White Biotechnology

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Leader of Global Biosystems Practice, McKinsey & Company
Press briefing
February, 2009
Industrial biotech - the next S-curve in biotechnology

Industrial applications today

**Bio-feedstock**
- Replacement of oil and gas with biomass

**Bio-processes**
- Replacement of chemical synthesis by fermentation or biocatalysis

**Bio-products**
- Products with new characteristics (e.g., biopolymers, enzymes, nutrition/health ingredients)
White biotech is on a strong growth path

Sales, EUR billions

Chemical products relying on either:
• Bio-based feedstock
• Fermentation
• Enzymatic conversion
  Or a combination of the above

Source: Team analysis
In 2007, 6% of all chemical sales were generated with the help of white biotechnology

### EUR billions

<table>
<thead>
<tr>
<th>Segment</th>
<th>Bio-dependent sales 2007</th>
<th>Product examples/comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biofuels</td>
<td>35</td>
<td>• Bioethanol, biodiesel</td>
</tr>
<tr>
<td>Traditional bio-based chemicals</td>
<td>46</td>
<td>• Nat. rubber, essential oils/nat. extracts, botanicals, nutraceuticals incl. PUFAs, hydrocolloids, oleochemicals</td>
</tr>
<tr>
<td>Chemicals by fermentation</td>
<td>14</td>
<td>• Biopolymers, polyols, organic acids, amino acids, vitamins, enzymes, biologics*</td>
</tr>
<tr>
<td>Chemicals by enzymatic processes</td>
<td>5</td>
<td>• Pharmaceutical ingredients*, others</td>
</tr>
<tr>
<td>Total sales white biotech</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

* Top-down estimate based on industry interviews and industry reports
** Estimated future chemical industry sales excluding B2C sales in pharma and personal care (estimation of 2.5% chemicals industry growth)

Source: SRI, F.O. Licht, Frost and Sullivan, Press clippings, McKinsey
White biotech sales are expected to further grow significantly and increase their share of chemicals production

EUR billions

<table>
<thead>
<tr>
<th>Segment</th>
<th>Bio-dependent sales 2007</th>
<th>Assumptions</th>
</tr>
</thead>
</table>
| Biofuels                       | 34 31 65                | • Continuation of current strong growth in biofuels  
• Mid term price pressure due to low price of crude oil  |
| Traditional bio-based chemicals| 46 14 60                | • Strong growth in nat. rubber, botanicals and PUFAs, moderate growth in hydrocolloids  
• Increase share of oleo surfactants but decreasing prices  |
| Chemicals by fermentation      | 7 14 21                 | • Introduction and growth of new biopolymers and bio-based bulk chemicals expected, enzymes growth with customer markets, biologics grow with 9%*  |
| Chemicals by enzymatic processes| 2 5 7                  | • Growing share of chiral API*  
• Moderate growth in new products/services  |
| Total sales white biotech      | 99 54 153              |                                                                                                                                              |

* Top-down estimate based on industry interviews and industry reports

** Estimated future chemical industry sales excluding B2C sales in pharma and personal care (estimation of 2.5% chemicals industry growth)

Source: SRI, F.O. Licht, Frost and Sullivan, Press clippings, McKinsey
Growth is driven by advantages along all 3 dimensions of sustainability

People
- New jobs
- Broad technological capabilities

Planet
- Less emissions
- Less energy
- Less resource depletion

Profit
- Lower cost
- Lower risk
- Higher sales and margins

Source: Source
Bio-based chemical products offer advantages for the carbon footprint and other environmental criteria

Example bioethanol*

<table>
<thead>
<tr>
<th></th>
<th>Crude-based gasoline</th>
<th>Corn ethanol</th>
<th>Sugar cane ethanol</th>
<th>LC ethanol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>80</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

-20% -90% -90%

Rationale

- Reduced environmental impact of bio-based products has resulted in a surge of industrial biotechnology
- Reduced GHG footprint compared to fossil-based feedstocks
- Reduced energy consumption during production processes (e.g., through use of enzymes)
- Reduced environmental impact ("green" solvents, reduced water consumption, degradable by-products, etc.)
- Renewable raw materials

- True benefits remain to be assessed for each individual compound, depending on
  - Type of raw material (e.g., sugar cane vs. corn)
  - Origin of raw material (e.g., production on agricultural land vs. deforestation)
  - Agricultural techniques (e.g., fertilization, irrigation, use of pesticides)

