Direct fermentation for Isobutene, Butadiene, and propylene production: a platform for renewable plastics, synthetic rubber, and fuels

December 9th 2014
Evry (France) – November 17th, 2014 – Global Bioenergies (Altenext Paris: ALGBE) announces having successfully carried out the first isobutene production trial in its industrial pilot of Pomacle-Bazancourt. Delivered on the Pomacle-Bazancourt site in July, the industrial pilot installation has since been taken through a series of mechanical and functional validations. A production run was initiated on November 3rd, 2014, and resulted in the very first production of fermentative isobutene in an industrial environment. This achievement is documented in a short press release.

Evry, November 26th, 2014 – Global Bioenergies (Altenext Paris: ALGBE) announces having succeeded in the production of bio-sourced butadiene by direct fermentation. It is the first time ever an entirely biological production process -i.e. without any chemical step- is reported for butadiene, one of the most important petrochemical building blocks.
Global Bioenergies at a glance

- **Mission:** Converting renewable resources into light olefins through direct fermentation
- Located in Genopole, the number 1 biotech cluster in France
- >60 employees, international Scientific Advisory Board
- Listed on NYSE Alternext since June 2011, market cap ≈ 130 million $
- 9/2012: Most Innovative European SME (EuropaBio Award)
- Collaborations with Audi, Synthos, Arkema, LanzaTech
Producing olefins in a different way

GASEOUS OLEFINS

- Ethylene
- Propylene
- N-Butenes
- Butadiene
- Isobutene
- Isoprene

TODAY: FOSSIL RESOURCES

Petrochemistry

TOMORROW: RENEWABLE RESOURCES

Industrial Biology
# Light olefins: a global market of $300 billion

<table>
<thead>
<tr>
<th></th>
<th>Volume (Mt)</th>
<th>Price ($/kg)</th>
<th>Market (b$)</th>
<th>Main applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene</td>
<td>115</td>
<td>1.25</td>
<td>144</td>
<td>Polyethylene (60%)</td>
</tr>
<tr>
<td>Propylene</td>
<td>83</td>
<td>1.20</td>
<td>100</td>
<td>Polypropylene (65%)</td>
</tr>
<tr>
<td>Linear butenes</td>
<td>37</td>
<td>1 - 2</td>
<td>37 - 74</td>
<td>Co-monomers in various plastics</td>
</tr>
<tr>
<td>Isobutene</td>
<td>15</td>
<td>1.7 - 2</td>
<td>25 - 30</td>
<td>Tires, organic glass, PET, fuels</td>
</tr>
<tr>
<td>Butadiene</td>
<td>10.6</td>
<td>1.8</td>
<td>19</td>
<td>Tires, nylon, coating polymers</td>
</tr>
<tr>
<td>Isoprene</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>Tires, adhesives</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>261.6</td>
<td>1 - 2</td>
<td>328 - 369</td>
<td>6.4% of oil consumption</td>
</tr>
</tbody>
</table>

1 ICIS statistics – January 29th, 2010  
2 SRI reports  
3 Platts – February 2013  
4 Platts – October 2012  
5 Nexant – March 2012  
6 DeWitt – March 2013  
7 GBE calculations from BP statistics 2013
The deployment of the shale gas industry results in ethylene overproduction and in a progressive shortage of propylene, isobutene and butadiene.
• Market trends create a need for alternative routes to isobutene, butadiene and propylene

• Chemical routes:
  – Several routes to propylene
  – Difficult access to butadiene
  – No route to isobutene described so far

• Biological routes:
  – State-of-the-art approaches cannot be used in the case of light olefins.
  – A breakthrough innovation was required to address this opportunity
State of the art

- Starting point: a natural strain that produces small amounts of the compound of interest.

- Development and industrialization:
  - Improvement of enzymes and metabolic pathways.
  - Construction of industrial strains and development of lab-scale process.
  - Scale-up of the fermentation process and downstream process engineering.

- This approach works well for compounds found in nature (propanediol, succinic acid, isobutanol,…).

- It cannot be used for gaseous olefins as they are not produced by microorganisms in nature.
Artificial metabolic pathways

The bioproduction of light olefins required a breakthrough innovation, based on the development of artificial metabolic pathways.

- Genetically engineered microorganism
- Undescribed enzymatic reactions
- Non typical-metabolic intermediates
- Glucose
- Isobutene
A two-step technology

I - Fermentation
Breakthrough technology by direct fermentation to a gas
No product associated toxicity
Pre-purification by product volatilization

II - Purification
Combination of proven petrochemical modules
High performance
Simple design

Glucose
Saccharose

BUTADIENE

ISOBUTENE

PROPYLENE
Industrial pilots

- Paris
- Berlin
- Leuna
- Pomacle
- Germany
- France
• BioDémo platform of the Pomacle-Bazancourt industrial site
• 500L fermenter
• Maximum capacity: 10 tons per year
• Simplified purification: oxidation-grade isobutene
• Applications: Methacrylic acid (< $1bn) and Plexiglas ($7bn)
• Public funding: Investissements d’avenir (€4m)
Fraunhofer CBP in the refinery of Leuna - unique combination of expertise in fermentation and olefin chemistry

- 5000L fermenters
- Maximum capacity: 100 tons per year
- Complete purification to high-purity isobutene
- Engineering performed by Linde
- Financing supported by a €5.7m grant from the German Federal Ministry of Education and Research
Isobutene: a wide product tree

- **SOLID**
  - Butyl rubber
  - Organic glass
  - Methacrylic Acid

- **LIQUID**
  - Gasoline
  - Jetfuel
  - Diesel
  - Industrial lubricants
  - Plastics

- Others:
  - >80 carbons
  - 8 carbons
  - 12 carbons
  - 16 carbons
  - 48-80 carbons
Butadiene: markets and distribution of rights

3 million tons

ABS plastics
Carpet backing, coatings
Nylon

Opportunity for further industrial agreements

7 million tons

Rubber

Royalties to be paid to Global Bioenergies

Global Bioenergies

Glucose

Butadiene
Propylene and derivatives

- Super-absorbents
- Hard plastics
- Varnishes
- Solvents
- Foams
- Synthetic textiles
Key dates and events

- Inception: 2008
- Venture capital: €3.2m raised
- 2009
- License option US Fortune 500 company
- 2010
- Butadiene partnership
- 2011
- Propylene and butadiene proofs of concept
- 2012
- IPO
- 2013
- €23m raised
- 2014
- Isooctane collaboration
- Launch of the industrial pilots phase
- €37.2m raised since company inception
David Gogerty
Business Development Manager

david.gogerty@global-bioenergies.com

www.global-bioenergies.com