AECOM

Efficient Costs of New Entrant Ethanol Producers

60515181-RPT-004

Prepared for Independent Pricing and Regulatory Tribunal

13 December 2016

Final Report

Efficient Costs of New Entrant Ethanol Producers

Client: IPART

ABN: 13 166 878 119

Prepared by

AECOM Australia Pty Ltd
Level 8, 540 Wickham Street, PO Box 1307, Fortitude Valley QLD 4006, Australia
T +61 7 3553 2000 F +61 7 3553 2050 www.aecom.com
ABN 20 093 846 925

13-December-2016

Job No.: 60515181-RPT-004

Quality Information

Document	Efficient Costs of New Entrant Ethanol Producers
Ref	60515181-RPT-004
Date	13 Dec 2016
Prepared by	Stewart Peters, Simon Ward
Reviewed by	Mike Stoke

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	21-Oct-2016	In Support of IPART's DRAFT Report	Geoff Hardy Industry Director, Advisory	
B	24-Oct-2016	In Support of IPART's DRAFT Report	Geoff Hardy Industry Director, Advisory	
C	13 December 2016	In Support of IPART's DRAFT Report	Geoff Hardy Industry Director, Advisory	

Table of Contents

Table of Figures

Executive Summary

IPART has been asked by the NSW Government to investigate and report on the maximum price for wholesale ethanol produced for use in automotive fuels. It released an issues paper in June 2016 which identified alternative methods for setting a maximum price or price methodology for wholesale ethanol, and in July 2016 IPART initiated a review of the efficient operating and capital costs of new entrant producers of ethanol. The review was awarded to AECOM, and this report presents the findings of that study.

The approach, agreed with IPART and used for this study, involved research by AECOM into production pathways to identify biomass balances, process requirements and plant needed for each feedstock being considered. The capital cost estimates included are based on North American plant designs adjusted for Australian prices, and on estimates provided by local equipment suppliers. A number of interested parties were interviewed to identify or confirm issues and assumptions, but no confidential information has been included or used in this report.

A review was undertaken to identify as far as possible the location, scale and yield of feedstock availability, referring to State and Federal data sources where available. An operational and financial model was developed to derive production costs for all feedstocks considered.

The findings of this study include:

- The assessed efficient new entrant ethanol production costs in Australia for several feedstocks and a range of production capacities are presented in Figure 1. The lowest cost of production is available through the use of wheat starch in an integrated facility that primarily produces gluten.

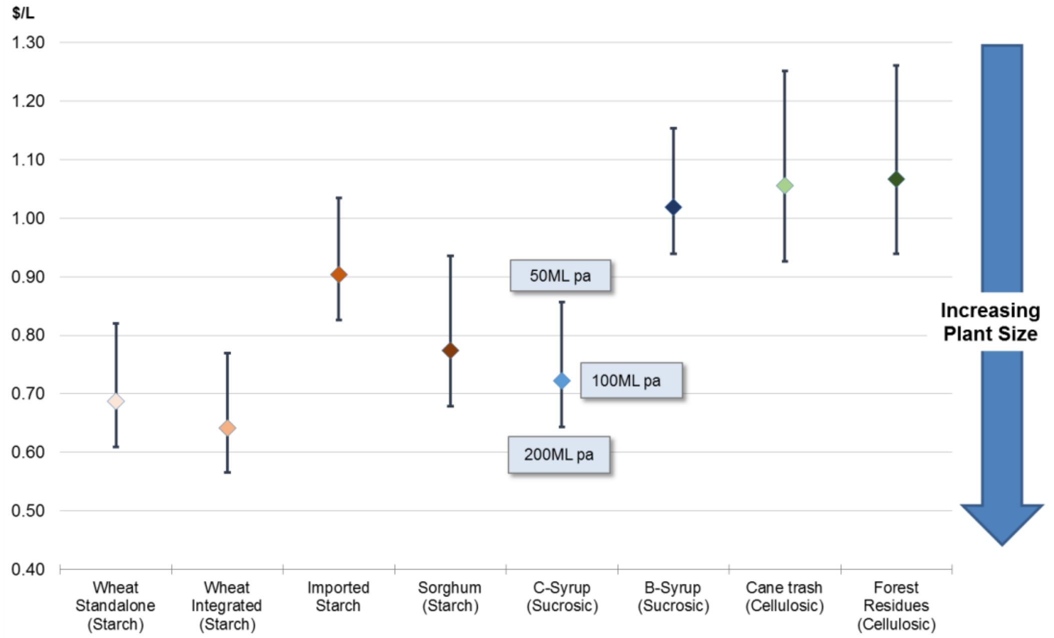


Figure 1 Range of efficient production costs of ethanol in Australia by feedstock and production capacity

