SECURING A SUSTAINABLE ETHANOL FUTURE FOR AUSTRALIA

A MARKET ANALYSIS FOR THE SUPPLY OF SECOND-GENERATION ETHANOL IN AUSTRALIA USING MICROBIOGEN'S YEAST TECHNOLOGY

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MICROBIOGEN

Australian Government
Australian Renewable Energy Agency

ARENA

Contents

Foreword

EnergyLink Services has been commissioned to write *Securing a Sustainable Ethanol Future* which follows on from an earlier 2019 report titled *A Market Analysis For Export Of Second Generation Ethanol To California, China And Southeast Asia* (also completed by EnergyLink Services). The initial report heavily focused on the ethanol export market, looking at trends within the three focus export markets, as well as any opportunities and/or barriers towards participation.

The report concluded that 'while the export market may be the most attractive option for a second-generation plant in Australia in the short term, given the declining level of indigenous oil production in Australia, along with a continuing decline in refining capacity, the most attractive market will eventually be the local Australian market itself'.

The initial report entirely focused on the trends, opportunities, and barriers towards entry on the demand side of the ethanol equation in these identified markets, in other words, there was no exploration around the conditions affecting the supply (production) of ethanol within Australia. Subsequently, *Securing a Sustainable Ethanol Future* aims to bridge that gap.

This second report follows on from the previous and provides a more holistic assessment of Australia's second-generation ethanol production capacity. It provides a series of recommendations on how the bioethanol industry can be developed and nurtured in Australia (through government assistance and incentive programs) to help the industry meet the critical mass required for self-sufficient growth. It is important to note that this will continue to become an increasingly important issue within the foreseeable future, as Australia's refinery capacity is dwindling, and the Government has implemented and is exploring a number of opportunities for improving domestic fuel security.

Executive Summary

MicroBioGen is an Australian company, that over the last three years, has directed their yeast technology towards the optimisation of biocatalysts for second-generation biofuel production. Their intention has been to increase the robustness of yeast, improve the production process, and enable yeast growth on waste streams generated through the process. After spending approximately A$8M over three years, MicroBioGen has demonstrated that their second-generation technology increases conversion efficiency and produces high-quality feed yeast as a by-product, thus resulting in an effective estimated cost reduction of 25% for second-generation ethanol.

Second-generation ethanol has the potential to decarbonise various sectors within the Australian economy, provide additional and diversified income streams to primary producers, improve fuel security and assist with animal feed self-sufficiency. MicroBioGen's second-generation yeast technology overcomes critical challenges that have inhibited the development of a second-generation ethanol industry globally, as well as fundamentally changing the economic and sustainability equations when it comes to second-generation ethanol production. The application of the optimised yeast strains developed by MicroBioGen will, for the first time, allow the efficient production of fuels and high protein feed utilising the one optimised yeast biocatalyst. Producing fuel and high-quality protein from biorefineries based on non-food biomass is a game changer. Not only does high-quality protein production improve biorefinery economics, it also enhances the social license of biofuel production by changing the community's perception of biorefineries from food consumers to food producers.

Feedstock Market

The feedstock used for ethanol production with MicroBioGen's second-generation yeast technology is known as "bagasse" – the woody, fibrous pulp that remains after processing sugarcane plants. Over the period 2004 to 2015, the annual available bagasse resource in Australia has been estimated to be 5.3 million tonnes[1]. If all this bagasse resource was used for ethanol production using MicroBioGen's second-generation technology, this could produce up to 1,663 ML of ethanol, as well as 133kt of high-protein animal feed for domestic or international markets. This would be sufficient to meet 95% of a national E10 mandate, without taking into account the production of ethanol from existing first-generation facilities, or other biomass wastes from forestry or non-bagasse crop residues. The emergence of a second-generation ethanol production industry would have significant economic benefits that would flow predominantly to regional areas. This includes delivering a diversified income stream to sugarcane farmers, helping stimulate regional economies, and providing a range of long-term employment opportunities in these areas.

Ethanol Market

The Australian ethanol market is currently dominated by first-generation ethanol technologies. The main drivers underpinning the supply of ethanol are the Queensland and New South Wales mandates for the blending of E10 fuel. However, the demand for ethanol has not been sufficient in sustaining production growth in the existing first-generation ethanol industry with expansion plans put on hold.

There currently are no commercial, second-generation ethanol facilities in Australia nor any schemes or market-based mechanisms in place to incentivise the production of second-generation ethanol within Australia. This market gap represents an unexplored opportunity from two distinct perspectives:

1. From an emissions reduction perspective.
    - Second-generation (and first-generation) ethanol has the potential to significantly reduce Australia's emissions associated with the transport sector. This includes emissions from passenger vehicles, shipping and logistics, as well as the aviation industry.
2. From a fuel security perspective.
    - Australia is heavily dependent on imported fuel products. Currently there are 4 refineries

in Australia which are largely dependent on imported crude oil for fuel production. Further, Australia does not hold sufficient reserves of transportation fuels to comply with its obligations under the International Energy Agency's 90-day stockholding obligations. This has been the subject of a number of Federal Government initiatives to help improve refinery economics and increase storage capacity.

By investing in – and developing – a domestic second-generation ethanol market, it can effectively address these market gaps and improve Australia's performance in these two key areas.

Animal Protein (Feed) Market

Australia is a net importer of animal protein (feed) for use in livestock production, despite being one of the top 30 producers of animal feed globally. The production of second-generation ethanol using MicroBioGen's yeast technology also results in the production of a high protein animal feed that has a nutrient profile (and therefore economic value) that lies between soybean meal and fish meal. Utilising all the available bagasse resources in Australia would produce 133,000 tonnes of animal feed per year, which would be enough to displace approximately 16% of total soybean meal imports. Overall, the production of second-generation ethanol and animal feed will help to improve both fuel security and food security, while providing additional revenue streams to sugarcane farmers.

In addition to increasing food security for Australia and the rest of the world, the impact of selling the high protein yeast is expected to lift revenues of a fuel and feed biorefinery by about 8% to 10% (ignoring any of the process benefits). If one ignores taxes etc. in the fuel selling price, the sale of high protein yeast increases biorefinery revenues by almost 25% per litre of ethanol. This represents a significant revenue boost and economic enhancer.

Conclusion

MicroBioGen's successful optimisation program for the production of both fuel and high-quality feed from low value biomass waste streams is a game changer for the biofuels and feed industries. This is the first biocatalyst that has been developed that is both superior in terms of biofuel production and can grow on its own waste streams to produce a high quality, high value, high protein feed.

While a game changing biocatalyst has now been developed for self-sustaining growth in the ethanol industry, specifically the second-generation ethanol industry, it will be necessary for government assistance and incentive programs to be implemented. This support should mirror the various programs and incentives, both on the supply and demand side, that were used to successfully create a mature domestic solar PV and wind industry. There are several options available to both State Governments and the Federal Government for how this may be achieved, including:

- Expanding ethanol mandates into other state jurisdictions or setting a national mandate.
    - This would create a long-term source of demand for ethanol that can be used as a basis for investing in ethanol production facilities.
    - This would also help mitigate fuel security risks currently faced by Australia.
- Implementation of a Low Carbon Fuel Standard.
    - Valuing the lower carbon intensity of fuels and fuels produced from waste products, such as sugar cane bagasse, helps to incentivise ethanol production in the least carbon intensive manner, such as using feedstocks currently considered as waste products while also recognising the additional carbon benefits associated with using a waste product as a feedstock (second-generation ethanol production).
- Leverage the Future Fuels Fund administered by ARENA to help facilitate greater uptake of ethanol-based fuel or products such as sustainable aviation fuels.
- Incorporating biofuels into Government procurement and operational requirements.
    - This includes the integration of biofuels into military procurement requirements.
- Using ethanol as an octane enhancer rather than fossil fuel-based octane enhancers.
- Improving and expanding the available Emissions Reduction Fund methodologies to encourage

greater participation, resulting in the monetisation of carbon benefits associated with biofuel usage.

