Private Equity

- LyondelBasell
- Ineos
- Huntsman

### Entrants

- Evonik
- Mitsui Chemical

## Companies from 1990 remaining in 2010

### Transforming within Industry

BASF  
Dow Chemical  
DuPont  
Mitsubishi  
Akzo

1990

Chemical Industry

2010

## Exits

### Acquired

- EniChem
- UCC
- GE
- Atochem
- BP
- Ciba-Geigy
- Hüls
- Rhone-Poulenc
- Asahi Chemical

### Shift to Lifesciences

- Bayer
- Hoechst
- ICI
- Monsanto
- DSM

### Oil Companies with Chemical Portfolios

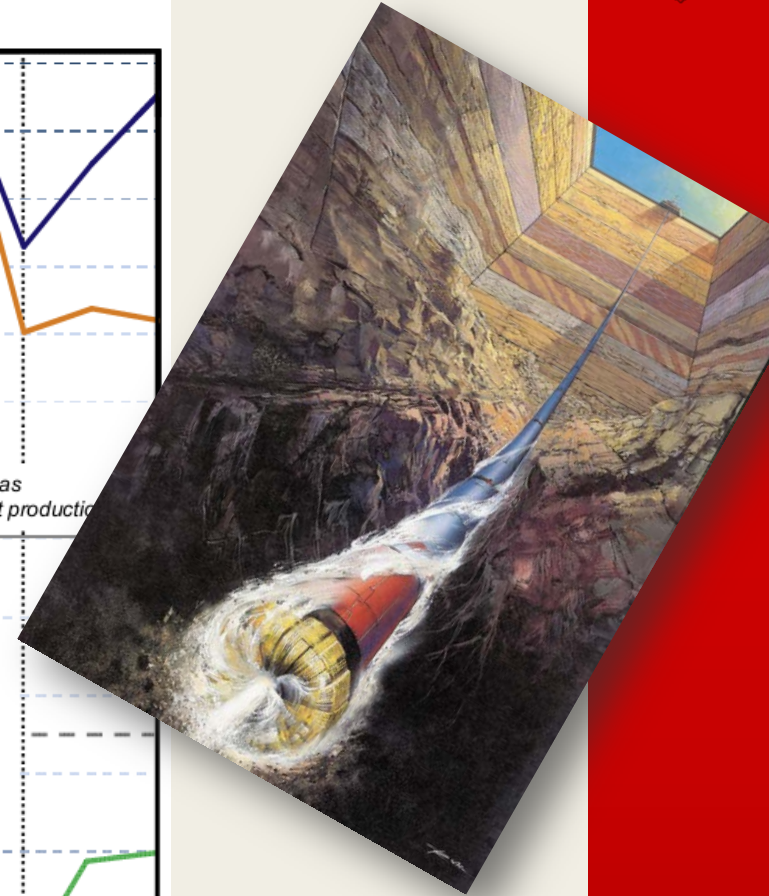
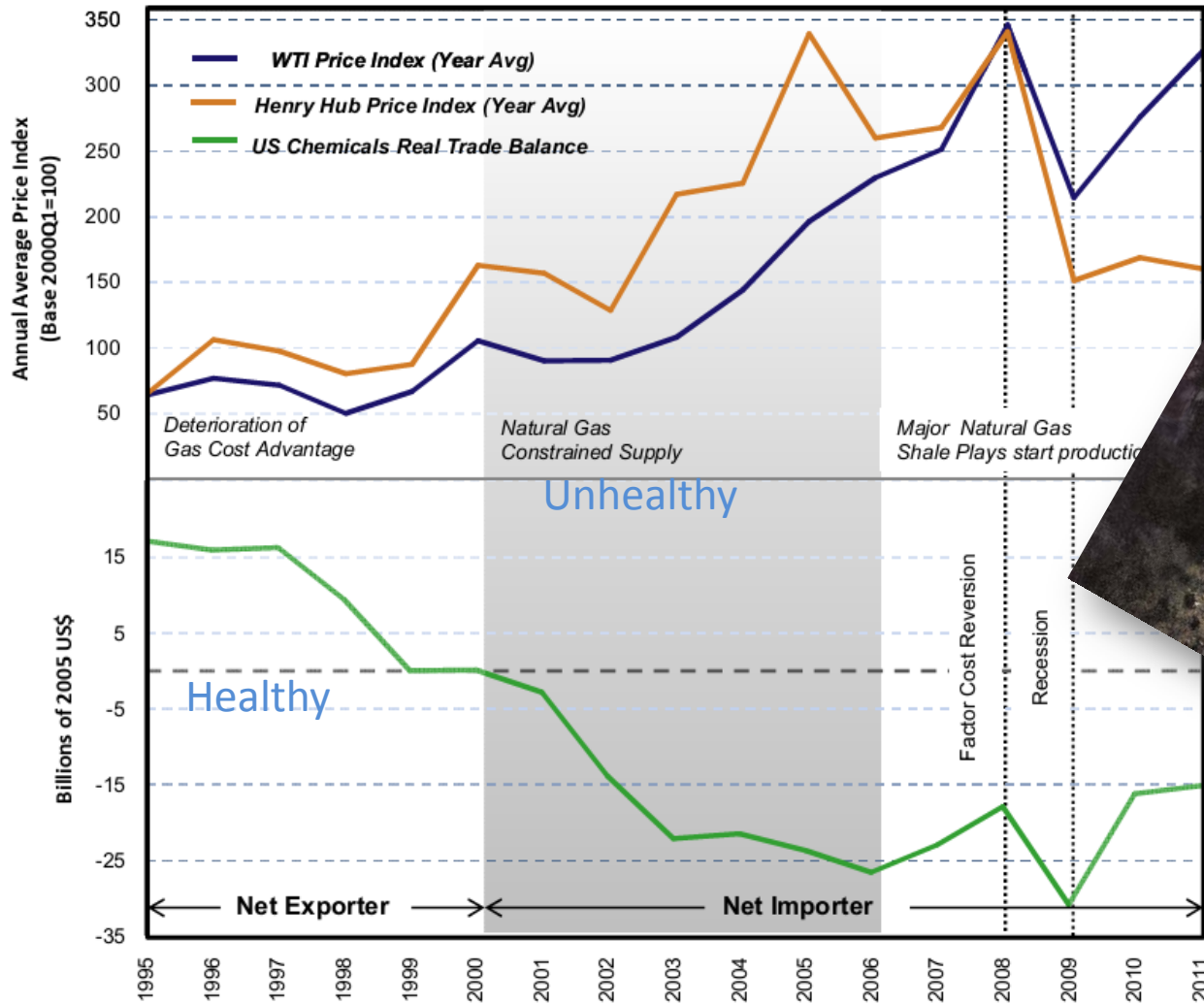
Exxon  
Shell  
Total