- Economies of scale apply, so that a larger plant will produce ethanol at a lower cost per unit. For comparison, Figure 1 shows the cost per unit changes as a result of scaling from a 50ML to a 200ML plant. Several locations have been identified throughout NSW where the C grade starch derived from the wheat available could yield a production capacity of 300ML. This would lead to further economies, and of the pathways reviewed, this produces the lowest efficient levelised cost of $0.54 per litre of ethanol delivered to Sydney.
- The use of wheat feedstocks is the most cost-effective at this time, but in order to be competitive a new entrant would have to invest in an integrated gluten and ethanol production facility and be based in remote NSW. This would allow them to take advantage of wheat price differentials and the current over-supply in global wheat markets.
- Feedstock costs are in general not closely linked to global commodity or oil prices.

It should be noted that the financial estimates and projections included in the financial model and referred to in this report are not based on information or data provided by any of the current Australian ethanol producers, and the circumstances of their investments and commercial arrangements may result in financial outcomes that are different to those derived during this study.

1.0 Introduction

IPART has been asked by the NSW Government to investigate and report on the maximum price for wholesale ethanol produced for use in automotive fuels. It released an issues paper in June 2016 which identified alternative methods for setting a maximum price or price methodology for wholesale ethanol, and in July 2016 IPART initiated a review of the efficient operating and capital costs of new entrant producers of ethanol.

The review of efficient operating and capital costs for new entrants was awarded to AECOM, and this report presents the findings of that study.

1.1 Context

Ethanol (ethyl alcohol: C_2H_5OH) is a colourless liquid with a range of commercial applications, including use as a petrol equivalent in transport fuels by blending with unleaded petrol to make E10, which is a retail fuel option. E10 does not require special fuelling equipment, and can be used in any conventional gasoline vehicle.

Ethanol contains approximately 34% less energy per unit volume but has a higher octane rating than unleaded petrol, so engines can be made more efficient by raising their compression ratios. A study released in July 2016 concluded that the efficiency improvements available from the use of ethanol in a suitably calibrated and designed engine/vehicle system are sufficient to offset its lower energy density and could completely offset the range loss typically seen for ethanol blends in conventional gasoline and flexible-fuel vehicles.[1]

Australian governments have presented a range of initiatives intended to encourage the use of environmentally sustainable alternative to transport fuels since 1980. The NSW ethanol mandate initially required that ethanol make up at least 2% of the total volume of petrol sold in NSW. The mandate was increased to 4% in 2010 and again to 6% in 2011.[2] The mandate originally applied only to retailers that operated or controlled more than 20 retail fuel sites, but in April 2016 it was extended to all fuel retailers that sell three or more types of petrol and diesel and have sales above a threshold prescribed by regulation.

The Queensland Government intends to also introduce a mandate in 2017 that will require 3% ethanol in unleaded petrol, increasing to 4% on 1 July 2018.

The NSW mandate is not being met. Data from NSW Fair Trading indicates that ethanol sales in NSW decreased from a peak of around 4% as a proportion of total petrol sold in mid-2012 (approximately 280 million litres) to around 2.8% in the September quarter of 2015.[3] The current cost advantage of E10 appears to be too small to persuade motorists to use it in sufficient quantities.

Automotive ethanol is currently produced by three organisations in Australia, each using a different feedstock:

- Manildra's ethanol refinery, located at Nowra, which uses wheat starch and flour as feedstock and has capacity to produce approximately 70% of Australian demand.
- Wilmar's Sarina Distillery, located south of Mackay, which uses molasses as a feedstock.
- Dalby Biorefinery, which uses Sorghum as a feedstock.

