Second Generation Bio-Refineries – Optimisation Opportunities and Implications for Australia

Chief Executive Officer

Microbiogen Pty Ltd

Sydney, Australia

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World produces more food than crude oil

The world currently produces approximately 7 billion tonnes of food (including some waste portions)

The world currently produces approximately 2 billion tonnes of gasoline and diesel from fossil sources

Source: FAO

Source: IEA
Demand for both is expected to increase significantly by 2050

Greater population and changing diets = a rise in food demand of 70%

Even taking into account biofuels, electric cars etc., IEA forecasts crude oil demand to rise by 39%

Demand for food is rising faster than demand for oil, but…

![Graph showing food demand and crude oil production](chart.png)
Taking energy density into account highlights the challenge ahead

...on an energy contained basis oil dwarfs that of projected food demand

Key assumptions: Average human consumption is 6,500KJ/day, energy density of food is 16.9MJ/kg and energy density of gasoline/diesel is 47.2MJ/kg and that half the food produced is wasted.
Clearly – converting food to fuels is not the answer

As a starting point, using food for biofuels has been very helpful

- Develop suitable infrastructure
- Stepping stone to non-food substrates
- Technology development and convergence opportunities

While developing biofuels, complimentary technologies will also help a transition

- Electric vehicles
- Fuel cells (Nissan recently developed a car that uses ethanol in a fuel cell)
- Greater efficiency engines to take advantage of higher octane fuels like ethanol

Transition to lignocellulosic biofuels

- Abundant supply of non-food substrates (Over 1 billion tonnes identified in the US alone)
- Higher intensity utilisation of biomass
Efficient and economic conversion to fuels and products the key

- Microbiogen (MBG) optimises the conversion of sugars and waste streams to valuable products
  - Greater conversion efficiency of sugars to ethanol
  - Production of high protein animal feed from biofuel waste streams
  - Optimise (speed, temperature and ethanol tolerance) catalysts for biofuels and bio-refineries

- 100% focus… the conversion catalyst – *Saccharomyces cerevisiae* yeast

- License + collaboration agreements - some of the largest biotech/food corporations in the world

- Over 750M liters of biofuels produced from trials so far
Next generation biofuels and bio-refineries are already here

- Seven commercial scale operations have been built
- Approximately A$3 billion already spent
- EtOH capacity of 500 million/l/yr.
- Under pressure from low oil prices
- Competing with 1st Gen biofuels
- Operations in commissioning phase

“Steel in the ground”
...almost €2 BN Total Investment Cost...
...with an EtOH production capacity of ~500 M lpy
...on 3 continents

Source: Novozymes
More projects waiting for investment decisions

- Despite weak oil prices and commissioning requirements, plans are underway for more developments
- Another 20 identified outside Australia
  but Australia is about to join the list…

3 year WTI crude oil price

3 year ethanol futures price

The next wave is on the way…

…”over 20 projects await investment decisions within the next 12 months

Source: Novozymes
Australia an ideal country for biofuels – macro perspective

- While Australia is an energy exporter, it is a net importer of liquid transportation fuels
- About 60% of oil needs come from offshore and increasing
- Oil refineries and oil exploration is declining

- Australia is a world leader in growing sugar cane
- Has large areas of suitable land for energy crops
- 1st world country with advanced equity and debt markets
- Infrastructure, rule of law and low levels of corruption
Australia’s first greenfield biofuel project is being deployed

Despite low oil prices, a new greenfield project is planned

- Renewable Developments Australia – Pentland Project
- Stage 1: Based on 1st Generation technology (sugar juice)
- Stage II: Add bioethanol derived from bagasse, trash and tops
- Potential for expansion to 1 billion litres over time in an integrated facility
- 2nd Gen Technology supplied by Beta Renewables and enzymes by Novozymes
- Construction could start as soon as 2017
Implications for Australian sugar cane industry over long term

A significant opportunity to add value

- Increase the value generated per tonne of sugar cane produced
- Expand the industry beyond its current geographical spread
- Diversify revenues streams from almost exclusively sugar
US corn ethanol history highlights the Aust. opportunity

While one may argue the benefits of converting corn to ethanol…

- The industry has made major advances in efficiency over the last two decades
  - Higher yields per hectare – increasing by over 1% per year
- Resulted in a more stable supply of corn for multiple applications
- More stable demand for corn
- Is able to generate returns in the low current oil price (profitable at US$0.40/liter ethanol)
- Is diversifying the revenue and product base reducing economic risk and adding value
The evolution of corn ethanol into bio-refineries