# What Unhealthy Looks Like



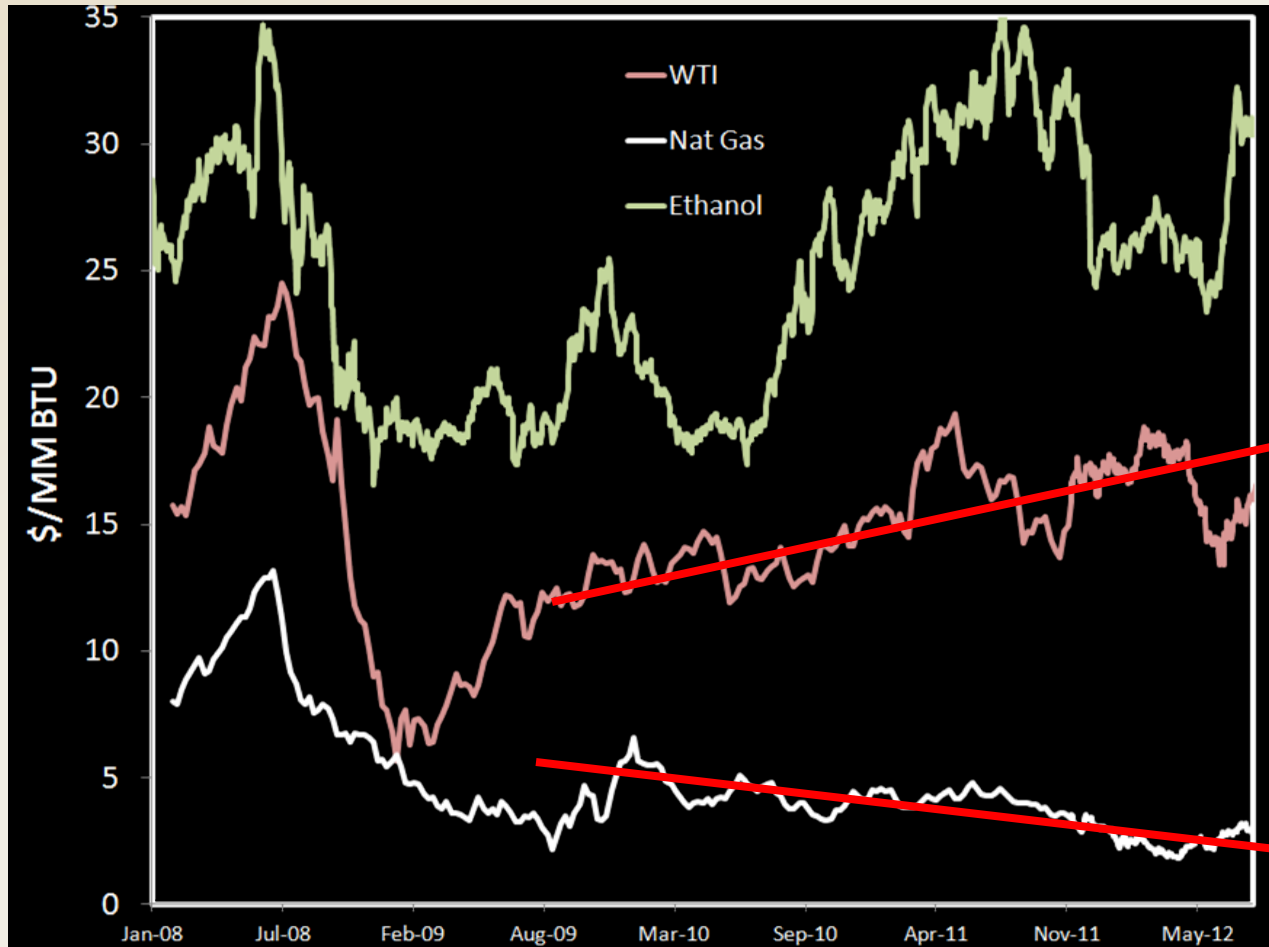
Natural Gas Cost Advantage  
And US Chemicals Trade