Successfully developing a biofuels industry with full stakeholder and Government support will require not only the efficient production of biofuels, but a social license to operate as well. Producing high quality protein as well as fuels enhances the perception of biofuels from food consumers to biorefineries that add to the global food supply. This game changing technology has been developed right here in Australia and is poised to not only enhance the prospects of biofuels in Australia but will be exported around the world.

Introduction to MBG

Background

MicroBioGen (MBG) is an Australian company that has been heavily involved in research and development of superior yeast for improving the fermentation process of converting sugars to ethanol since 2001. Throughout their research and development (R&D), they have optimised the yeast used in first-generation (1G) ethanol to produce a 2.5%+ improvement in yield, as well as being able to withstand harsher operating conditions. This same technology and genetics is now being utilised to optimise second-generation (2G) biofuel production, with the intention of increasing the robustness of the yeast strain, improving the production process, and enabling the production of high quality protein from waste streams – all utilizing the one micro-organism. The result will be a yeast strain process that will efficiently convert non-food biomass into fuel ethanol as well as high value animal feed.

Since 2006, MBG's research has been supported by three Federal Government grant schemes, all of which have been integral in taking MBG's 2G technology from the R&D phase to near commercialisation. In 2019, MBG won the Australian Export Awards for their work in 1G biofuel technology (a by-product of 2G work) and continue to apply the Gen 2 technology and genetic tools towards their work in optimising 2G ethanol production.

1. From 2007 to 2011, the Renewable Energy Development Initiative (REDI) Program contributed $2.48 million towards a $5 million project that demonstrated MBG's yeast technology at the laboratory scale.
2. From 2010 to 2013, the Gen II Biofuels Program contributed $4.8 million in collaboration with the US National Renewable Energy Laboratories (NREL) to assist MBG in proving the feasibility of a new model for a "fuel and feed" bio-refinery through a larger pilot project.
3. Since 2017, ARENA's Advancing Renewable Grant has contributed $2.7 million (and will provide $4.03 million over the 3.5-year project life) to an $8 million project that will optimise MBG's 2G yeast technology and deliver a commercial strain for global deployment.

MBG estimates that their 2G technology could increase conversion efficiency, produce additional high-quality feed, and reduce the quantity of yeast requirements for a combined cost reduction of 25% for 2G ethanol. It will also solve a number of production process issues, such as fermentation inhibition due to acetic acid production that has previously impeded the full capacity and efficiency of commercial scale 2G ethanol production.

Process Overview

Ethanol is a type of alcohol typically produced from biomass through the fermentation of sugars[2]. It is commonly used in the production of potable alcohol (i.e., consumable by humans), for industrial production purposes, the manufacturing of pharmaceutical and cosmetic products, as well as blending with, or in the case of Brazil, full replacement of fossil fuels in many ICE power motor vehicles. The blending of ethanol has been largely due to its effectiveness in simultaneously improving octane ratings, whilst also decreasing the emissions associated with combustion.

Traditionally, in 2G ethanol production, the biomass is pre-treated and undergoes hydrolysis to separate it into C5 and C6 sugars, which are then fermented using yeast and distilled to produce ethanol plus a lignin by-product. MBG's yeast technology is applied during the primary fermentation stage with bagasse as the feedstock of choice. Bagasse is a lignocellulosic material consisting of the biopolymers cellulose, hemi-cellulose and lignin. MBG's yeast has the ability to convert C6 and C5 sugar monomers into ethanol under difficult 2G conditions. The first major advantage of the MicroBioGen yeast is the near complete utilisation of C6 and C5 sugars at higher solids loadings resulting in higher ethanol titres, leading to an improved production process. Improved production includes higher ethanol yields, shorter fermentation times, lower distillation costs through higher ethanol titres and lower capital costs.

The second major benefit of the MicroBioGen yeast is that it can efficiently convert sugars to ethanol (under anaerobic conditions), and when air is added to the fermentation waste stream (containing glycerol, organic acids and residual sugars), the MicroBioGen yeast can also grow on all these carbon sources converting very low value wastes into high protein, high value animal feed.

The final benefit of the MicroBioGen yeast is that, unlike other biochemical processes where the yeast required for primary fermentations must be cultured on C6 sugars (which could otherwise be converted to ethanol), the MicroBioGen yeast that have grown in the waste streams can again be used for the following primary fermentation, leading to an even greater ethanol yield.

Based on MBG's work (and assuming that 90% of the polymers are broken down through the hydrolysis stage), 1 tonne of dry bagasse converted using MBG's optimised biocatalyst technology is able to produce:

- 312 litres of ethanol
- 25 kg of high-protein feed
- 312kg of lignin and ash
    - The lignin can be burned to produce energy to run the entire lignocellulosic process.

Feedstock Market

Main Feedstocks for Ethanol Production Currently Used in Australia

Feedstock is used to describe the organic raw material that is treated and subsequently converted to ethanol via a biochemical pathway. Ethanol produced for commercial and industrial uses at Australia's major refineries is 1G ethanol, with wheat starch, sugarcane (molasses) and sorghum being the predominant feedstocks for the production process.

The largest ethanol producer in Australia is Manildra Group[3], with their ethanol refinery located in Nowra, NSW. The facility uses wheat starches and other wheat processing by-products as their principal feedstock for ethanol production[4]. Australia produced 17,597,561 tonnes of wheat for grain in FY2018-19[5], meaning there is plentiful feedstock available for their ethanol production process.

Australia's wheat resources are predominantly located in the wheat belt, which spans across eastern South Australia (SA), Victoria (VIC), New South Wales (NSW), lower Queensland (QLD) and south-west Western Australia (WA). Around 65-75% of this wheat is exported, predominantly to Asian countries, who use it for the manufacturing of their breads and noodles[6].

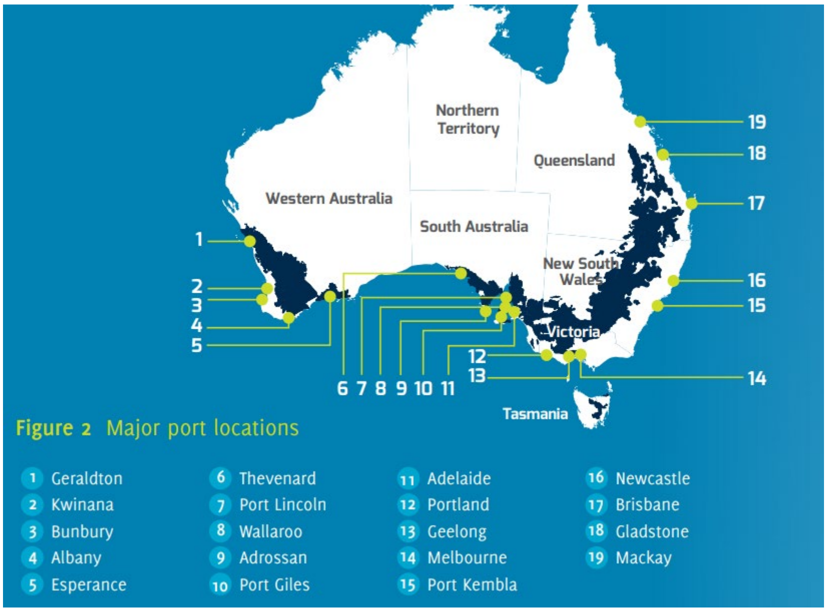

Figure 1: Major Port Locations (from AEGIC Australian Wheat report 2018[7])

Wilmar Sugar Australia is the second-largest ethanol producer in Australia using molasses (a by-product of sugar-processing) as their feedstock for ethanol production. In 2019-20, Australia harvested 30.04 million tonnes of sugarcane[8] from approximately 370,000 hectares of land, the majority of which was used to produce raw sugar for export[9] to Asia. Four million tonnes of raw sugar is produced annually at 24 sugar mills[10] operated by 9 companies[11], 80-85% of which is exported, making Australia the 2nd largest sugar exporter globally[12]. Sugarcane is grown along a 2,100km stretch across Australia's east coast, with 95% of this being in QLD and the remainder extending into northern NSW[13].

