Glycell™ - Leaf Resources’ pretreatment process for the conversion of lignocellulosic biomass

Alex Baker Bio PacRim Conference
December, 2014
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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.
The carbon evolution
The future of materials

Coal was the industrial material of the 19\textsuperscript{th} century

Oil was the industrial material of the 20\textsuperscript{th} century

Cellulose will be the industrial material of the 21\textsuperscript{st} century\textsuperscript{*}

\textsuperscript{*} Lüder Gerking, CEO, Nonoval GmbH & Co.KG
Figure 3 - Analogous Model of a Biobased Product Flow-chart for Biomass Feedstocks
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
Development pipeline

Glycell™ Technology Development Pipeline
Leaf Resources Limited

- Glycell™ CS
- Glycell™ FT
- Glycell™ MC
- Glycell™ CD
- Research and Development
- Scale Up
- Commercialisation
- Licensing
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
The Glycell™ Process
Proprietary technology for cellulose production

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

Product benefits:
- Innovative process
- Uses a renewable biodegradable reagent
- Mild 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 a range of scales
- High Cellulose recovery
- High conversion of Cellulose to Sugars

1 see announcement lodged ASX 7th July 2014
2 See announcement lodges ASX 14th July 2014
Leaf Resources Glycell™ CS Process

Glycell™ Core Technology

Biomass

Glycell™ Biomass preconditioning

Glycell™ Biomass digestion

Glycell™ Unique solid/liquid separation

Solids to Enz

Liquid Rec

Hexose rich stream

Pentose fraction
Biomass flexibility

Poplar

Bagasse

Oil Palm fibre (EFB)

Eucalyptus
Eucalyptus
C6 sugar yield

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”

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.
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; 0.8:1 glycerol: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>
</thead>
<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>
</table>

- Other than Acetic acid, all typical degradation products were not detected for both bagasse and Eucalypt conditions.
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>
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<td>55</td>
<td>5</td>
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</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)
Zeacchem 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
- Pretrial work at Andritz Springfield - 17 conditions evaluated on poplar furishes
- Glycell CS on poplar chip effective
- Saw dust and planar dust 50:50 blend also tested
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.
Thank You

Looking forward to Partnering

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