# Natural Gas and Oil Prices Diverge

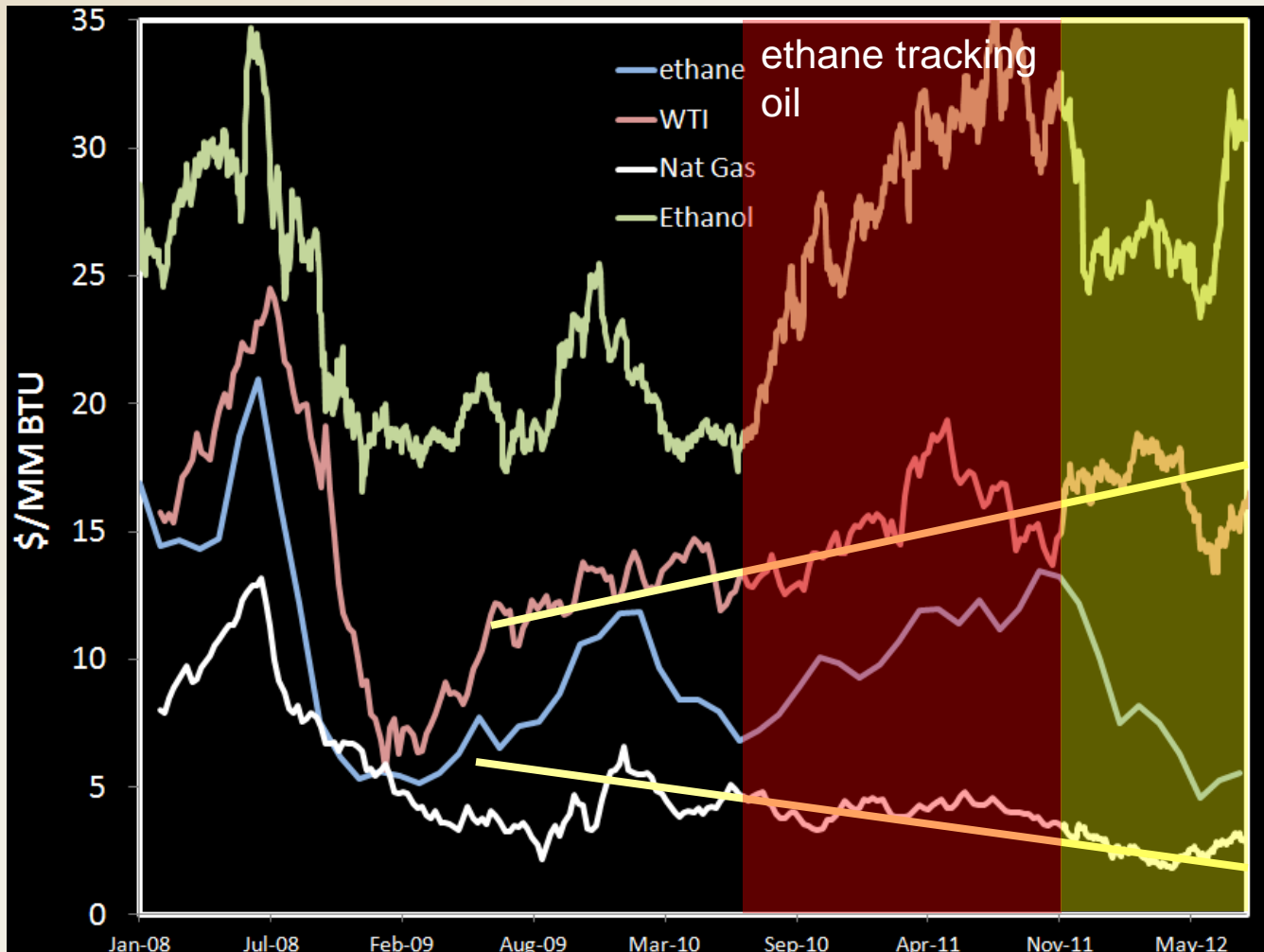


Bio considerably higher

Diverging energy cost



# Natural Gas and Oil Prices Diverge

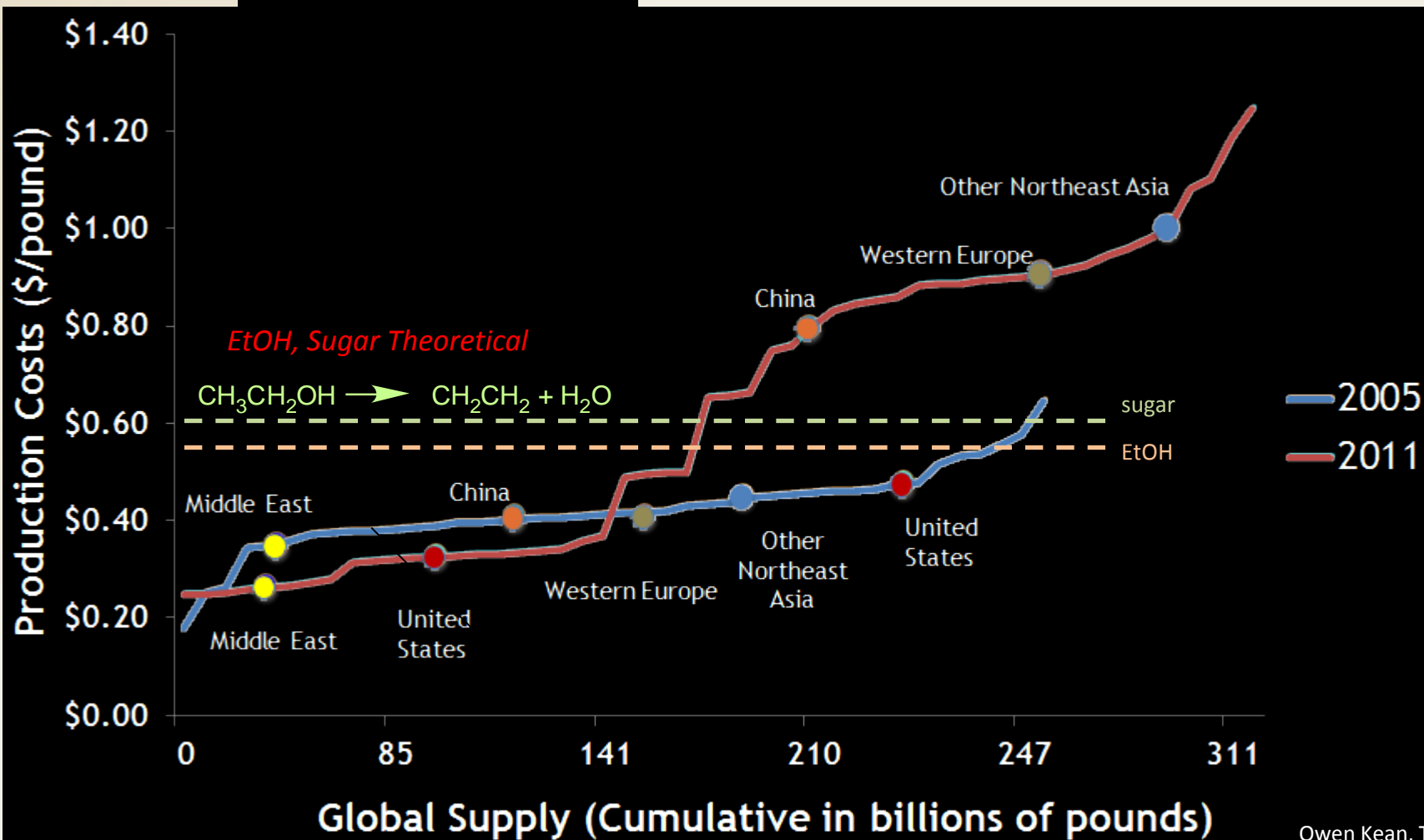