Wilmar Sugar Australia produces around 500,000 tonnes of molasses per year, of which 235,000 tonnes is fermented to produce about 60 million litres[14] of ethanol and agricultural products, while the remainder is sold to the livestock industry or exported due to storage constraints[15].

Sugarcane is the predominant feedstock proposed for new ethanol production facilities. This is because there are vast areas of land (almost 7 million ha[16]) on which sugarcane could be grown in QLD. Even if the entirety of this is not currently being used, it will not be economic to dramatically increase production purely for sugar production. However, currently there is minimal value ascribed to 'waste products' of sugarcane farming, such as bagasse, where 2G ethanol production technology has the potential to create significant value from these waste resources.

Australia's third key feedstock for ethanol production is sorghum, which is used at the Dalby refinery operated by United Petroleum. In 2018-19, Australia produced 1.16 million tonnes of grain sorghum, which decreased to an estimated 0.298 million tonnes in 2019-20 but is forecast to rise to 1.728 million tonnes in 2020-21[17] due to the expected favourable spring/summer conditions[18]. The majority of sorghum is produced in QLD, with the remainder produced in NSW.

Second-Generation Ethanol Feedstock in Australia

2G ethanol is produced using lower value lignocellulosic materials from forestry, agricultural residues, or dedicated energy crops as the feedstock[19]. Currently, there are no 2G commercial ethanol plants operating in Australia as the process is significantly more complex and historically it has not been economically viable at a commercial scale. However, there are a number of potential feedstocks that can be used for 2G ethanol production, including the focus of this study; bagasse.

Bagasse Resource Availability

Bagasse is the fibrous residue that remains after the sugar juice is extracted from crushed sugarcane stalks. Currently, bagasse is either burnt on site at sugar mills to create electricity and steam to power the sugar making process, or it is left in the sugar fields[20]. Importantly, bagasse is also used for other purposes globally, including as animal feed, for paper production and for particle and fibre board production. Traditionally, the processing of sugarcane into energy has been relatively inefficient at making use of the high volumes of bagasse that remains after extracting the sugar juices. Recently, as the sugar making industry progresses and higher efficiencies are reached, sugar mills are becoming more proficient at extracting energy from excess bagasse[21] while simultaneously lowering their processing costs.

In the absence of 2G refineries in Australia, bagasse is not currently used for the local production of ethanol. Considering the large amounts of bagasse being produced, predominantly along the QLD coast (as mapped in Figure 3) with good access to transportation infrastructure and population centres[22], it is not surprising that bagasse is starting to attract attention as a potentially abundant, widely available resource for ethanol production. There is a significant opportunity for ethanol distilleries to be co-located with existing and/or proposed sugar mills to maximise mill efficiency, reduce feedstock and transportation costs, and extract greater value from bagasse.

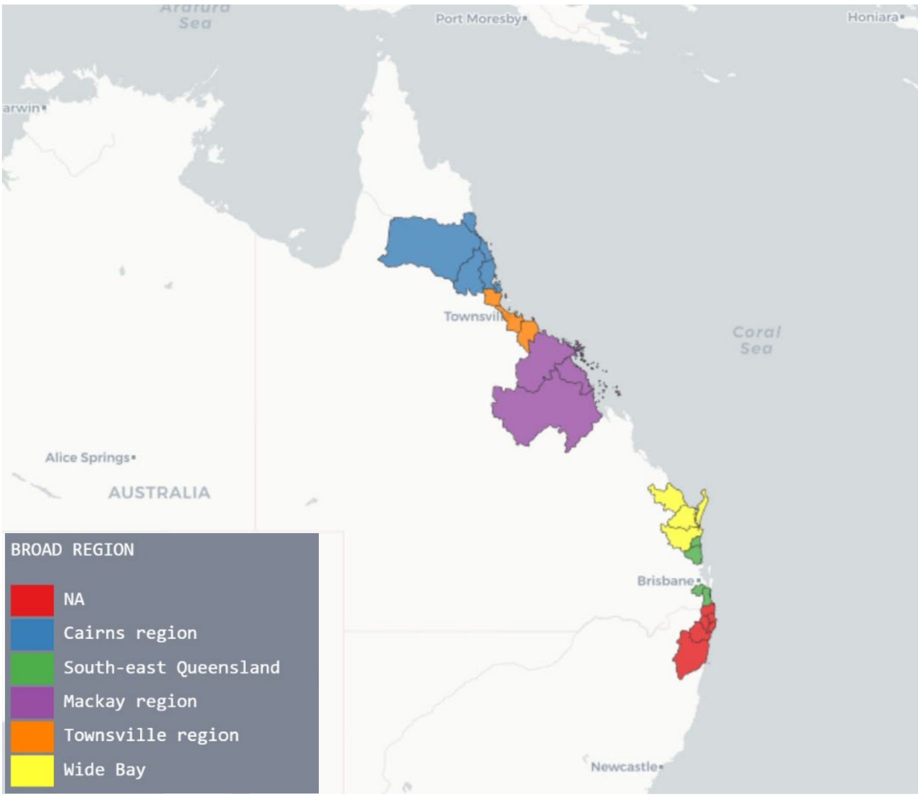

Figure 2: Available bagasse resource Australia[23]

Total Australian Bagasse Resource

Over the period 2004 to 2015, the annual available bagasse resource has been estimated to be 5.3 million tonnes[24]. If all this bagasse resource was used for ethanol production using MBG's 2G technology, this could produce up to 1,663 ML of ethanol and 133kt of high-protein animal feed for domestic or international markets.

Resource Availability Trends

As bagasse is the dry mass waste by-product of sugarcane processing, the production of bagasse in Australia is directly correlated to Australia's sugarcane resources. Sugar is Australia's second largest crop export after wheat. It has a generating revenue of almost $2 billion per annum[25] and is a readily available resource within Australia, having harvested 30.04 million tonnes of sugarcane[26] in 2019-20 (down from preceding years[27]).

Over half (16.43 million tonnes) of Australia's sugarcane production in 2019-20 was produced across five regions in QLD. These regions were also the largest producers in previous data publications from the Australian Bureau of Statistics and are detailed below in Table 1.

Table 1: Largest sugarcane producers by region[28]

Region	Production 2019/20 (tonnes)
Burdekin	7,013,900
Ingham Region	3,602,200
Tully	2,183,400
Walkerston-Eton	2,157,800
Pioneer Valley	1,473,500

Australia has 24 sugar mills operated by 9 companies. Wilmar Sugar Australia is the largest of these, operating 8 mills across QLD, one sugar refinery and a bioethanol distillery at Sarina[29].

Asian countries, including South Korea, Indonesia, Japan, and Malaysia, are Australia's key export markets and are expected to drive the demand for raw sugar from Australia into the future. They currently are the recipients of the majority of Australia's raw sugar production[30].

Globally, sugar production and consumption over the last five years has remained relatively steady.

