**Towards an Interdisciplinary Approach to Next-Generation Biofuels**

**Environmental, Techno-Economic, and Governance Perspectives**

**Introduction**

Higher-order alcohols are an attractive set of potential fuels due to their high energy content, relative immiscibility in water, and compatibility with native microbial metabolic systems. These factors, along with their early value as platform chemicals and the potential to make use of abandoned ethanol facilities, makes them particularly commercializable - a viable substitute for today’s petroleum fuels. But what hazards might these new fuels bring - hazards both conventional and unconventional, anticipated and unanticipated? As we explore these questions, we provide an excellent case study for interdisciplinary learning, Green Chemistry and a critical lens on the nature of ‘clean energy’ technologies.

### Higher-Order Alcohols

<table>
<thead>
<tr>
<th>Compound</th>
<th>Energy Content</th>
<th>Water Solubility</th>
<th>KOW</th>
<th>Highest Reported Titers</th>
<th>Acute Human Hazard</th>
<th>Chronic Human Hazard</th>
<th>Ecological Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>butanol</td>
<td>27.3 MJ/L</td>
<td>8.7 g/100ml</td>
<td>2.03</td>
<td>0.21 g/L</td>
<td>Irritation, otherwise Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>pentanol</td>
<td>21 MJ/L</td>
<td>7.9 x 10^3 g/100ml</td>
<td>-0.31</td>
<td>&gt;37 g/L</td>
<td>Irritation, otherwise Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>ethanol</td>
<td>8.7 g/100ml</td>
<td>0.76 g/100ml</td>
<td>1.15</td>
<td>0.01 g/L</td>
<td>Irritation, otherwise Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>gasoline</td>
<td>21 MJ/L</td>
<td>2.03 g/100ml</td>
<td>3.00</td>
<td>0.21 g/L</td>
<td>Irritation, otherwise Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

**Carbon Metabolism**

- **Butamax** - Est 2009. Joint Venture between DuPont and BP. Current potential capacity 500 million gallons per year.
- **Joule** - Est 2007. Producing alcohols and other fuels with cyanobacteria. Only inputs are CO₂, water, sun. Relies on a complex engineered tanks, but targeting $1.28/gallon production.

**Commercial Landscape**

- **BioEnergy Biofuels**
- **Cellulosic Biofuels**
  - Est 2007. Producing alcohols and other fuels with cyanobacteria. Only inputs are CO₂, water, sun. Relies on a complex engineered tanks, but targeting $1.28/gallon production.

**References**

- JBEI.
- **Butamax** - Est 2009. Joint Venture between DuPont and BP. Current potential capacity 500 million gallons per year.
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**Challenges**

- **Technical**
  - Shunting carbon metabolism to alcohol production without disrupting organism growth.
  - Energetics (NADH/NADPH)
  - Separation of alcohol from growth media.
  - Scale-up engineering.
  - Process Modeling.

**Governance**

- Regulation of Non-traditional risks such as bioengineering requires different structures and approaches compared with past efforts.
- Balancing trade-offs among non-commensurate hazards operating over a variety of scales in time and place, with potential threshold effects and other non-linearities.
- Balancing efforts to accelerate technology development with the need to proceed cautiously and with confidence that new problems are not being created with new technology.
- Understanding when and how new technological tools such as biotechnologies may require different property rights protections or different types of regulatory oversight.

**Acknowledgements**

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