desire return to  
tradition:  
ethane tracks gas



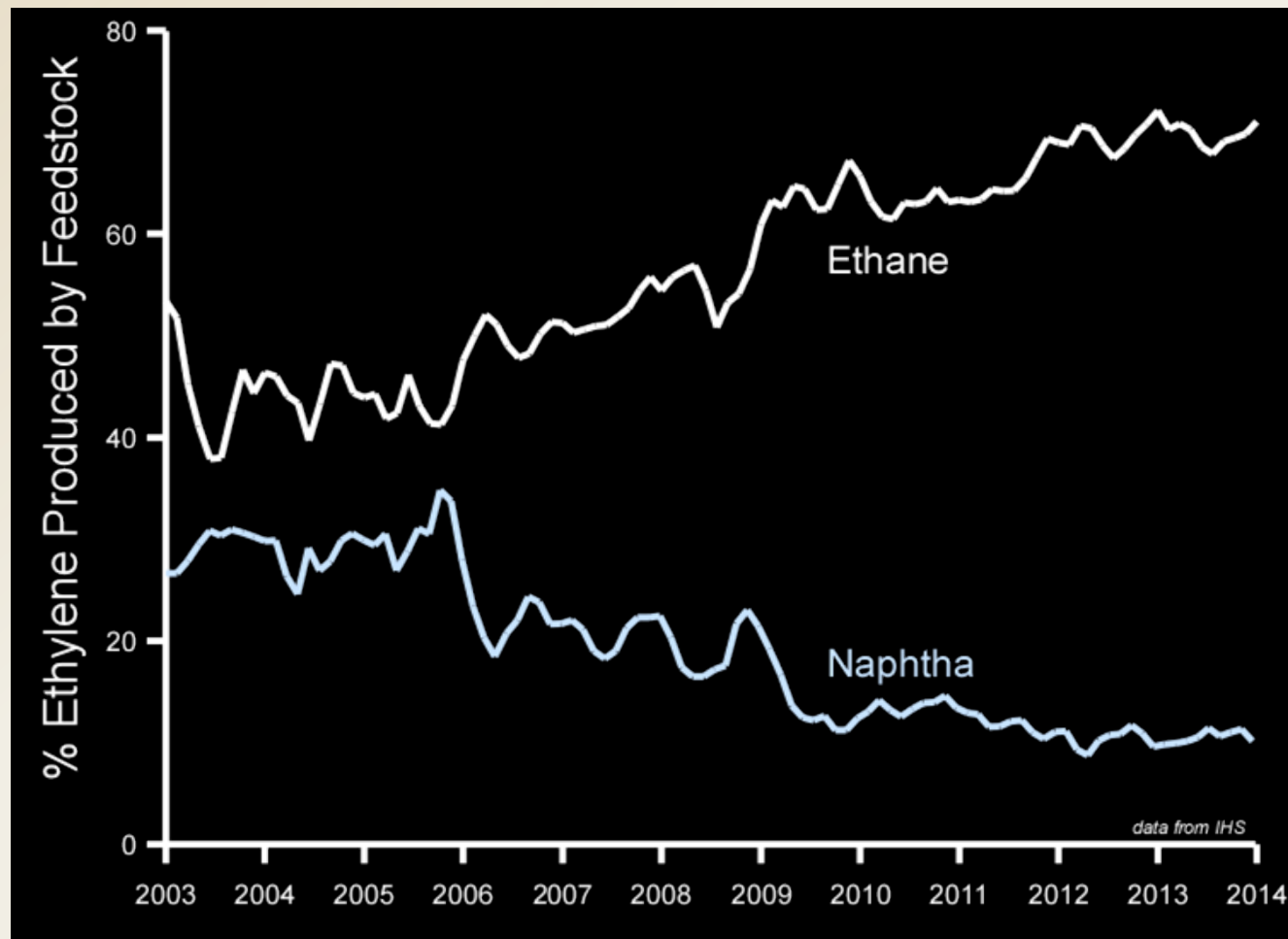
# Impact of Low Gas Prices

*EtOH, Sugar Actual 2-4 X*



Owen Kean, TK Swift ACC