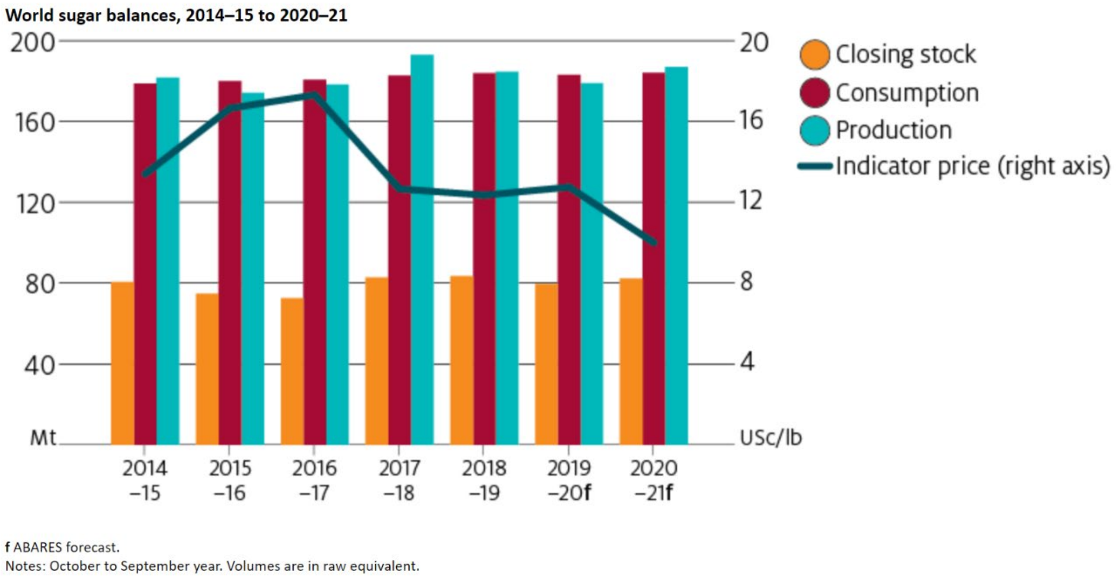

Figure 3: World sugar balances, 2014-15 to 2020-21[31].

Up until recently, the price of sugar had declined due to a number of factors on the demand and supply side. On the sugar demand side, the effects of the COVID-19 pandemic have resulted in the demand for sugar products contracting due to a decreased consumption of food and beverage products by the hospitality industry[32]. On the supply side, exporting nations such as Thailand and India have returned to above average production seasons after a previous poor production season in 2019. It can also be noted that exports have also fallen due to COVID-19 pandemic related shutdowns. There has also been an increase in Brazilian sugar production in response to falling crude oil prices. As demand for fuel ethanol is inherently linked to the price of crude oil, falling oil prices make ethanol less competitive, and as a result production is diverted from ethanol to sugar. Note: At the time of writing this Market Analysis the price of sugar had recovered to a three-year high.

In Australia, rainfall in late summer/autumn saw good crop yields for sugarcane farmers, and there were no significant disruptions to operation[33]. However, overall, the per unit price of sugar has been trending downward since 2016-17 (Figure 4). By unlocking additional revenue streams for sugar producers through MBG's 2G technology, there is opportunity to counteract the falling sugar price and hedge exposure to fluctuations in the sugar market.

Sustainability of Long-Term Supply

Australia has, and continues to produce, significant quantities of sugarcane. As a result, it is likely that sugarcane and bagasse availability, under a business-as-usual scenario, will remain high. However, there are several factors that will affect the ongoing viability of sugarcane farming, and subsequently bagasse availability. Such factors include, but are not limited to:

- Biosecurity concerns;
- Prevailing sugar market pricing (discussed above); and
- Domestic electricity market trends.

If plants utilising MBG's 2G technology become commonplace in the domestic market, and bagasse becomes a more valuable resource, it is unlikely that the supply of bagasse (or lack thereof) will constrain the growth of 2G production facilities.

There are however some complications in obtaining bagasse feedstock in an Australian context, as the sugarcane processing facilities, as opposed to the individual sugarcane farmers, often own the bagasse. While this is not always the case, it does reduce the number of potential suppliers of bagasse (and therefore reduces any competitive tensions). However, this is countered by the fact that much of the bagasse has already been collected (generally for use in co-generation i.e., electricity and heat production engines), indicating there are unlikely to be additional costs associated with feedstock collection. It also highlights the advantage of co-locating a bioethanol refinery close to an existing sugar mill.

Biosecurity Concerns

There are a number of exotic diseases and pests that are not yet found throughout Australian sugarcane regions[34]. It is important to note that the widespread incursion of a biosecurity hazard may have significant, negative consequences for production volumes in Australia, and jeopardise the availability of bagasse supply in Australia.

Domestic Electricity Market Trends

Currently the primary use for bagasse is to produce electricity through combustion. In 2015, Australia had a combined electricity generation potential from bagasse of 593MW[35]. Higher electricity pricing will incentivise electricity production from bagasse and divert resources away from other uses, such as 2G ethanol production.

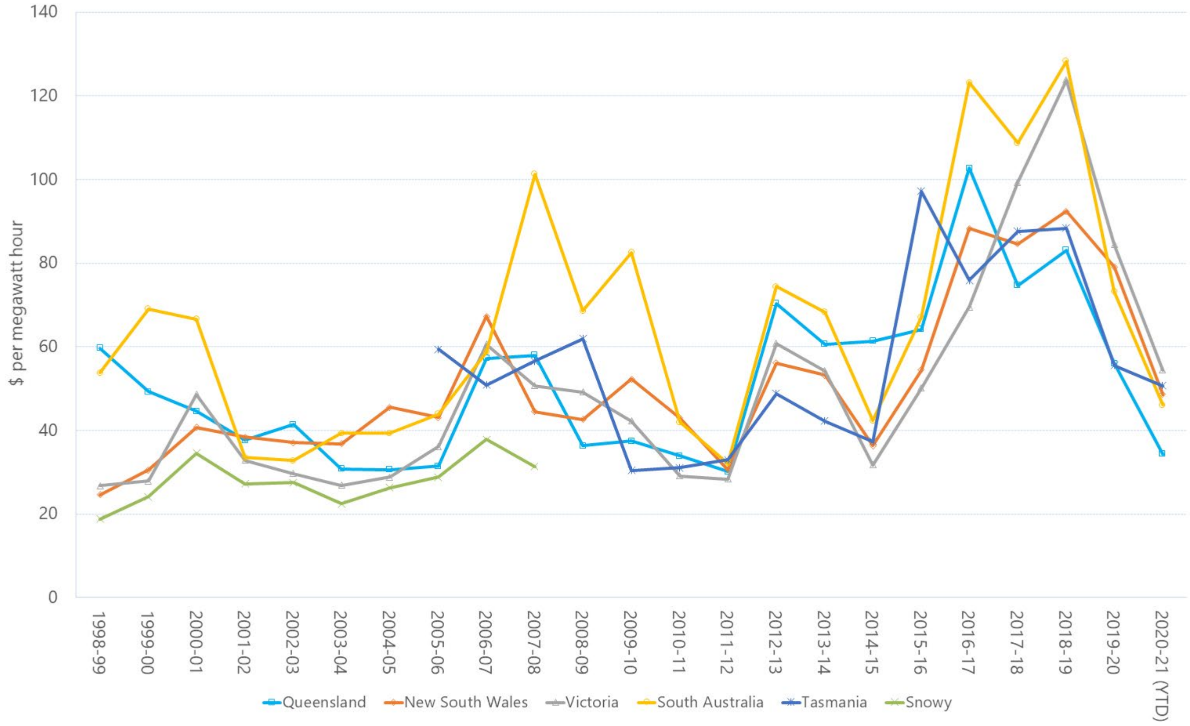

Figure 4: Average NEM Electricity Prices[36]

Figure 5 shows that electricity prices have fallen from the highs between 2016 to 2019 in the above states. Long term low electricity prices will help ensure high availability of bagasse for higher value add processes, such as 2G ethanol production, rather than combustion for electricity production. Energy production can also be supplemented through use of the lignin by-product from 2G ethanol production, which helps to alleviate the impact of diverting bagasse from electricity generation.

Australia's Ethanol Market

Existing Market Overview

Australia predominantly produces energy from black coal, with renewables accounting for only 2% of energy production in 2018-19[37]. The majority of Australia's energy production is exported, with 70% being black coal[38]. Oil (including crude oil), liquefied petroleum gas (LPG) and refined products accounted for 39% of energy consumption in 2018-19, signifying the greatest share of Australia's energy consumption[39]. The majority of oil-based energy sources come via imports.