* Conventional view excluding land use changes

Source: McKinsey analysis
Alternative feedstocks provide a mechanism to hedge the exposure of chemical companies to oil price increases

* Fossil cost based on a correlation of historic price with crude oil; the correlation is not statistically perfect (R2 of 0.9) and has no predictive value

** Bio-routes based on cost estimate of chemical conversion of ethanol,

*** Assuming backward integration into sugar cane in Brazil

Source: SRI; PEP; CMAI; McKinsey
Regulatory support across the globe helps the increasing use of bio-based chemicals

- EUR 90 million grant from French Industrial Innovation Agency to promote IBT*
- Global mandates for biofuels of ~ 65 bgy** bioethanol and 12 bgy of biodiesel in 2020
- EC 7th framework programme for sustainable non-food products and processes (EUR 700m)
- DOE grant to DSM, Abengoa, Los Alamos Laboratory and Sandia National Laboratory for an extensive enzyme development program

- Governments have strongly pushed the use of renewables through mandates, subsidies and grants
- Major focus has been on the transportation fuel sector but DOE and the European Commission are pushing for renewable chemicals as well
- Chinese government (NDRC) is supporting development of bio-based chemicals from an energy security point of view
- New US President wants to “double share of renewables” in 3 years

* Resulting, e.g., in the DSM/Roquette partnership to produce fermented succinic acid based on starch in France
** Billion gallons per year – corresponds to ~ 190 million tons of bioethanol and 40 million tons of biodiesel

Source: McKinsey analysis
Also, companies are increasingly branding their products as "green" to promote a sustainable image

* Currently debated in the academic world

Source: McKinsey analysis
While the innovation potential around traditional chemical building blocks appears to be largely exploited…

Source: McKinsey
... new bio-based building blocks could create the next wave of innovation in polymers and beyond

Source: McKinsey
Also existing polymers can become “bio” by using bio-based monomers or intermediates

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Sales 2007 USD billion</th>
<th>Biotechnology inroad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyurethane</td>
<td>~27</td>
<td>Soy-based polyols</td>
</tr>
<tr>
<td>Unsaturated polyester resins</td>
<td>~13</td>
<td>Maleic anhydride from succinic acid</td>
</tr>
<tr>
<td>Nylon 6</td>
<td>~13</td>
<td>Caprolactam from fermentation</td>
</tr>
<tr>
<td>ABS*</td>
<td>~11</td>
<td>Butadiene from succinic acid</td>
</tr>
<tr>
<td>Polyacrylamide**</td>
<td>~7</td>
<td>Acrylonitrile from 3HP</td>
</tr>
<tr>
<td>Polybutadiene</td>
<td>~6</td>
<td>Adipic acid from fermented succinic acid</td>
</tr>
<tr>
<td>Acrylic fibers</td>
<td>~5</td>
<td>Acrylamide from 3HP</td>
</tr>
<tr>
<td>Nylon 6.6</td>
<td>~5</td>
<td>Butadiene from succinic acid</td>
</tr>
</tbody>
</table>

* Acrylonitrile-Butadiene-Styrene Resins
** Excludes superabsorbent applications
Source: SRI; CMAI; Tecnon; McKinsey analysis
A new Value Chain is emerging with lots of places to play

Value chain
Enablers

- Logistics
- Technology
- Equipment
- Financing

Feedstock provision
- Farming
- Storage
- Distribution

Feedstock processing
- Grain/seed milling
- Biomass pre-treatment and enzymatic conversion

Primary conversion
- Fermentation
- Chemical conversion
- Enzymatic conversion

Secondary conversion
- Polymerization
- Downstream processing
- Complex chemical synthesis

Products (examples)

- Corn: Energy crops
- Soy: Straw, stover
- Oil: Protein
- Sugar: Lignin
- Ethanol: Platform chemicals
- Vitamins
- Biodiesel
- Bio-polymers
- Fine chemicals
- Specialty chemicals

End-markets examples
- Food
- Feed
- Energy
- Transportation
- Pharma
- Food/feed
- Cosmetics
- Automotive
- Electronics
- Consumer goods
- Pharmaceuticals

Source: McKinsey
What could limit the growth?

1. Lack of public support
2. Continued low oil prices
3. Lack of private investment

... unlikely to play out in the long run