# US Trend



U.S. trend is toward lighter gas cracking and it is an old trend

Implications:

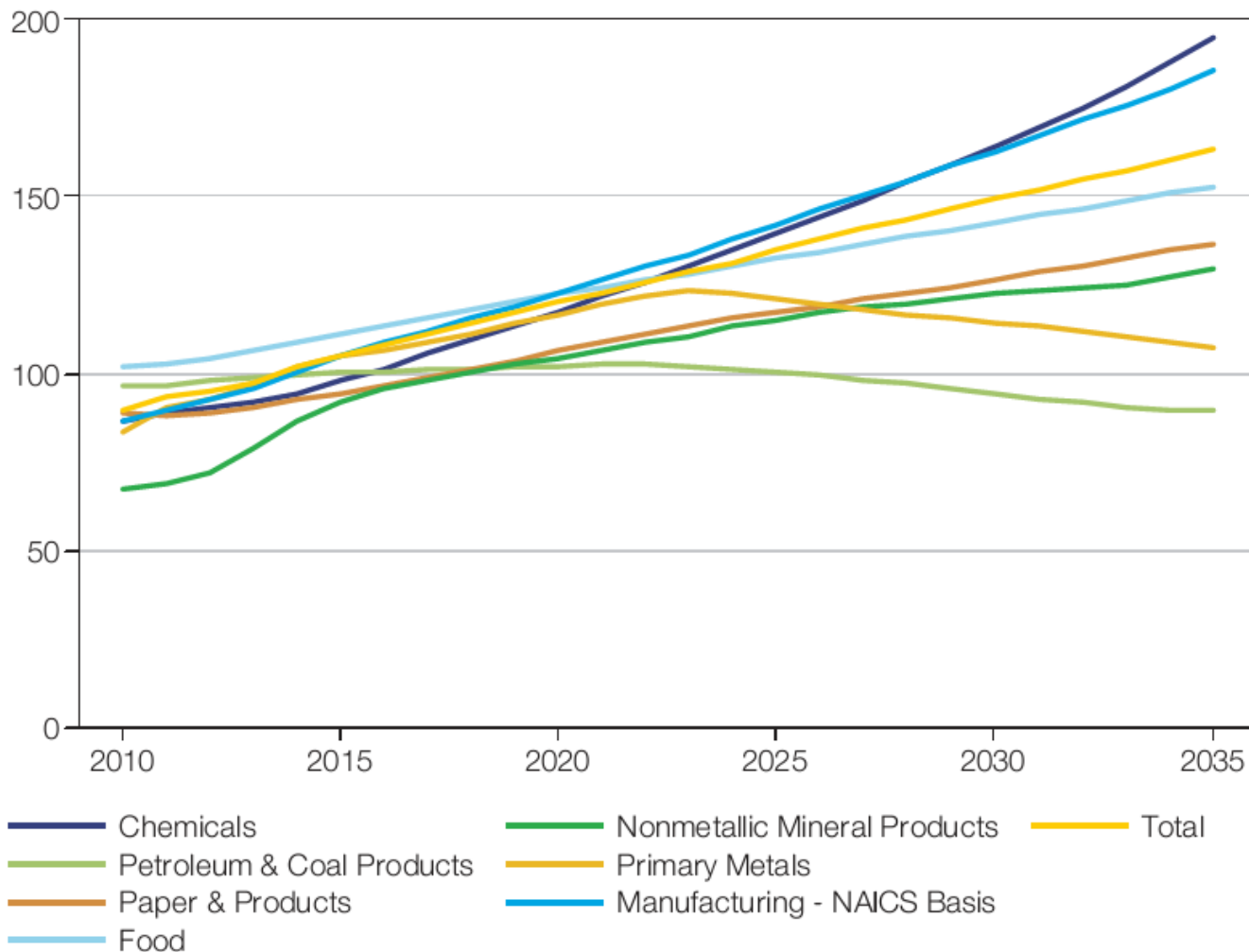
- less propylene
- less butadiene
- less benzene