Until recently, Domestic ethanol producers were provided with a subsidy via the Ethanol Production Grants Program, and, in contrast to other liquid fuels, ethanol has been excise-free. Under the *Excise Tariff Amendment (Ethanol and Biodiesel) Act 2015*, the excise duty rate for ethanol is now being increased annually towards a final schedule rate of 32.77% of the Petrol Excise rate, to be reached by 30 July 2021.

[1] Summary of High-Octane, Mid-Level Ethanol Blends Study, Oak Ridge National Laboratory, July 2016.
[2] ACCC Petrol Report_December qtr 2015
[3] NSW Fair Trading, Biofuels marketplace data, http://www.fairtrading.nsw.gov.au/ftw/Businesses/Specific_industries_and_businesses/Biofuels_industry/Biofuels_marketplace_data.page, accessed on 18 January 2016.

1.2 Terms of Reference

In order to satisfy its Terms of Reference, IPART authorised a study into the efficient operating and capital costs of new entrant producers of ethanol. The scope included consideration of:

1)	Fixed Costs	a) Feedstock costs (wheat, sorghum or molasses), yeast, enzyme, other chemicals and denaturants, given that total production costs and yield vary by feedstock. Feedstock costs also vary over time, typically with seasonal conditions and other factors in the global market. Ethanol yields are also expected to vary for different feedstocks. b) Labour, management and administration costs. c) Transport costs. d) Water. e) Electricity, gas and other energy costs. f) Administration, IT and other overhead costs. g) Capital costs (including asset values and economic lives). h) Any other costs.
2)	Location of ethanol plant	The location of the ethanol plant will affect the cost of land as well as the availability and transport cost of feedstock, and the transport cost of ethanol sold. As a result, the appropriate location of the ethanol plant may vary depending on the feedstock, which will affect the cost associated with production.
3)	Revenue from co-products	Ethanol producers derive revenue from the generation of multiple by-products from ethanol production. This may include starch (in dried and liquid forms), gluten, glucose syrup, and dried distillers' grains (used as stock feed). The revenue from these by-products will need to be included and both gross and net costs of production for each feedstock estimated.
4)	Costs to meet different levels of demand	Different levels of demand would be expected to require different sized capital investment. The consultant should examine and report on the relationship between demand and the appropriate capital investment for new entrant producers.
5)	Environmental externalities from ethanol production	While tailpipe emissions from ethanol or E10 do not vary by feedstock, the pollutant emissions of ethanol production do depend on the feedstock being used. The consultant is required to estimate the environmental externalities associated with production of ethanol from each feedstock type.

Following IPART's normal practice, the analysis has included derivation of a return on the asset base employed, using a weighted average cost of capital (WACC) defined by IPART for the purposes of this study.

1.3 References

A complete list of reference documents and interviewees is attached as Appendix A and Appendix B.

2.0 The Context for Ethanol Production

2.1 Approach and Methodology

The approach agreed with IPART and used for the study involved:

- Research into production pathways to identify biomass balances, process requirements and plant needed for each feedstock being considered, drawing largely on North American sources;
- Cost estimates prepared by professional cost estimators based on the plant needed, using Australian prices where possible and estimates provided by offshore suppliers;
- Interviews with a range of researchers in an attempt to identify and quantify feedstock availability in NSW and Queensland, and to understand issues seen as affecting ethanol production;
- Interviews with the current producers and with the majority of proponents currently piloting production or intending to invest in the industry. It should be noted that no confidential information has been used in producing this report;
- Location and analysis of current spatial data resources to develop a view of the location, scale and yield of feedstock availability, referring to State and Federal data sources where available;
- Development of an operational and financial model that indicates production costs and provides summary performance information for all feedstocks considered. The model derives a return on assets as required by IPART, but also calculates a return of and on capital and a margin as an alternative view; and
- Preparation of a draft report for review by stakeholders and interested parties.

A schematic of this methodology is presented in Figure 2.