Further improvements coming:
- Corn stover to ethanol
- Corn oil to biodiesel
- Waste streams to protein
- Increased conversion efficiency

<table>
<thead>
<tr>
<th>1990 standard corn ethanol</th>
<th>Add corn oil extraction</th>
<th>Add corn kernel cellulosic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol from corn</td>
<td>Ethanol from corn – increased conversion efficiency by 10%</td>
<td>Ethanol from corn – increased conversion efficiency by 10%</td>
</tr>
<tr>
<td>US$65M</td>
<td>US$73.5M</td>
<td>US$76.3M</td>
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<tr>
<td>DDGS co-product</td>
<td>DDGS co-product</td>
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<tr>
<td>Corn oil</td>
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<th>Typical corn operation 20 years ago</th>
<th>Most facilities now extracting corn oil</th>
<th>Some operations commencing corn cellulosics</th>
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<tbody>
<tr>
<td>Revenues up 13%</td>
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<td>Revenues up 17%</td>
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<td>US$65M</td>
<td>US$73.5M</td>
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Key assumptions: Corn = US$3.50/lb, Ethanol = US$1.52/gallon, DDGS = corn price, Corn oil = US$0.35/lb, Production capacity = 35M gallons/year
Evolution of non-food bio-refineries will also occur driven by tech

Conventional 2nd Generation Fermentation

> 35% loss

- Incomplete breakdown
- Residual sugars
- By-products (glycerol, acetate and xylitol)
- Organism growth
- Residual ethanol

Impact on yield and costs

Fuel Ethanol

Less than 65% of contained sugars in biomass converted to fuel

30%+ of sugars to low value biogas
...through more efficient conversion and multiple products

MBG
“Fuel and Feed” bio-refinery fermentation

Biomass

Pre-treatment and hydrolysis to sugars

Grow yeast on
Residual C6+C5 sugars
- Glycerol
- Acetate
- Organic acids
- Xylitol

Over 80% of contained sugars in biomass converted to fuel and feed

Low value biogas

Fermentation yeast

Product (1)
Fuel Ethanol

Product (2)
High value feed
Helping to add value well above sugar only

Value of product per tonne of Sugar Cane (dry basis)

<table>
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<tr>
<th></th>
<th>Sugar only mill</th>
<th>Current 1st and 2nd Gen bio-refinery</th>
<th>Optimised 1st and 2nd Gen bio-refinery</th>
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<tr>
<td></td>
<td>US$154</td>
<td>US$301</td>
<td>US$335</td>
<td>US$342</td>
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<tr>
<td>Sugar from cane juice</td>
<td></td>
<td>US$168</td>
<td>Feed Yeast US$27</td>
<td>Feed Yeast US$82</td>
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<tr>
<td>Ethanol from cane juice</td>
<td>US$133</td>
<td>Ethanol from bagasse, trash and tops</td>
<td>US$140</td>
<td>US$92</td>
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Key assumptions: Sugar = US$0.15/lb, Ethanol = US$0.60/liter, High Protein Yeast Feed = US$1/kg, Met Coal = US$80/tonne
Note: The lignocellulosic component includes trash and tops over an above the 1 tonne of cane
Note: Exported power is considered insignificant for this analysis.
The sugar cane industry opportunity

• Transition from single product price “taker” to multi-product diversified industry

• New bio-refineries based on 1st and 2nd generation technologies will likely have many products
  - Ethanol
  - High Value Feed
  - Sugar (depending upon design)
  - Green coal
  - Bio-chemicals

• Most products are higher value than sugar on a per kg basis
Sugar will remain important, but change is coming

- The first 2\textsuperscript{nd} generation bio-refineries are already built and being commissioned
- Plans for the first commercial plant in Australia are progressing
- Just like the corn ethanol industry in the US – technology will evolve over time
- Expect multiple “value added” products to be added over time
- Expect efficiencies and competitiveness to increase and costs decline
- The outlook for the industry is highly attractive in Australia
Questions…

Geoff Bell
Microbiogen Pty Ltd
geoff.bell@Microbiogen.com
Ph: +61 2 9418 3182