The International Energy Agency (IEA) predicts that global biofuel production will increase 25% over the next 5 years[40], even with electrification and transport efficiency gains. The main drivers for this are emission reductions, particularly across the transport sector, as well as energy security concerns. In 2018, renewable fuels met approximately 2.7% of transport fuel demand globally, with biofuels being 93% of this and the rest being supplied by renewable electricity[41].

In Australia, biofuels (biodiesel and ethanol) currently hold little market share due to the barriers they face around commercialisation[42]. Biofuel production peaked in 2014[43], coinciding with the end of the Federal Government's Ethanol Production Grants Scheme and Cleaner Fuels Grant Scheme[44]. Biofuels accounted for only 1.9% of energy use 2018-19, representing 3.2% annual growth in biofuel consumption from 2017-18, but also a 3.2% decrease in consumption over 10 years[45]. The majority of this energy was provided in the form of ethanol (1.5%), with no biodiesel and only a small proportion of other liquid biofuels consumed.

Ethanol consumption in Australia is mostly supplied by domestic producers, as imports are generally uncompetitive due to Australia's 5% ethanol import tariff and $A 0.401 per litre[46] customs tax.

Biofuels are likely to become significant contributors in the heavy freight, shipping, and aviation sectors, while electric solutions are more likely to dominate the passenger, light commercial and rail sectors in the long term.

Current Ethanol Production in Australia

Approximately 250 ML of ethanol was produced in Australia in 2019[47]. This equates to only 0.04% of the quantity produced by the world's largest ethanol producer, the United States, who produced approximately 60,000 ML in 2019[48].

Manildra Group (Australia's largest producer of ethanol) produces a range of ethanol grades for not only the transport sector but also for food and beverage, pharmaceuticals, and industrial applications[49]. Manildra Group use 1G production processes, taking wheat starch and producing a range of food and industrial grade starches, glucose syrups and ethanol products, with the waste converted to stockfeed for animals[50].

The two other major producers are Wilmar Sugar Australia, who produce ethanol from sugarcane at their Sarina Distillery in QLD, and United Petroleum, whose BioRefinery in Dalby, QLD, uses sorghum as the feed. Sarina Distillery's annual ethanol output is approximately 60 million litres[51], of which approximately two thirds was sold to the Australian market for use in ethanol blended fuels[52]. The Dalby facility, however, was shutdown indefinitely in late 2020, and both facilities were 1G production plants. It is clear that ethanol supply is not constrained due to idle production capacity, rather that demand is currently insufficient to warrant the operation of existing bioethanol production facilities, or construction of new bioethanol production facilities.

There are also a number of proposed 1G biofuel facilities in Australia, predominantly located in QLD due to their proximity to sugarcane crops[53]. However, limited domestic demand and a lack of supply contracts has constrained their development. It is unlikely that further growth in ethanol production, both

1G and 2G, will occur without additional government policy support to help drive the uptake of ethanol demand in Australia.

Second-Generation Ethanol

Overview of Second-Generation Technology

First-generation (1G) ethanol production is the process by which simple sugars, such as commercially grown crops, are converted into ethanol. This can be summarised into 3 broad steps:

1. Crops (typically corn or wheat) are collected and pre-treated.
2. Enzymes are introduced to break down the crops into monomeric sugars like glucose.
3. Yeast biocatalysts convert the simple sugars into ethanol through a fermentation process.

Second-Generation Ethanol

Second-generation (2G) ethanol can be produced through either a biochemical process or a thermochemical process. This report focuses on the biochemical pathway. The biochemical process involves a pre-treatment process to break down biomass and subsequent enzymatic hydrolysis to component sugars. An organism, in this instance MBG's yeast biocatalyst, is then used to convert these sugars into bioethanol.

The key difference between 1G and 2G ethanol is that 2G ethanol can be made from biomass that does not have readily available glucose, such as the bagasse of sugarcane and corn stover (i.e., the stalks of the corn plant). In 2G ethanol, the biomass is pre-treated releasing most of the C5 sugars before the cellulose is enzymatically hydrolyzed into C6 sugars (glucose primarily). The liberated glucose and other sugars derived from the biomass are then converted into ethanol. The biomass in these crops is often considered low value material and is either left on the fields or combusted to produce electricity or heat. The upgrading of this lignocellulosic material to much higher value, high octane fuel ethanol is why the process can add substantial value to the farmer and processor.

This process is, at a high level, illustrated below in Figure 5.

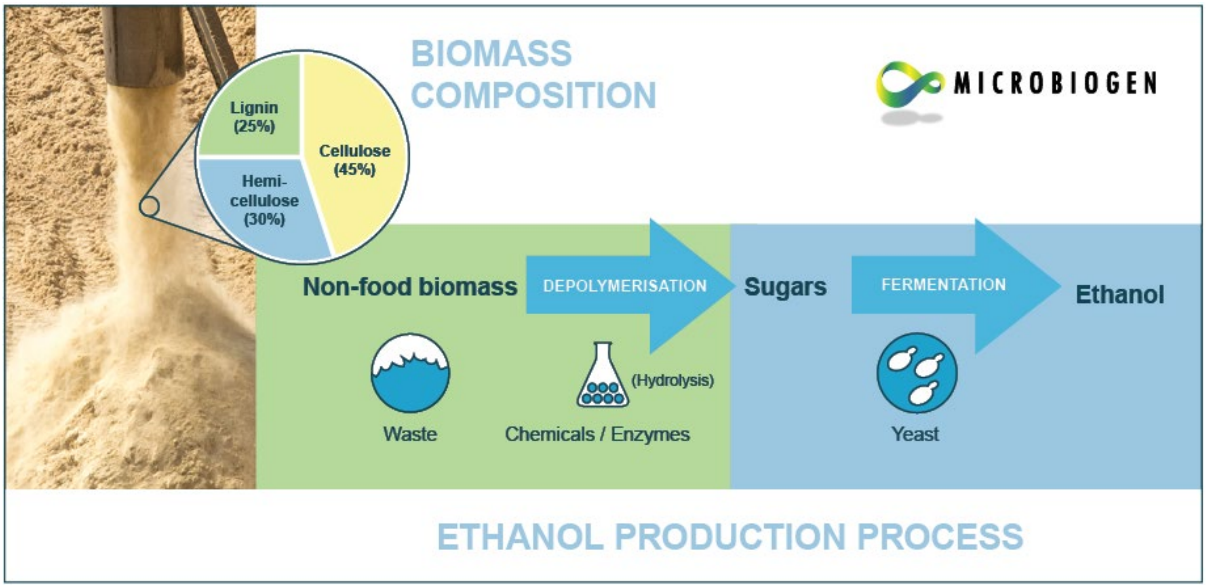

Figure 5: Biomass composition and basic process flow for production of ethanol [54]

Benefits of Second-Generation Ethanol

2G ethanol has key advantages over 1G ethanol production, which include:

- Lower cost and competition for feedstock.
- Production of high value by-products such as lignin.
- Politically less challenging to use as a waste product for energy production.
- Expansion of resources available without increasing feedstock production footprint.
- Greater reduction in life cycle production of CO_2.
- Much greater volume of non-food biomass available relative to current starch or sugar cane juice.

Conversely there are also several additional challenges that are faced in 2G ethanol production that do not exist in 1G production. These include:

- Production processes that are more complex than first-generation ethanol[55].
- Higher capital costs (and financing costs) of production facilities[56].
- Acetic acid released from the hemi-cellulose (which inhibits fermentation by yeast).
- Inhibitors generated through the pre-treatment phase – particularly if dilute acid is utilised.
- Recalcitrant nature of feedstock, meaning it is difficult to break it down into monomers.
- Production of low value glycerol, organic acids and residual sugars as an end-of-process by-product.

MBG's yeast technology is the first to be able to solve these problems, especially the struggle for efficient fermentations in the inhibitory sugar streams generated in 2G ethanol production facilities. MBG's technology is advantageous as it produces not only a high value, high protein yeast by-product, but does not impact the ability to utilise lignin. Lignin can be used to meet the energy needs of the biorefinery, and as either a metallurgical coal substitute, or as a building block for aviation fuel. Further information on this is provided in the *Ethanol as a Building Block* section of this report.

Opportunity to address fuel security concerns

In December 2018, the Australian Government published a report that described the number of days of fuel consumption in storage for Australia (Table 2). The results show that Australia has limited fuel reserves, which means that in the event of a supply shock and/or supply chain disruption, we do not meet our obligation under the IEA's 90-day stockholding obligations[57].

Table 2: Australian Fuel Security - Consumption Days [58]

	Petrol	Diesel	Jet Fuel	Crude Oil
Consumption Days	18	22	23	24
IEA Days	53			

In response to these findings, several initiatives have been announced to increase the number of consumption days of fuel storage held in Australia. These initiatives include[59]:

- Investing $200 million in building new diesel storage capacity in Australia through a competitive grants program, which is estimated to result in 780 ML of additional storage capacity.
- Creating a minimum stockholding obligation for key transportation fuels.
- Developing a long-term income stream to refineries that value their contribution to national security and sovereign capability.
- Modernising Australia's current suite of liquid fuel legislation to support a more effective government response in the event of market disruptions.

This has recently been supplemented by the announcement of production payments (on a c/L basis) from the Australian Government to fuel refineries in Australia to alleviate financial pressures resulting from the COVID-19 pandemic, as well as encourage the continued production of fuel products in Australia.

The first six months of these payments is expected to equate to $83.5 million[60].

These fuel security initiatives however did not recognise the role of, or provide any additional incentives for, biofuels within Australia. This was a missed opportunity. Biofuels can play a significant role in helping improve Australia's fuel security, as the entire production process and all inputs occur domestically. Government initiatives, such as the expansion of NSW and QLD mandates to other jurisdictions, can also be used to increase uptake of ethanol in the transport sector throughout Australia. This reduces the demand for petrol as well as increases the fuel reserve measured in consumption days without the need for additional storage volumes or refinery subsidies.

Similarly, Australia can also boost its reserves of jet fuel by producing sustainable aviation fuel (SAF) from bioethanol. A 2011 study by CSRIO – supported by the aviation industry – found a biofuel industry is feasible within Australia over the next 20 years, which could generate more than 12,000 jobs, leverage private investment, and act as a vital stimulus to rural and regional economies[61]. Importantly, this would reduce Australia's reliance on imported jet fuel. Currently there are only 4 refineries in Australia that account for 40% of Australia's domestic jet fuel[62], and with an increasing demand for jet fuel projected due to tourism sector growth as the effects of COVID-19 diminish, our reliance on imported jet fuel is expected to increase.

Future Market Developments

Policy Directives

Renewable energy support and development in Australia has primarily been focused on the decarbonisation of the electricity sector, with transport fuels only drawing attention over the last few years[63].

On a federal level, in the early 2000s, the Howard Government's energy policy white paper did not support a mandate for alternative fuels, as the capacity for domestic production was not strong enough. It did however encourage the use of domestically produced ethanol, with a target production of 350 ML of biofuels (ethanol and biodiesel) by 2010[64]. Since then, there has been little Federal Government support for industry growth. In addition to this, in the 2014-2015 budget, the Ethanol Production Grants Scheme and Cleaner Fuels Grant Scheme were also removed[65]. However, federal agencies such as ARENA and the Clean Energy Finance Corporation (CEFC) have been continuously supportive of bioenergy projects.

On a State level, in 2007, the NSW Government passed laws to mandate the sale of ethanol and biodiesel blended fuels by the State's larger fuel retailers. This required fuel retailers to sell 6% of ethanol as a proportion of all their petrol sales. However, in reality, this required 60% of customers to purchase E10 (a blend of 10% ethanol and 90% unleaded petrol fuel) by 2012. This target was not reached, with E10 sales only amounting to 37% in 2013, then dropping to 31% in 2015.

This NSW mandate remains under the *Biofuels Act 2017*, with the administration and enforcement enacted through NSW Fair Trading. However, it includes new provisions around the marketing of E10, as well as increasing the number of E10 nozzles in comparison to other petrol offerings. Subsequently, E10 has become more widely available in NSW since the ethanol mandate was amended in January 2017. However, in 2018, E10 sales only accounted for 24% of all petrol sales. As a result, the percentage of ethanol sales represented 2.4% of total sales, which remains well below the mandated volume of 6%[66].

In QLD, a biofuels mandate commenced on 1 January 2017, which consisted of a separate bio-based petrol and bio-based diesel mandate. The bio-based petrol mandate requires fuel retailers to sell 4% of ethanol as a proportion of the total volume of regular unleaded and ethanol-blended fuel sales[67]. The introduction of this mandate has increased sales, with the percentage of ethanol sales increasing from 1.5% in the first quarter of 2016, to 2.1% in the first quarter of 2017, then peaking at 3.0% in the final quarter of 2019. However, this remains below the mandate of 4%[68].

In 2019, Federal Minister for Energy and Emissions Reduction Angus Taylor announced plans to develop a national Bioenergy Roadmap as a guide to identify the role of bioenergy in Australia's energy transition[69], which is due for release shortly. It is likely that this will be used to guide bioenergy policy at a national level moving forward.

National E10 Mandate

Only 1% of Australia's total transport fuel consumption in 2018 was supplied by ethanol fuels, with E10 consumption making up a slightly higher proportion in states with legislative mandates (i.e., NSW and QLD).

A future national E10 mandate has several positives outcomes for Australia, including:

- Increased domestic fuel security and sovereign capability, which is a recently heightened issue that needs addressing due to disruptions in the supply chains caused by the COVID-19 pandemic.
- Decreased reliance on oil imports.
- Regional development.
- Positive environmental outcomes due to the lower environmental footprint resulting from the use of ethanol blended fuels.

As a point of comparison, Australia consumed 17,570.4ML[70] of automotive gasoline. Therefore, to meet a national E10 mandate, 1,757.04 ML of ethanol would need to be produced in Australia. If MBG's 2G technology was the only method used to produce the ethanol required to meet this target, then 5.6 million tonnes of bagasse would also be needed. From this, 140 kt of high protein feed would also be produced, which adds as an additional value stream for producers when implemented at a mandate at a national level. The currently annual available bagasse resource has been estimated at 5.3 million tonnes, which means that MBG's technology could process all current bagasse resources into ethanol and meet 95% of Australia's E10 requirements.

Ethanol as a Building Block

While there are significant opportunities to use ethanol as a fuel blend or substitute, it can also be used as a building block for other products, such as:

- Low sulphur marine fuel;
- Aviation fuel;
- Heavy vehicle high octane fuel;
- Ethylene; and
- Butadiene.

These other products present significant opportunities in the current Australian market where there are limited opportunities for fuel ethanol growth without additional government intervention. These areas also represent 'hard to abate' areas where there are no readily available alternatives. The production of these products from 2G ethanol helps to improve productivity by utilising waste products and may provide greater environmental outcomes relative to 1G ethanol.

Lignin, which represents approximately 220kg/tonne of bagasse processed using MBG's yeast, can be blended with ethanol to produce a low sulphur marine fuel. Mixing lignin and ethanol to produce fuel is currently being explored by Maesk, Wallenius Wilhelmsen and Copenhagen University[71]. Global shipping emissions represent 2%-3% of total global emissions[72] and the International Maritime Organisation (IMO) has set a goal of reducing annual shipping emissions by at least 50% by 2050 (compared to a 2008 baseline year)[73]. The drop in biofuels, such as an ethanol and lignin blend, can assist in meeting these emissions reduction goals.