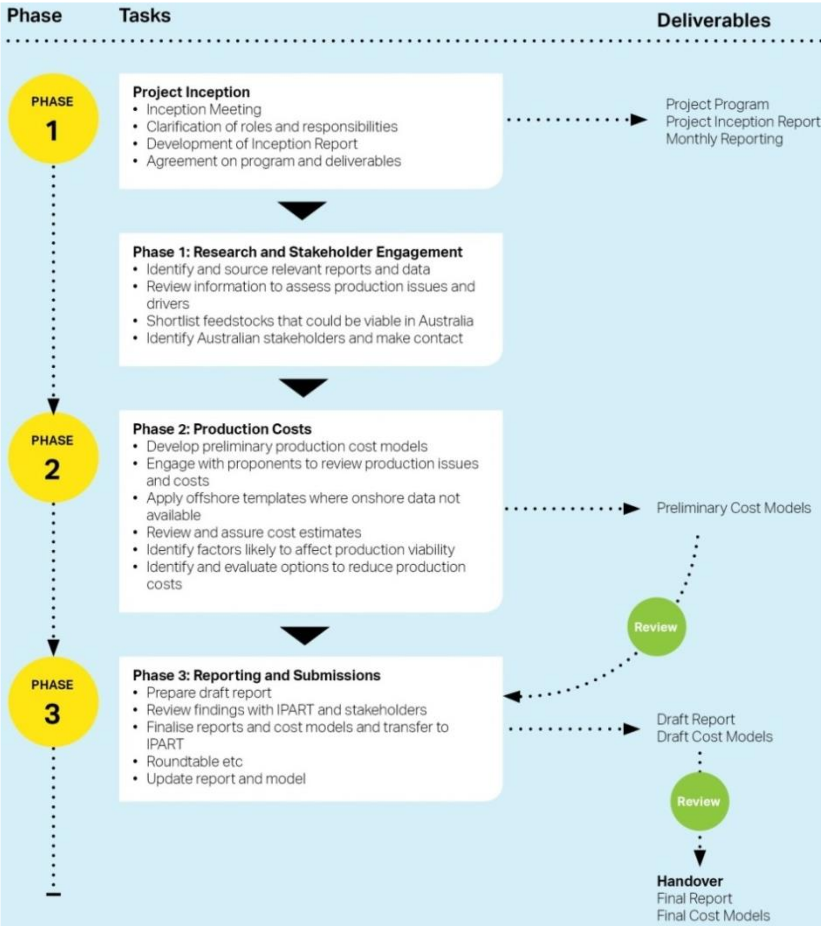


Figure 2 Schematic of study methodology

It should be noted that the financial estimates and projections included in the financial model and referred to in this report are not based on information or data provided by any of the current Australian ethanol producers, and the circumstances of their investments and commercial arrangements may result in financial outcomes that are different to those derived during this study.

2.2 The Demand for Transport Biofuels

The *Biofuel (Ethanol Content) Act* 2007 (the Act) was enacted to provide for a minimum ethanol content requirement (an ethanol mandate) of 2% in respect of the total volume of petrol sales in NSW, at the primary wholesale level. The introductory statement by the then Premier of NSW identified a number of policy objectives for the legislation, including:

- Investment and jobs in rural and regional NSW;
- Greenhouse gas reductions and cleaner air;
- Cheaper fuel; and
- Less reliance on fossil fuels and Middle Eastern oil.

The Act was amended by the *Biofuels (Ethanol Content) Amendment Act 2009.* The amendments included:

- Increasing the volumetric ethanol mandate to 4% from 1 January 2010 and further increasing the mandate to 6% from 1 January 2011;
- Requiring all regular grade unleaded petrol to be E10 from 1 July 2011 (this requirement was repealed on 31 January 2012 by the NSW State Government);
- Establishing a volumetric biodiesel mandate of 2% (this requirement was suspended until 1 January 2010);
- Increasing the biodiesel mandate to 5% from 1 January 2012;
- Amending the definition of primary wholesaler to include diesel as well as petrol;
- Applying the volumetric mandates to major retailers (controlling more than 20 service stations) as well as primary wholesalers;
- Providing for sustainability standards for biofuels; and
- Providing for exemptions from the requirement for all ULP to be E10 (for marinas and small businesses suffering hardship).

