The Future of Fuels and Alternative Feedstocks – Recognizing Hype vs. Practical Limitations
Too much hype for the possible and not enough focus on the practical

Chemical Engineering is letting society down!
Challenges to Society

Academic Success

Invention

Economic Viability

Business Success

Impact to Society

Risk vs. Reward

What people want ≠ What they will pay for ≠ What they can afford

What they will pay for impacts society
Business Success vs. SCIENCE

Impact to Society = Business Success

Low

High

Quality of Science

Low

High

Man Made Diamonds

Transistors

Antibiotics

LEDs

Ethylene Styrene Interpolymers

H₂ fuel cells

SkyMine®

CALERA

Green Cement for a Blue Planet

Electrochaea
Energy Sources Have Changed

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

Is that enough?

Source: IEA, EIA; US Primary Energy
Funding Follows the Hype

Published Articles Reflect the Focus on “Bio” Related Research:

- Biodiesel + Cellulosic Ethanol + Bioengineering
- Reactor Design + Transp. Phenomena + Fluid Dynamics

Percentage of Faculty with “Bio” Related Research Interests:

- Caltech: 23%
- UC Santa Barbara: 28%
- Northwestern: 35%
- Georgia Tech: 42%
- Berkeley: 44%
- UT Austin: 45%
- U Illinois: 58%

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

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

<table>
<thead>
<tr>
<th>Hydrogen Car</th>
<th>Corn Ethanol</th>
<th>Biodiesel</th>
<th>Cellulosic Ethanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;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 Chu, Energy Secretary, May 2009</td>
<td>&quot;...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</td>
<td>“Biofuels are contributing to higher prices and tighter markets.” Timothy Searchinger, Princeton University April 2011</td>
<td>“…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</td>
</tr>
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<tr>
<th>Bio Plastics</th>
<th>Glycerin to Epi</th>
</tr>
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<tbody>
<tr>
<td>Dow launched the JV with Cargill in 1997 to develop and market PLA from corn, exited the JV in 2004.</td>
<td>Dow postponed in 2009 due to uncertain supply +</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Bio based packaging launched in 2009 but discontinued by late 2010, due to performance perception issues</th>
<th>Natural oil Polyols</th>
</tr>
</thead>
</table>
Biofuels Key Issues

• How much biomass is available? 
  *not enough to replace fossil fuels*

• How much will the biomass cost? 
  *it is not cheap!*

• How much will biofuels cost? *more than fossil*

• How much more are we willing to pay? *no premium*

• How realistic is chemical production from biomass? 
  *we already do, but chemical use doesn’t address the big issues*

Migration to Higher Energy Density Sources

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

Crude oil is three times as energy dense as biomass.

Btu/lb

<table>
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<tr>
<th>Energy Equivalency</th>
<th>$ Capital / Usable MM Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Oil Refinery</td>
<td>$164</td>
</tr>
<tr>
<td>27 Power Plants</td>
<td>$167</td>
</tr>
<tr>
<td>60 Ethanol Refineries</td>
<td>$321*</td>
</tr>
</tbody>
</table>

*land & water penalty not included

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.
The Cellulosic Fad

High cash and capital costs

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

improved performance due mainly to higher yield (gal/bdt)
## Scale of Fuels Makes it Harder

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

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

**Development**
- 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

Impact / Market Penetration

- Single Site Catalysis: ~$10s MM, ~$50 MM, ~$150 MM
- Super Critical Coal Power: ~$100s MM, ~$500+ MM, ~$2 B

Sources:
- *400 mT LLDPE plant, 2008*
- **600 MW plant, 2009**
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

## Costs*

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<tr>
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<th>USA</th>
<th>Brazil</th>
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<tbody>
<tr>
<td>Ethane</td>
<td></td>
<td></td>
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<tr>
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<td></td>
<td></td>
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<tr>
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<td>0</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>0</td>
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## Market Prices

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**Bio Commodities Too Expensive**

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

*Excludes Capital*
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

• Too much hype for the possible and not enough focus on the practical
  • Incumbent fossil sources set the standard for competition
  • It takes decades to deploy a new technology
  • Scale wins and biomass availability limits biofuels scale

• Small companies access to capital makes success challenging

• Fundamental engineering 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
Dow Supports Chemical Engineering

- $250 million total program
- foster better balance
- 10 year program
- 11 major universities
- areas
  - catalysis
  - process development
  - new materials
    - electronics
    - energy
    - transportation
    - consumer applications
Thank You