# Impact on Industry



## US Outlook for Natural Gas-Intensive Industries

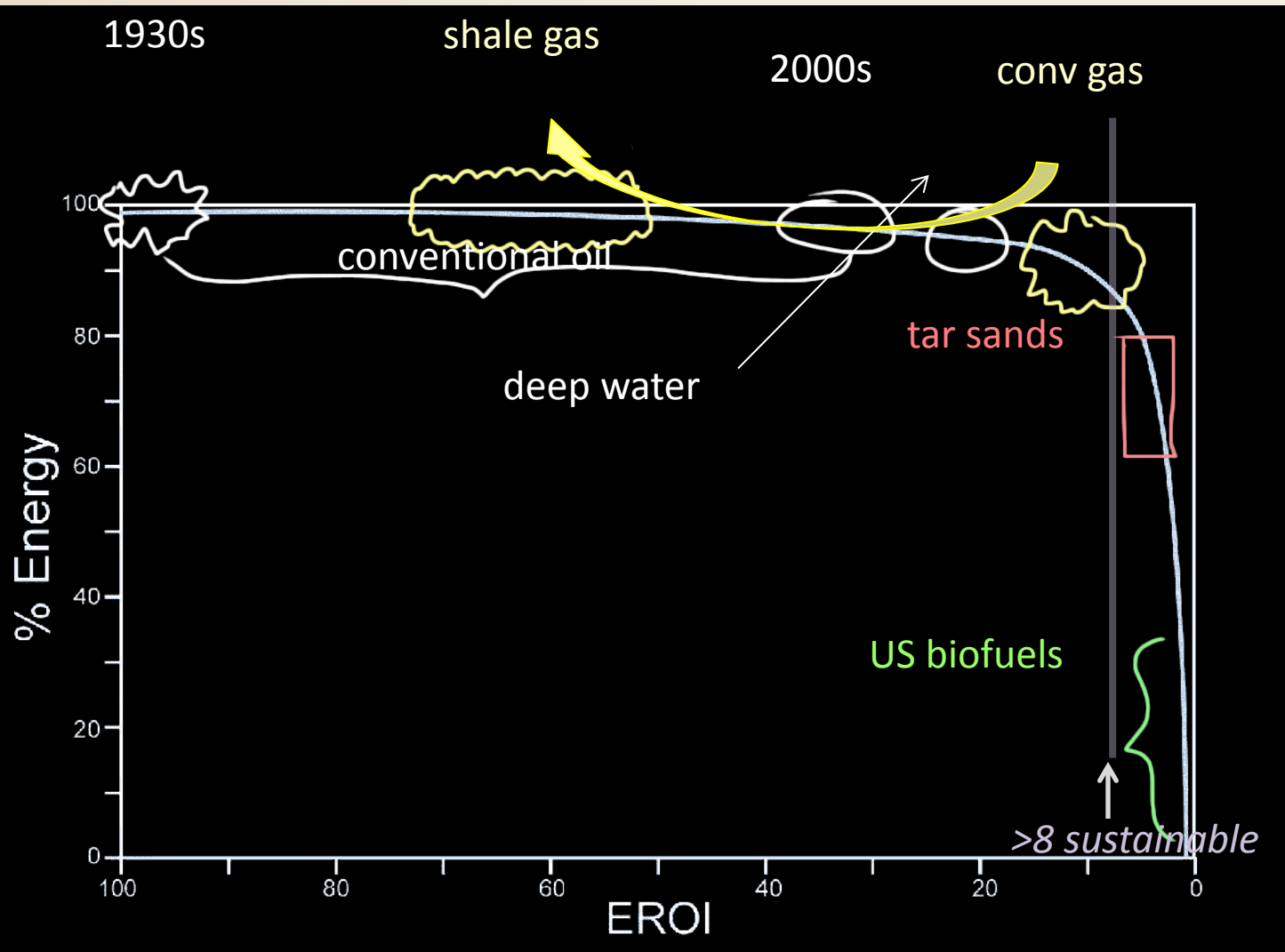
Natural Gas Consumption By Industry (Index 2002=100)



