Chemical Industry Dynamics:  
Innovation is Not Enough
The World Needs Chemistry

Value of chemistry as % of all materials

- Prescription drugs
- Paint
- Carpets
- Tires
- Water
- Hospitals
- Toys & Games
- Diapers
- Sporting & Athletic Goods
- Surgical Appliances & Upholstered Furniture
- Mattresses
- Magazines
- New Home Construction
- Cars
- Computers

Direct chemical use
Indirect chemical use correction

American Chemistry Council
**Light Gas Cracking**

<table>
<thead>
<tr>
<th>Material</th>
<th>Per Capita Consumption (lb/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>olefins</td>
<td>271</td>
</tr>
<tr>
<td>polyolefins</td>
<td>171</td>
</tr>
<tr>
<td>petroleum</td>
<td>6619</td>
</tr>
<tr>
<td>natural gas</td>
<td>8037</td>
</tr>
<tr>
<td>coal</td>
<td>6439</td>
</tr>
<tr>
<td>sand and gravel</td>
<td>13923</td>
</tr>
<tr>
<td>cement</td>
<td>512</td>
</tr>
<tr>
<td>iron ore</td>
<td>340</td>
</tr>
<tr>
<td>salt</td>
<td>403</td>
</tr>
<tr>
<td>beef</td>
<td>54.3</td>
</tr>
<tr>
<td>chicken</td>
<td>55.7</td>
</tr>
</tbody>
</table>
Product Integration at Dow

C2/C3 Product Flows

Banholzer Bird Symposium
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 1870-1930 1895-1935 1925-present
- rocks ↔ coal ↔ biomass ↔ petroleum NGL

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Energy Sources Have Changed

What’s Changed?
• Oil Price Rise
• CO2 awareness

Is that enough?

Source: IEA, EIA; US Primary Energy
Relative Source of Profit

- Operations
- Feedstock cost
- Scale
- Innovation

Legend:
- Purple: Operations
- Green: Scale
- Red: Feedstock
- Blue: Innovation

Idealized Data

- 1930's
- 1980's
- 2014

Feedstock cost: Increasingly Important
LDPE Cost Trend

Source: PCDB.Santafe.edu

2013 USD

$/lb

2013
1993
1983
1973
1963
1953

Source: PCDB.Santafe.edu

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Basic Raw Material Transformations

Technology is Decades Old

1900
- Chlorine (Electrolysis of Brine)
- Cell Effluent (Electrolysis of Brine)

1910
- Propylene Steam Cracking
- Propylene Oxide (Chlorohydrin)

1920
- Butadiene Steam Cracking
- Ethylene Steam Cracking
- Ethylene Oxide (Chlorohydrin)

1930
- Styrene (EB Cracking)
- Ethylene Oxide (Direct Oxidation)

1940
- Ethylene Dichloride (Direct Chlorination)
- Propylene Oxide (Chlorohydrin)

1950
- Ethylene Dichloride (Oxychlorination)

1960
- Low Pressure Methanol

1970
- Chlorine (Membrane)
- Cell Effluent (Membrane)

1980
- Propylene Oxide ($\text{H}_2\text{O}_2$)

1990
- Ethylene Dichloride (Direct Chlorination)

2000
- Banholzer Bird Symposium
There is NO Entitlement....

### Top US Chemical Companies 1970

<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
<th>Chemical sales (Millions)</th>
<th>Total revenues (Millions)</th>
<th>Chemical sales as per cent of total revenues</th>
<th>Company class</th>
<th>After-tax earnings (Millions)</th>
<th>Profit margin</th>
<th>Rank '69 '68</th>
<th>Total COMPANIES</th>
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<tbody>
<tr>
<td>1</td>
<td>Du Pont</td>
<td>$3220</td>
<td>$3,655</td>
<td>88%</td>
<td>281</td>
<td>$343.5</td>
<td>9.4%</td>
<td>4</td>
<td>3</td>
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<tr>
<td>2</td>
<td>Union Carbide</td>
<td>2,333</td>
<td>2,333</td>
<td>62</td>
<td>281</td>
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<td>3</td>
<td>Monsanto</td>
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<td>2,381</td>
<td>89</td>
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<td>109.4</td>
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<td>Dow Chemical</td>
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<td>84</td>
<td>281</td>
<td>148.7</td>
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<td>5</td>
<td>Celanese</td>
<td>1,250</td>
<td>2,281</td>
<td>82</td>
<td>281</td>
<td>76.3</td>
<td>8.1</td>
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<td>6</td>
<td>W. R. Grace</td>
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<td>1,812</td>
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<td>281</td>
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<td>16,900</td>
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<td>89.9</td>
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<td>Uniroyal</td>
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<td>301</td>
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<td>100</td>
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<td>31.6</td>
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<td>18</td>
<td>Rohm and Haas</td>
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<td>453</td>
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<td>Mobil Oil</td>
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<td>434.5</td>
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<td>20-21</td>
<td>Borden</td>
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<td>1,756</td>
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<td>202</td>
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<td>2.7</td>
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<td>47</td>
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<td>517</td>
<td>74</td>
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<td>6.4</td>
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<td>20</td>
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<td>22-20</td>
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<td>5</td>
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<td>23</td>
<td>Ashland Oil</td>
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<td>1,151</td>
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<td>34</td>
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<td>24</td>
<td>Diamond Shamrock</td>
<td>559</td>
<td>559</td>
<td>59</td>
<td>291</td>
<td>36.7</td>
<td>5.5</td>
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<td>17</td>
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<tr>
<td>25</td>
<td>Continental Oil</td>
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<td>2,607</td>
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<td>291</td>
<td>146.4</td>
<td>5.6</td>
<td>26</td>
<td>21</td>
</tr>
</tbody>
</table>

