Glycell™—Leaf Resources’ pretreatment process for the conversion of lignocellulosic biomass to fuels and chemicals

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Outline

- Glycell™ Cellulosic Sugars (CS) Process
  - Glycell at pilot scale
- Saccharification kinetics
- Cellulosic sugars production and fermentation tests
- Glycerol recovery by SMB chromatography
- Approaches to market
  - Pulp mill expansion, Retrofit, bolt-on, Greenfield
- Key technological advantages
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.
Leaf Resources Glycell™ CS Process

Biomass

Glycell™ Biomass preconditioning

Glycell™ Core Technology

Solids to Enz

Hexose rich stream

Liquid Rec

Pentose fraction
Glycell at pilot scale

- Several trials at the Andritz pilot plant facility in Springfield since November 2013
- Continuous production rates of 3-5 BDT per day
- > 40 independent pilot scale tests totalling over > 20 tonnes (dry basis) biomass
- Data presented here do not represent proprietary optimised conditions, but are chosen from pilot plant data to demonstrate the technical advantages of the Glycell process.
Biomass flexibility

- Poplar
- Bagasse
- Oil Palm fibre (EFB)
- Eucalyptus
Andritz Pilot Plant, Springfield OH
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
Effects on solids loading on Glycell pretreated biomass

- pH 5.0 - 50°C optimal reaction temperature
- 2 & 10% solids
- 20 mg/g glucan enzyme dose tested
- Testing on Glycell bagasse and Eucalyptus pretreated samples
- Confirmed washing effect
Enzymatic efficacy sustained at higher solids

- pH 5.0; 50 °C; 20 mg/g enzyme
- bagasse and eucalyptus at 2 and 10% solids
High solids saccharification studies at Andritz (Glens Falls, NY)

- Glycell Pretreated poplar chips
  - Glycell - 1.15% acid on biomass db, 55% glycerol
  - Dilute acid - 1.07% acid on biomass db, no glycerol

- 15% solids, pH 5.5, CTEC 3 at 12 mg/g of cellulose

- Initial cellulose saccharification rate of the Glycell pretreated biomass was 3.0 times that of dilute acid pretreatment.

- Final yield of monosaccharides from the Glycell pretreated biomass was 166.6% that of dilute acid pretreatment.
Fermentation testing - 2L biostats

Sugars support microbial growth with no inhibition

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**P. holstii**

- Glucose Conc (g/L)
- Optical Density (600nm)

**S. cerevisiae**

- Glucose Conc (g/L)
- Optical Density (600nm)

**E. coli**

- E. coli Glucose Conc (g/L)
- E. coli Optical Density (600nm)
Glycerol recovery at Amalgamated Research LLC (ARi)

- ARi simulated moving bed chromatography services include:
  - Testing at the ARi pilot facility.
  - Lease of pilot skids for on-site testing.
  - Sale of custom design pilot plants for customer testing or demonstration purposes.
  - Project R&D, supervision and engineering from lab to industrial scale implementation.
- ARi testing on ca. 1 tonne of filtrate over 4 weeks confirms that >95% of the glycerol in the filtrate is recoverable by SMB chromatography at ca. 95% purity
Process modes for industry settings

- Biomass, acid & water
- Glycerol
- Screw press/impregnator
- Horizontal screw digester
- Pressurised disk refiner
- Screw press
- SMB separator
- Counter current washer
- Pentose rich syrup
- Solid fraction for saccharification
- Saccharification or SSF
- Fermentation products
- TM Pulp + conc liquor

BOLT ON
RETROFIT
PULP MILL EXPANSION
GREENFIELD
Greenfield design case
Glycell model vs Dilute acid model

- Common Class 5 estimate
  - 367,200 tonnes (d.b.) p.a. at $66.10/dry tonne
  - 60% debt funding at 8% over 10 years
  - CapEx spend over 3 years and revenue commencing mid-year 3

- Dilute acid model (NREL design report)
  - Normalised to 80% cellulose to glucose efficiency
  - Capital required for enzyme production removed and purchase of enzymes included in OpEx
28.7% advantage of Glycell over normalised NREL model (net of ROI and CapEx)

- Represents a $0.09/kg saving
In a greenfield design case, including coproduct benefit:

- Includes CapEx and OpEx required to realise coproduct revenue (Glycell lignin at $450/tonne).
- Represents a $0.21/kg saving.
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.

- Improved enzymatic conversion of cellulose to sugars.

- Produces a high purity glucose liquor due to milder conditions and separation of pretreatment solids and liquids.

- Other possible benefits – glycerol pacifying metal surfaces impacts on cost and life of plant.
Thank You

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