Source: IHS Global Insight



# Thermodynamic Entitlement



Energy return is a key parameter when the products are fuels

*Shale gas goes against recent trends.*

# Shale Gas Supply

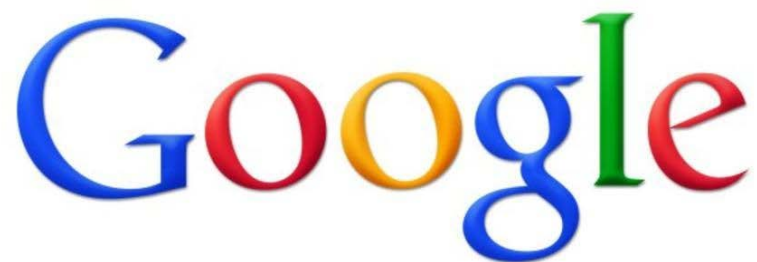


## US Lower 48 Annual Natural Gas Production and Well Completions: Shale Gas versus Total Gas

	2010	2015	2020	2025	2030	2035
<b>PRODUCTION</b>						
Shale (Mcf)	5,771,561,991	9,898,869,883	12,998,811,671	15,026,085,081	16,664,762,297	18,899,176,790
Total Gas (Mcf)	21,229,024,284	23,276,996,872	26,000,032,080	27,769,207,506	29,114,085,717	31,263,775,082
Shale Share of Total	27%	43%	50%	54%	57%	60%
<b>WELL COMPLETIONS</b>						
Shale Gas	5,123	4,383	5,472	4,886	5,654	6,588
Total Gas	17,858	18,344	19,532	17,355	16,213	16,224
Shale Share of Total	29%	24%	28%	28%	35%	41%
Henry Hub Price	\$4.38	\$4.77	\$4.57	\$4.84	\$4.91	\$5.15
(Constant 2010 \$US per MMBtu)						

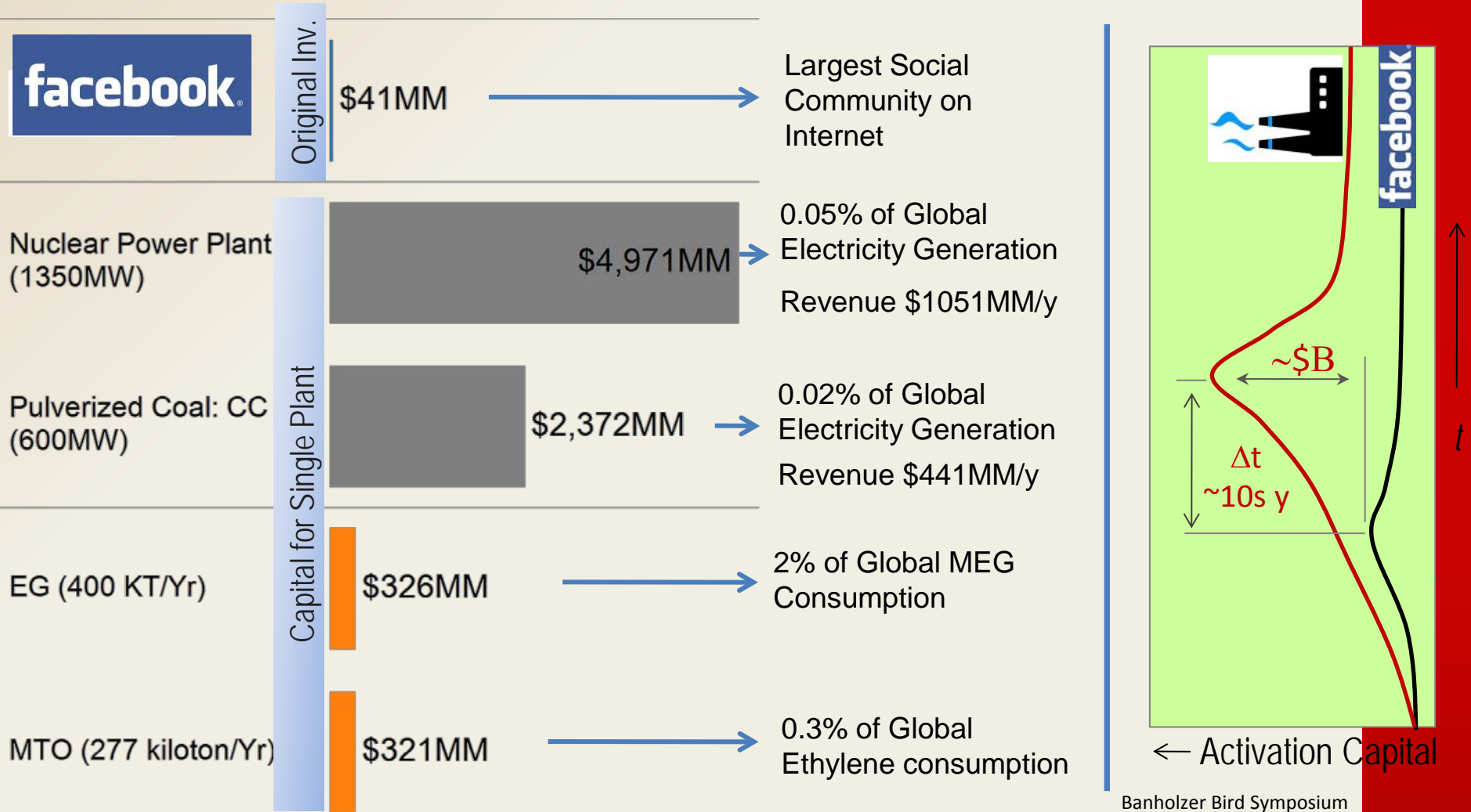
Source: IHS CERA and EIA

# Venture Model in Chemicals?



Where are the Facebook and Google  
of the Chemical Industry?