Progress of the ethanol mandate in achieving its goal of a 6% ethanol supply was steady for the first three years, driven by the volume fuel sellers rolling out E10 to the service stations they control. In many cases this was done by replacing regular unleaded petrol (RULP) with E10 in anticipation of the requirement for all RULP to be E10 from 1 July 2012, one of the 2009 amendments to the Act.

Following the announcement on 31 January 2012 of the Government's decision to repeal the requirement for all RULP to be E10, the roll-out of E10 slowed dramatically and subsequently RULP began to be reintroduced as a choice at a significant number of sites. The average NSW ethanol content has fallen from a peak of 3.98% in the third quarter of 2012 to 3.49% in the fourth quarter of 2013.

The Act currently applies to volume fuel sellers (primary wholesalers and major retailers that control more than 20 service stations) and requires them to ensure that ethanol makes up not less than 6% of the total volume of petrol that they sell in NSW or for delivery in NSW. No volume fuel seller has achieved the required 6% since the first quarter of 2013. No volume fuel seller is forecasting increasing ethanol sales.

The mandate originally applied only to retailers that operated or controlled more than 20 retail fuel sites, but in April 2016 it was extended to all fuel retailers that sell three or more types of petrol and diesel and have sales above a threshold prescribed by regulation. A major reason why primary wholesalers are unable to improve compliance with the 6% volumetric mandate is that many of the state’s 1,990 service stations are independently owned and operated, and under the *Federal Government Oil Code*, wholesalers may not require independent retailers to sell E10.

Australian governments have presented a range of initiatives since 1980 intended to encourage the use of environmentally sustainable alternatives to transport fuels. The NSW ethanol mandate initially required that ethanol make up at least 2% of the total volume of petrol sold in NSW. This proportion was increased to 4% in 2010 and further to 6% in 2011.[4] The mandate does not force motorists to use E10, however, and the cost advantage of E10 appears to be too small to persuade motorists to use it in sufficient quantities.

In addition to the NSW mandate, the Queensland Government passed the *Liquid Fuel Supply (Ethanol and Other Biofuels Mandate) Amendment Act 2015* on 1 December 2015. This Act applies to all fuel retailers who operate more than 10 sites, or who sell more than 250,000L/quarter of petrol. It will come into effect on 1 January 2017,

[4] ACCC Petrol Report December Quarter 2015

and will require that 3% of the total volume of regular unleaded petrol sales must be bio-based petrol (ethanol). This is scheduled to increase to 4% from 30 July 2018.

NSW sold the most ethanol blended fuels in 2015-16 of all Australian States, but this was still about 25% of the quantity required to meet the mandate[5] (Figure 4). Data from NSW Fair Trading indicates that ethanol sales in NSW decreased from around 4% as a proportion of total petrol sold in mid-2012 to about 2.6% in Q1 2016[6].