Ethanol can also be converted from an alcohol to a jet fuel to facilitate emissions reductions in air transport. The upgrading of ethanol to jet fuel is already a commercialised technology, with airlines such as All Nippon Airways (ANA) signing offtake agreements to purchase sustainable aviation fuel (SAF) that had been produced from ethanol[74] and the emergence of commercial scale alcohol to jet fuel production facilities such as the 30,000 tonnes p.a. SkyNRG facility[75] . This is also supported by the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) implemented by the International Civil Aviation Organisation (ICAO). CORSIA sets out carbon offsetting requirements for the aviation industry.

Ultimately, there is a growing and emerging market for products that can decarbonise supply chains and reduce embodied emissions of products. Ethanol is well placed to play an integral role throughout the supply chain for these products. This is especially relevant in fields where there are no currently viable alternatives to liquid fuels (such as aviation and shipping) due to weight/energy density requirements, and the cost of constructing additional infrastructure for the fuel sources (i.e., biofuel equivalents) can be avoided as biofuels can be 'dropped in' to the existing supply chain.

Animal Protein (Feed) Market Overview

Australia's Animal Feed Market

Australia is one of the top 30 feed producers globally, with production of feed relative to other Asian nations shown below in Figure 6.

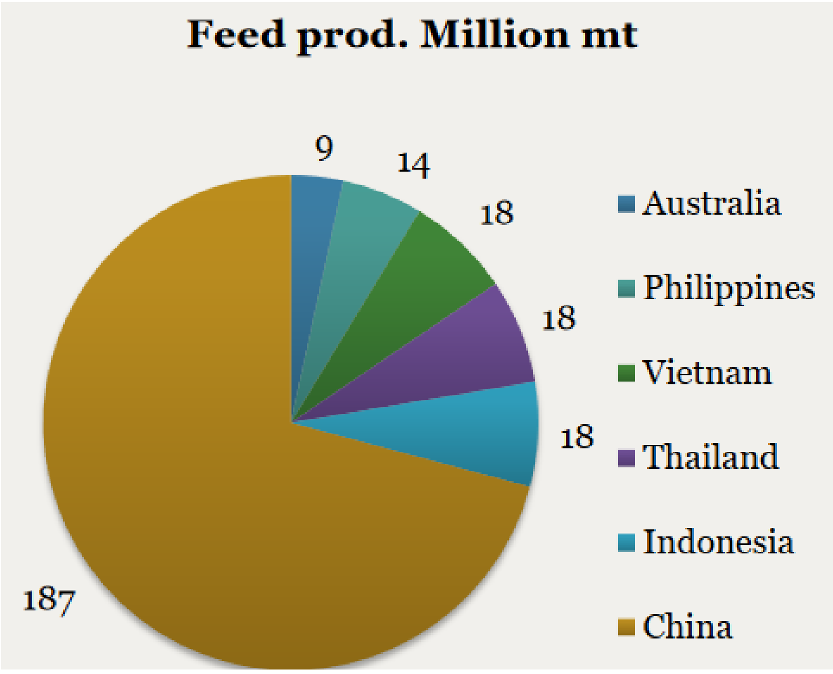

Figure 6: 2017 feed production[76]

From Figure 6, it can be seen that Australia's feed *production* was approximately 9 million tonnes in 2017, compared to a feed *consumption* of approximately 13.5 million tonnes in 2017-18[77]. This indicates that Australia is a net importer of feed, with approximately 35% of the total feed consumption supplied by imports from other countries. This proportion is likely to have increased during recent drought years where domestic production would have decreased (noting that domestic demand for feed would have also fallen with lower animal headcount on farms).

Role of MBG's Yeast

Under the scenario outlined earlier in this report, where all available bagasse is used for 2G ethanol production using MBG's technology, an additional 133,000 tonnes of feed in the form of yeast biomass would be produced. This quantity can be compared to the amount of imported soybean meal, a substitutable animal feed, shown in Figure 7.

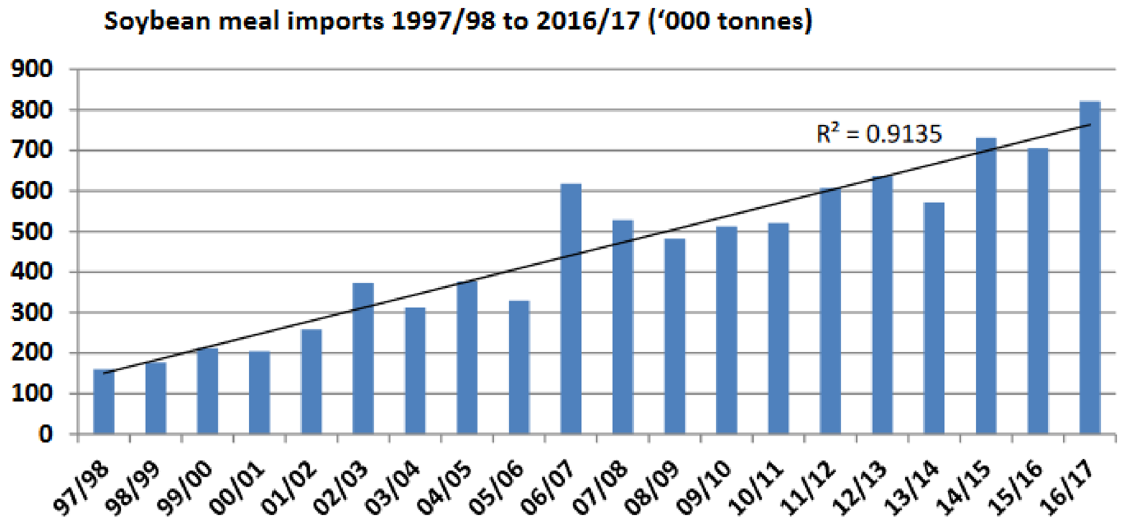

Figure 7: Soybean meal imports[78]

Figure 7 shows that soybean meal imports amounted to approximately 800,000 tonnes in 2016-17, and there is the opportunity to displace approximately 16% of these imports with MBG yeast biomass produced on bagasse. The nutritional content of the yeast produced has a similar amino acid breakdown to soymeal along with a higher protein, energy and phosphate density as shown in Figure 8.

	MBG3248	Soymeal *
Moisture (%)	5.3	5.4
Ash (%)	7.9	5.2
Crude Protein (%)	50.4	43.6
Energy (MJ/kg)	10.47	9.37
Phosphorous (g/kg)	16.7	6.6
Amino Acids (mg/100mg)		
Methionine	0.78	0.65
Isoleucine	2.29	2.39
Histidine	1.36	1.10
Lysine	2.97	2.93
Tryptophan	0.61	0.67
Arginine	2.50	3.28

Figure 8: MBG yeast analysis compared against soybean meal, data provided by MBG

Value of the Protein By-product

Yeast animal feeds have been shown to have similar benefits to animal-based nutritional supplements, such as increased efficiency of production due to the higher nutritional value as well as immunological benefits in developing animals gut health for stocks such as fish, pigs, and poultry[79,80,81].

Figure 9 is an updated version of a figure from a previous report completed by EnergyLink Services titled

Market assessment of potential value of dry yeast biomass including characterisation of dry yeast biomass product, which shows the estimated price range of the yeast to be between $800-$1,000 US per tonne.

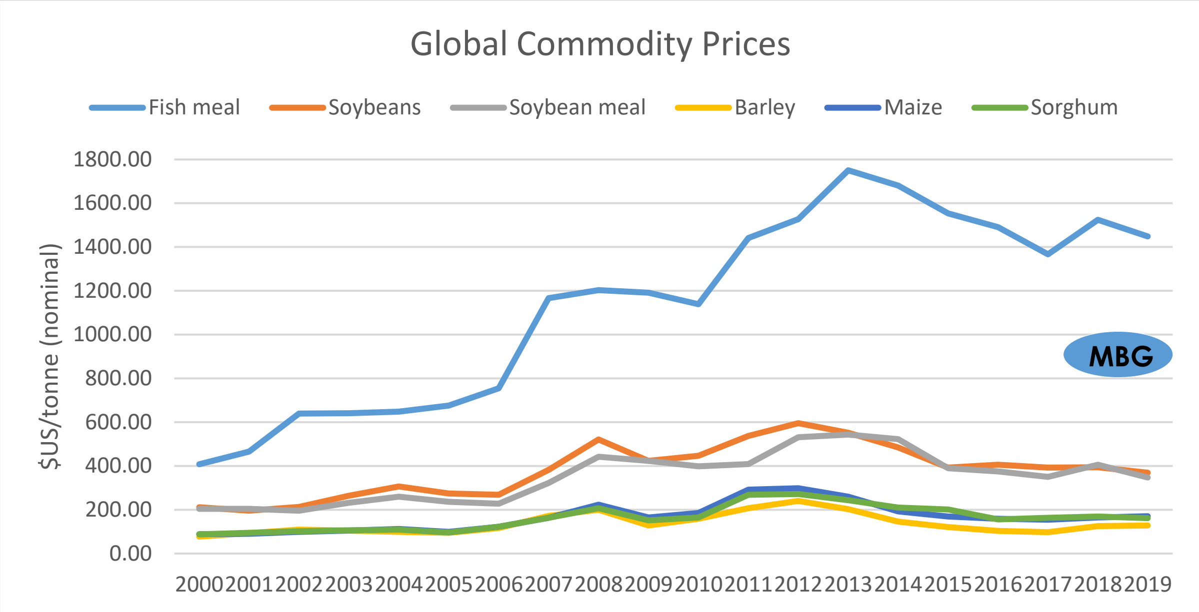

Figure 9: Likely MBG Yeast price range within current commodity prices for common animal feed stocks 2001-2019 in nominal US dollars[82]

As Figure 8 shows, MBG's yeast product would attract a premium relative to plant-based feeds such as soybean, soybean meal, maize, sorghum, and barley due to its excellent amino acid profile and the lack of any anti-nutritionals such as phytic acid etc. However, it would not attract the same pricing as fish meal. Over the longer term, additional features such as pro-biotic effects could see yeast attract a similar price to that of fish meal, but this is yet to be proven or developed.

Benefits for ethanol production

The high protein yeast by-product of 2G ethanol production using MBG's technology is beneficial to a 2G biorefinery, as it provides an additional revenue stream other than the sale of ethanol.

An indicative analysis of the financial benefits of yeast production per litre of ethanol produced is shown below in Table 3.

Table 3: Financial benefit of yeast production

	Quantity	Unit
Ethanol production	312	L
Yeast production	25	kg
Yeast per unit ethanol	0.080128205	$kg_{Yeast}/L_{ethanol}$
Upper price estimate of yeast	$1.00	USD/kg_{Yeast}
Lower price estimate of yeast	$0.80	USD/kg_{Yeast}
Upper estimate of additional benefit	$0.08	$US/L_{ethanol}$
Lower estimate of additional benefit	$0.06	$US/L_{ethanol}$
Exchange rate	$1.37	AUD per USD
Additional benefit per litre (upper estimate)	$0.11	$AUD/L_{ethanol}$
Additional benefit per litre (lower estimate)	$0.09	$AUD/L_{ethanol}$

Table 3 shows that, based on a unit price of yeast of USD 800-1,000 per tonne, the additional revenue to a biorefinery equates to between 9 – 11 cents (Australian) per litre of ethanol produced.

In NSW, the Independent Pricing and Regulatory Tribunal (IPART) determines reasonable wholesale price of fuel ethanol each year. The price for 2020 was 111.7 cents (Australian) excl. GST per litre of fuel ethanol and is based on the equivalent cost of importing ethanol from the US or Brazil[83]. The additional revenue from yeast production represents an 8%-10% premium on the wholesale price of fuel ethanol when using MBG's technology.

The wholesale price of fuel ethanol determined by IPART annually is somewhat misleading for this analysis, as it includes additional costs such as import duties and transportation costs, which apply strictly to the Australian scenario. A comparison between the premium relative to the mill gate price of ethanol is shown below in Table 4.

Table 4: Mill gate price premium

	Quantity	Unit
IPART mill gate of ethanol for 2020	$0.44[84]	$AUD/$L_{ethanol}$
Upper price premium	25%	
Lower price premium	20%	

Table 4 shows that the premium associated with the production of yeast relative to the mill gate price is significant. The benefit of using MBG's 2G technology and to produce ethanol and a high protein yeast is approximately 20%-25% per litre, before accounting for any additional government incentives globally that reward the production of low carbon fuels. This additional revenue improves the economics and decrease the risk associated with a 2G refinery by providing a natural hedge to fluctuations in the ethanol price and diversification of revenue streams.

Conclusions

In conclusion, second-generation (2G) ethanol has the potential to decarbonise various sectors within the Australian economy, provide additional, diversified income streams to primary producers, improve fuel security and animal feed self-sufficiency. MicroBioGen's (MBG) 2G yeast technology overcomes some of the critical challenges that have inhibited the development of a 2G ethanol production industry globally and changes the economic equation when it comes to 2G ethanol production.

There is sufficient available biomass (bagasse) in Australia to support the production of 1,663 ML of ethanol and 133kt of high-protein feed for domestic or international markets. This would be sufficient to meet 95% of a national E10 mandate, without taking into account ethanol produced by existing first-generation (1G) facilities. The emergence of an ethanol industry would have significant economic benefits that would flow predominately to regional areas. This includes providing a diversified income stream to sugarcane farmers, help stimulate regional economies, and provide a range of long-term employment opportunities in these areas.

There is a mature industry for animal feed consumption/production in Australia, however, the emergence and growth of the ethanol industry (1G and 2G) is constrained as Australia currently does not take full advantage of the available resources and benefits associated with its production. Existing first-generation ethanol production facilities have been idled due to a lack of demand, and the industry is stagnating as there is little government support to help drive demand (or supply).

It will be necessary for government assistance and incentive programs to help the ethanol industry meet the critical mass required for self-sufficient growth. Similar interventions to establish an industry have been successfully carried out with the wind and solar industries, where the Government intervened on the demand (reverse auctions and Renewable Energy Target) and supply (ARENA and CEFC funding) sides, helping to kickstart the industry in Australia. There are several options available to both State Governments and the Federal Government for how this may be achieved, including:

- Expanding ethanol mandates into other state jurisdictions or setting a national mandate.
  - This would create a long-term source of demand for ethanol that can be used as a basis for investing in ethanol production facilities.
  - This would also help mitigate fuel security risks currently faced by Australia.
- Implementation of a Low Carbon Fuel Standard.
  - Valuing the carbon intensity of fuels and fuels produced from waste products helps to incentivise ethanol production in the least carbon intensive manner and recognises the additional carbon benefits associated with using a waste product as a feedstock for 2G ethanol production.
- Leverage the Future Fuels Fund administered by ARENA to help facilitate greater uptake of ethanol-based fuel or fuel products such as sustainable aviation fuels.
- Incorporating biofuels into Government procurement and operational requirements.
  - This includes the integration of biofuels into military procurement requirements.
- Using ethanol as an octane enhancer rather than using fossil fuel-based octane enhancers.
- Improving and expanding the available Emissions Reduction Fund methodologies to encourage greater participation, resulting in the monetisation of carbon benefits associated with biofuel usage.

2G ethanol production is a more complex process than that of 1G ethanol production. As a consequence of a recalcitrant biomass, complex process and evolving technology, 2G ethanol has not yet reached its potential. The successful optimisation of the next generation of 2G yeast biocatalysts developed by MBG promises to be a game changer. It significantly lowers effective production costs and converts biofuel production from food consumers to food producers.

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