Glycell™ - An Update on Leaf Resources’ Pretreatment Process for the Conversion of Lignocellulosic Biomass to Fuels and Chemicals

Les Edye
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Leaf Resources
Active participants in the advanced bio-economy

- Leaf Resources Limited (ASX:LER) is focused on making sustainable products from plant biomass.

- We offer an advanced technology package for breaking down plant derived biomass to useful, sustainable, renewable and biodegradable products.

- Leaf Resources’ innovative Glycell™ is a disruptive process technology that can reshape the economics of using large scale biomass resources as a replacement for petroleum derived products.
Clean sugars feed bio-based chemicals market

Bio-based chemicals: growing 20%pa, exceeding $500b by 2017

Glycell™ process
Low cost clean sugars... faster

Proprietary technology owned by others converts the sugars to

Renewable chemicals and green sustainable products.

Bio-based chemical examples

- Zeachem - Acetic Acid, Ethyl Acetate
- Bioamber - Succinic Acid
- Myriant - Succinic Acid
- Avantium - PET replacement
- Baskem - Polyethylene
- Renovia - Adipic and Lactic acid
- Multiple - Ethanol
- Others - Many uses

Used by companies such as:

- Toyota
- Dow
- Dupont
- Mitsui
- Johnson and Johnson
- Proctor and Gamble
- Coca-Cola
- Plus many others

* See announcement 14th July 2014
Glycell™ CS Key objectives
Process focus

- **Key proposition and competitive advantage**: “Produce low cost cellulose at any scale”
- **Cellulosic sugars**: Maximise cellulose conversion to cellulosic sugars
- **Clean enriched streams**: Separate pentose rich and hexose rich liquid products
- **Funding Model**: Partnerships for a capital light approach
- **Glycerol recovery**: Profound effect on cost of sugars
Lignocellulosic biomass is impregnated with sulphuric acid and steam at atmospheric pressure over a period of 10 to 20 minutes. The impregnated biomass is fed into a horizontal screw reactor and crude glycerol is added. The mixture of biomass, acid, water and glycerol is held in the horizontal reactor for 30 minutes at 160 °C and then discharged into a pressafiner (screw press) where the solid and liquid components are separated. The solid component is washed with water and treated with a hydrolysing enzyme cocktail, filtered on a belt filter and the filtrate is concentrated to produce a sugars syrup. The lignin-rich filter cake is dried. The liquid component form the pressafiner containing glycerol, soluble sugars, dissolved lignin and acid is processed by simulated moving bed chromatography to recover components.
Cost of Sugars

<table>
<thead>
<tr>
<th>Feedstock Input Price ($/as is tonne at 50% moisture)</th>
<th>Sugar cost (¢/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>85% glycerol recovery</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>12</td>
</tr>
<tr>
<td>75</td>
<td>8</td>
</tr>
<tr>
<td>55</td>
<td>5</td>
</tr>
</tbody>
</table>

- Class 5 conceptual design & costing
- Sugars Cost – Marginal cost of combined C5 & C6 sugars production net of lignin revenue less capital cost of production over 20 year plant life
- Estimates give ~4¢/lb cost of capital (40 tph as is brown field plant)
Product R&D

- Biomass pretreatment technologies
  - US activities
  - Australian activities
Andritz Pretreatment Reactor
Biomass flexibility

Poplar

Bagasse

Oil Palm fibre (EFB)

Eucalyptus
Eucalyptus
Laboratory optimisation

- A significant reduction of lignin content in the Glycell pretreatment solid fraction.
C6 sugar yield

The saccarification (digestibility) procedure measures the efficacy of a given pretreatment based on a maximum enzyme loading and is reported as a percentage of the theoretical mass yield.

Cellulase enzyme cocktail used was Cellic® CTec3 (Cellic® CTec3 is a registered trademark of Novozymes) at 20 FPU/g cellulose at 2% cellulose weight loading applied to all samples.

Cellulose saccharification after enzymatic hydrolysis using the Glycell™ process - C6 Sugar yield as % of theoretical maximum
- High cellulose recovery (94%) High sugar conversion
- 30% more sugars – boost economics
- Minimal degradation products detected
- This is commercially significant as many products need “clean sugars”

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**Improved saccharification kinetics**

Significant opportunity to reduce enzyme load and size of reactors

- Dilute acid – NREL design target (2013) – 0.9 % acid; 2.3 liquid:solid; 5 min – 90 % hydrolysis of cellulose after 84 hours with enzyme load of 10 mg/g cellulose
  - ca. 5 % conversion of xylan to furfural

- Glycell best to date – Hardwood – 0.8 % acid; 160 % glycerol; 2.4 liquid:solid; 30 min
  - No measurable furfural formation
Degradation products

<table>
<thead>
<tr>
<th>Description</th>
<th>Cellobiose (g/L)</th>
<th>Xylitol (g/L)</th>
<th>Formic Acid (g/L)</th>
<th>Acetic Acid (g/L)</th>
<th>Levulinic Acid (g/L)</th>
<th>Ethanol (g/L)</th>
<th>HMF (g/L)</th>
<th>Furfural (g/L)</th>
</tr>
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<tbody>
<tr>
<td>Bagasse</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Eucalyptus</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>1.85</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
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- Other than Acetic acid, all typical degradation products were not detected for both bagasse and Eucalypt conditions
Zeachem Collaboration

- Collaboration Agreement with ZeaChem Inc.
- The evaluation by ZeaChem and Leaf Resources of the Leaf Glycell™ process for the production of fermentable sugars at ZeaChem’s demonstration plant at Boardman, Oregon.
- The trials will use Poplar as a feedstock.
- SMB chromatic separator pilot from ARI in Twin Falls, Idaho
Key competitive advantages

Based on current data, Leaf Energy’s Glycell™ process when compared to other pretreatment processes, such as acid hydrolysis and/or steam explosion:

- Produces high yield cellulose with less degradation products;
- Excellent enzymatic conversion of cellulose to sugars;
- Enzyme kinetics improved on the Glycell™ pretreated biomass allowing quick sugar production, and;
- produces clean sugars due to milder conditions.
The Glycell™ Process
Proprietary technology for cellulose production

The Glycell™ process has compelling advantages over traditional methods of cellulose extraction

Product benefits:
- Simple, innovative, low cost and effective
- Uses a biodegradable reagent
- Low temperature and low pressure
- Continuous Process design
- Short processing time

Economic benefits:
- Significantly lower capital costs
- Significantly lower operating costs
- Industrially available equipment
- Operates at any scale
- High Cellulose recovery
- High conversion of Cellulose to Sugars

1 see announcement lodged ASX 7th July 2014
2 See announcement lodged ASX 14th July 2014
Thank You

Les Edye
l.edye@leafresources.com.au

Alex Baker
a.baker@leafresources.com.au

www.leafresources.com.au