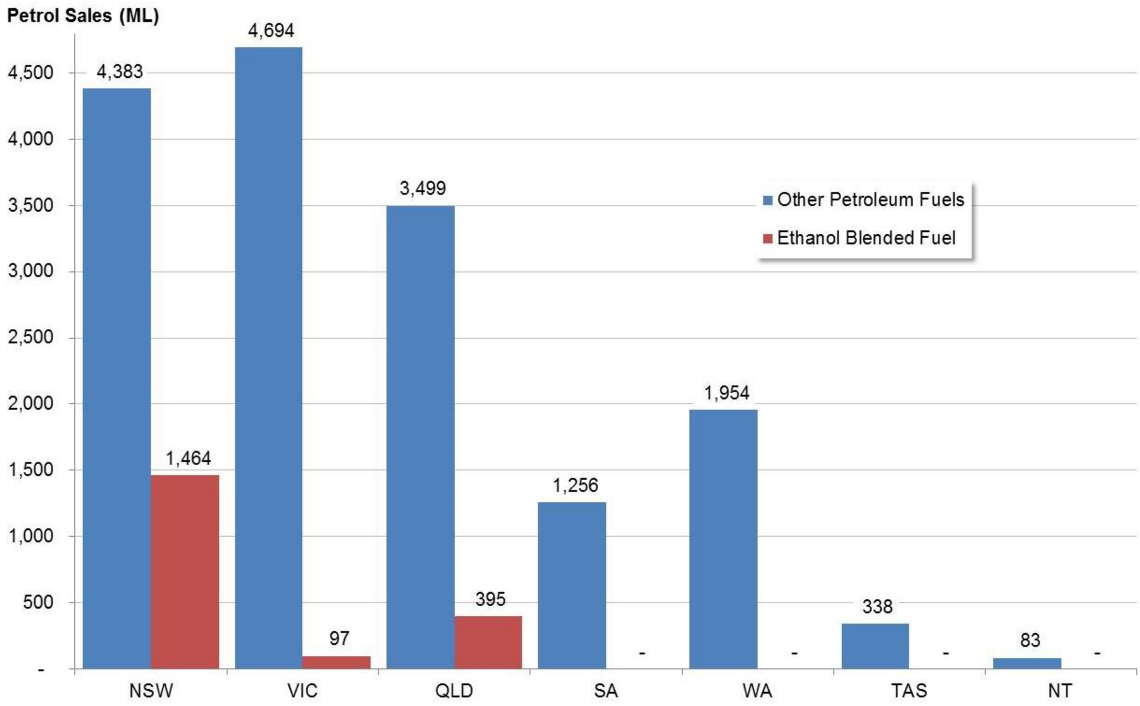


Figure 3 2015-16 Petrol and Ethanol Sales by State

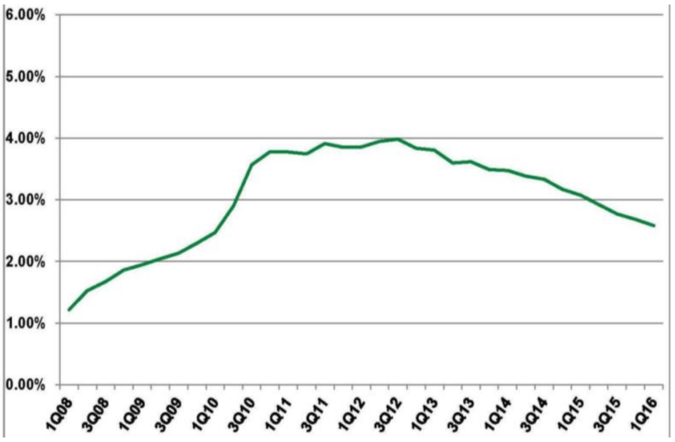


Figure 4 Ethanol sales as a percentage of NSW petrol sales per quarter

Based on fuel consumption in 2015-16, 350ML of ethanol would be needed to meet the mandated 6% in NSW, and in Queensland, a mandate of 4% would demand a further 155ML of ethanol. [7]

---

[5] Australian Petroleum Statistics, Issue 239, June 2016, www.industry.gov.au/oce

[6] http://www.fairtrading.nsw.gov.au/ftw/Businesses/Specific_industries_and_businesses/Biofuels_industry/Biofuels_marketplace_data.page? accessed 29 August 2016

[7] Australian Petroleum Statistics, Issue 239, June 2016, www.industry.gov.au/oce, Table 3C

2.3 The Global Experience

More than 50 countries have implemented biofuel blending mandates and targets. The growth in global biofuel production has responded accordingly, but few countries have policies to support the development of advanced biofuels, relying instead on the conventional feedstocks. Biofuels (including biodiesels) accounted for 1.9% of global transport fuels in 2014,[8] and the International Energy Agency projects an increase to 6.3% by 2035.

Global biofuel production (bioethanol and biodiesel) has grown from 16bn litres in 2000 to an estimated 110bn litres in 2012[9]. Growth in global production has subsequently stalled due to higher feedstock prices and poor yields due to adverse weather conditions.

The United States is the largest global consumer of biofuels[10], and together with Brazil and the EU consume about 80% of the world's total. Biofuels represent a relatively small share of the total US transports fuels at just 4.35% (2010 figures). Brazil experiences the largest proportional use of biofuels at 20.1% (2010 figures)[11].

The United States is also the largest global producer of ethanol, accounting for 57% of global ethanol production in 2015[12] (Figure 5) and has mandated 164bn litres of ethanol in fuel blends by 2022.

The EU intends to replace 10% of each member states' transport fuels with renewable fuels by 2020, while Sweden is aiming to be completely free of fossil fuels by 2030[13].

Brazil began producing bioethanol from sugar cane in 1975[14] and in 2010 had 430 ethanol producing plants producing 26bn litres. In September 2014 Brazil approved a law to increase the mandated ethanol component in fuel from 25% to 27.5%[15].

Ethanol production in North America is predominantly based on corn (Figure 6), and only 3% of current production uses other feedstocks. Investment in non-conventional feedstocks is increasing, however, and of the total proposed investment in ethanol production in North America, 23% (400 ML) will use feedstocks other than corn.

Canada has a national mandate of 5%, and several Asian nations are also implementing mandated levels[16].

New Zealand has an excise duty exemption for ethanol which is produced at three sites from lactose specific fermenting yeast using whey serum from acid casein plants.

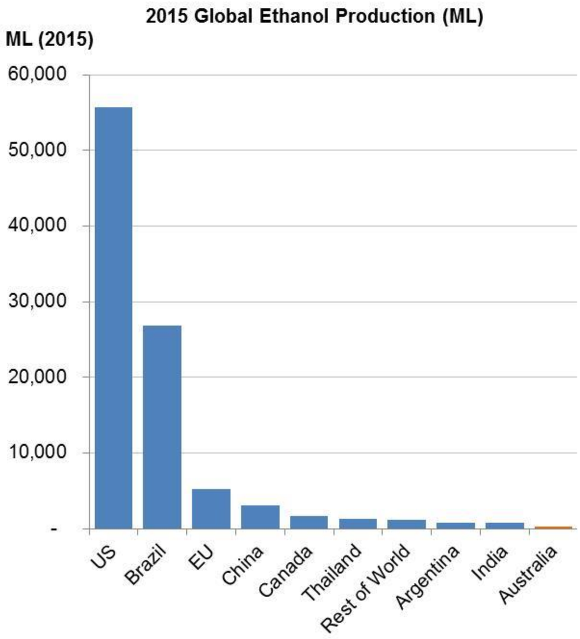


Figure 5 Global production of ethanol in 2015

Country	Platform	Existing	Proposed	Grand Total
Canada	Sugar/Starch	375		375
	Cellulosic	47	117	164
US	Sugar/Starch	18	168	206
	Cellulosic	17	115	132
Total Non-Corn		**458**	**400**	**878**
Corn	**Starch**	**17,345**	**1,712**	**19,080**

Figure 6 Ethanol production plant capacity in North America

[8] Australian Government, Department of Industry, BREE, Australian Energy Resource Assessment, 2nd Edition, 2014
[9] Australian Government, Department of Industry, BREE, Australian Energy Resource Assessment, 2nd Edition, 2014
[10] Australian Government, Department of Industry, BREE, Australian Energy Resource Assessment, 2nd Edition, 2014
[11] Australian Government, Department of Industry, BREE, Australian Energy Resource Assessment, 2nd Edition, 2014
[12] Renewable Fuels Association (RFA), Fueling a High Octane Future, 2016
[13] http://biofuelsassociation.com.au/biofuels/ethanol/ethanol-use-around-the-world/
[14] http://www.ers.usda.gov/media/126865/bio02.pdf
[15] http://www.soybeansandcorn.com/news/Oct1_14-New-Biofuel-Mandates-tage-Effect-in-Brazil
[16] http://biofuelsassociation.com.au/biofuels/ethanol/ethanol-use-around-the-world/

2.4 The Maturity of Ethanol Production Pathways

Ethanol is produced on a commercial basis by three organisations in Australia. Manildra uses waste starch by-products from its flour milling activity as feedstock, and the other producers use red sorghum and molasses (a by-product of sugar processing). All these first generation (conventional) pathways are well established.

Ethanol producers must compete for supply of these first generation feedstocks, the costs of which have been estimated to represent between 78% and 84% of the gross cost of ethanol production depending on the type of feedstock.[17]

The major producers are the United States (from corn) and Brazil. European production is reliant on sugar beet. