The Bioeconomy

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Agricultural and Biological Engineering
Petroleum is the Primary Source of Carbon for:

- Fuels
- Plastics
- Solvents
- Other Valuable Chemicals
Biology Has Found a Way to Convert Solar Energy To Chemical Energy

Carbon Dioxide $\rightarrow$ Chlorophyll molecules in the leaves $\rightarrow$ Oxygen

$\text{Carbon Dioxide} \quad 6\text{CO}_2 + \quad \text{water} \quad 6\text{H}_2\text{O} \quad \rightarrow \quad \text{light energy} \quad \text{chlorophyll} \quad \text{glucose} \quad \text{C}_6\text{H}_{12}\text{O}_6 + \quad \text{oxygen} \quad 6\text{O}_2$

Water $\rightarrow$ Glucose
Spinning Straw into Gold

Fuels

Plastics

Solvents

Other Valuable Chemicals
Bioeconomy

Food

Non-food

Biomass

natural resources

climate change

public health

energy security

sustainable production

food security

economic and social development
Bioeconomy Today

- Grown for Biofuel
- Biologics
- Polylactic Acid
- Enzymes for Cleaners
$369 Billion/year
4 million US jobs

The 2012 U.S. Bioeconomy Breakdown
Numbers in Billions ($USD)

- Biotech Seeds, $125
- Biologics, $100
- Industrial Biotech, $125
- $66
- $30
- $16
- $12
- $1

Source: Rob Carlson, industrial biotech breakdown provided by Darlene Solomon of Agilent Technologies.
Figure 16: Estimated Growth in Employment from 2015 through 2020 for the Biobased Products Sector in the U.S. Excluding Enzymes

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Feedstock</th>
<th>Crops</th>
<th>Process</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most expensive</td>
<td>Oils</td>
<td>Soy</td>
<td>Transesterification</td>
<td>Biodiesel</td>
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<tr>
<td>Transportable (energy dense)</td>
<td></td>
<td>Palm</td>
<td>Catalysis</td>
<td>Olefins</td>
</tr>
<tr>
<td>Easily refined</td>
<td></td>
<td>Jatropha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderately expensive</td>
<td>Starches</td>
<td>Corn</td>
<td>Ethanol</td>
<td></td>
</tr>
<tr>
<td>Transportable &amp; storable</td>
<td></td>
<td>Cassava</td>
<td>Butanol</td>
<td></td>
</tr>
<tr>
<td>Easily converted to sugar</td>
<td></td>
<td></td>
<td>Other fuels</td>
<td></td>
</tr>
<tr>
<td>Moderately expensive</td>
<td>Sugars</td>
<td>Sweet sorghum</td>
<td>Fermentation</td>
<td>Designer oils</td>
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<tr>
<td>Direct source of fermentable sugar</td>
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<td>Sugarcane</td>
<td>Catalysis</td>
<td>PET</td>
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<tr>
<td>Must be processed immediately</td>
<td></td>
<td>Sugar beet</td>
<td></td>
<td>Bioisoprene</td>
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<tr>
<td></td>
<td>Biomass</td>
<td>Biomass sorghum</td>
<td></td>
<td>Other chemicals</td>
</tr>
<tr>
<td>Cheapest feedstock</td>
<td></td>
<td>Perennial grasses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport limited (low bulk density)</td>
<td></td>
<td>Short rotation-woody</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storable</td>
<td></td>
<td>crops</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Most difficult to process</td>
<td></td>
<td>Wastes &amp; residues</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fuels &amp; chemicals</td>
</tr>
</tbody>
</table>

Bioeconomy of the Future

• Plant Biotechnology

• Microbial Synthetic Biology

• Catalysts and Enzyme Biotechnology

• Bioprocess Engineering
Plant Biotechnology
Engineering Healthier and More Productive Crops
Synthetic Biology
Engineering Bacteria into Living Factories
Bioprocess Engineering
Designing the Systems that Make it Work
Bioeconomy

Using biology to fuel our economy and produce sustainable products