# Scale of Fuels Makes it Harder



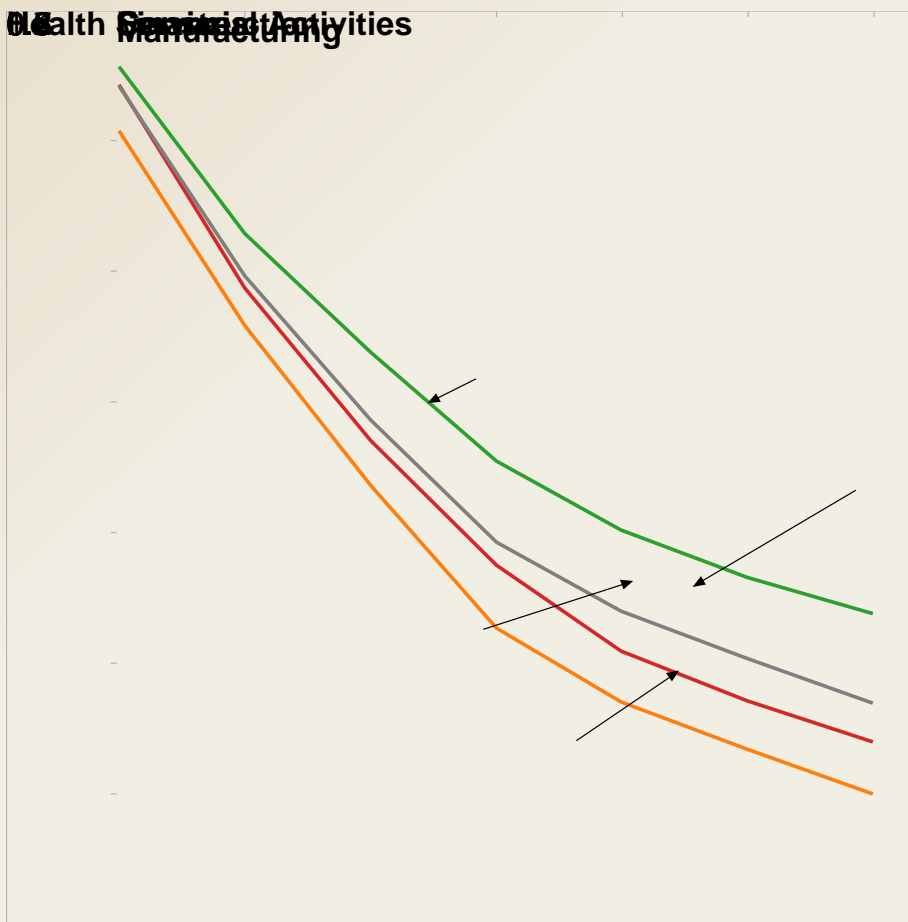
Banhölzer Bird Symposium

**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 Report 21 – SRI; **Revenues** for Power Plants calculated using 2010 electricity average retail prices (all sectors) 9.88 cents/kWh (data from DOE)



# The Challenge of a New Company

*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

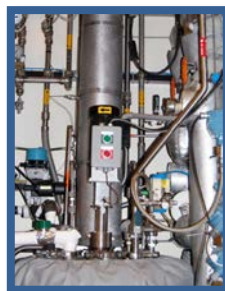


# Timeline for Impact



Impact / Market Penetration

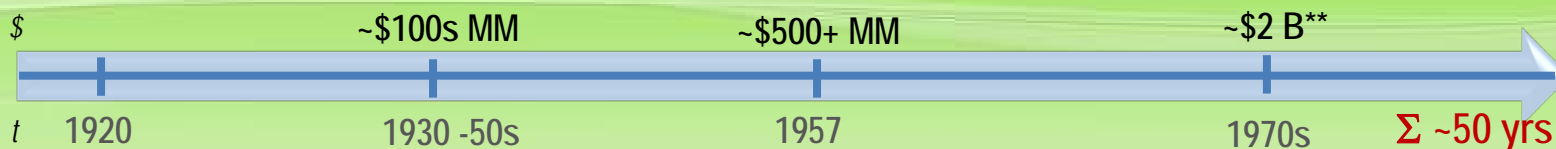
Invention      Development      Demonstration      Deployment



Single Site  
Catalysis



Super Critical  
Coal Power



Banholzer Bird Symposium

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\$

# World Trends

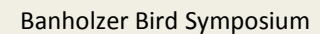


- Price convergence of carbon sources as a function of energy content
  - Regional price differentials: North America vs. Middle East
  - Source price differentials: coal vs. natural gas vs. biomass
- Focus on energy
  - driven by price convergence
  - new transportation technologies – new fuels
  - separation focus
- Carbon concerns
  - decarbonization of transportation and electrical generation
  - reduced industrial emissions

**Disruption of Feedstock Easy to  
Claim, Tough to Achieve**



**Thank You**







# Energy Costs