*Bio/Rest.*
Evolution of the Chemical Industry
Top 20 companies: 1990 - 2012

1990

**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**
  - LyondellBasell
  - Ineos
  - Huntsman

- **Entrants**
  - Evonik
  - Mitsui Chemical

**Exits**

- **Acquired**
  - Enichem
  - UCC
  - GE
  - Atochem
  - BP

- **Shift to Lifesciences**
  - Bayer
  - Hoechst
  - ICI
  - Monsanto
  - DSM

**Companies from 1990 remaining in 2010**

- **Transforming within Industry**
  - BASF
  - Dow Chemical
  - DuPont
  - Mitsubishi
  - Akzo

**Oil Companies with Chemical Portfolios**

- Exxon
- Shell
- Total

Compliments of McKinsey
What Unhealthy Looks Like

Natural Gas Cost Advantage
And US Chemicals Trade

- WTI Price Index (Year Avg)
- Henry Hub Price Index (Year Avg)
- US Chemicals Real Trade Balance

- Deterioration of Gas Cost Advantage
- Natural Gas Constrained Supply
- Major Natural Gas Shale Plays start production

Unhealthy

Healthy

Billions of 2005 US$


Net Exporter  Net Importer

Banholzer Bird Symposium
Natural Gas and Oil Prices Diverge

Diverging energy cost

Bio considerably higher
Natural Gas and Oil Prices Diverge

desire return to tradition: ethane tracks gas
Impact of Low Gas Prices

EtOH, Sugar Actual 2-4 X

EtOH, Sugar Theoretical

CH₃CH₂OH → CH₂CH₂ + H₂O

Owen Kean, TK Swift  ACC

Banholzer Bird Symposium
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

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

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

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Capital for Single Plant</th>
<th>Revenue</th>
<th>Global Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear Power Plant (1350MW)</td>
<td>$4,971MM</td>
<td>$1051MM/y</td>
<td>0.05% Electricity Generation</td>
</tr>
<tr>
<td>Pulverized Coal: CC (600MW)</td>
<td>$2,372MM</td>
<td>$441MM/y</td>
<td>0.02% Electricity Generation</td>
</tr>
<tr>
<td>EG (400 KT/Yr)</td>
<td>$326MM</td>
<td></td>
<td>2% MEG Consumption</td>
</tr>
<tr>
<td>MTO (277 kiloton/Yr)</td>
<td>$321MM</td>
<td></td>
<td>0.3% Ethylene consumption</td>
</tr>
</tbody>
</table>

**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.
- 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

**Invention**
- Single Site Catalysis: 1957, 80
- Super Critical Coal Power: 1920

**Development**
- Single Site Catalysis: 1980-90
- Super Critical Coal Power: 1930-50s

**Demonstration**
- Single Site Catalysis: 1989
- Super Critical Coal Power: 1957

**Deployment**
- Single Site Catalysis: 1991
- Super Critical Coal Power: 1970s


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*400 mT LLDPE plant, 2008*

**600 MW plant, 2009**
Disruption of Feedstock Easy to Claim, Tough to Achieve

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
Thank You
Raw Materials

ALL NEW! WEEKLY WORLD NEWS
THE WORLD’S ONLY RELIABLE NEWSPAPER
WHAT THE GOVERNMENT DOESN’T WANT YOU TO KNOW . . .
NO MORE OIL!
WORLD SUPPLY WILL BE GONE IN 6 MONTHS
• ECONOMY WILL COLLAPSE!
• MILLIONS WILL STARVE!

DRY!
## Energy Costs

<table>
<thead>
<tr>
<th>Material</th>
<th>$/gal</th>
<th>$/lb</th>
<th>$/bbl</th>
<th>$/gal</th>
<th>$/ton</th>
<th>$/Bu</th>
<th>$/gal</th>
<th>$/L</th>
<th>$/tonne</th>
<th>$/kW-hr</th>
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As of Oct 2013

Banholzer Bird Symposium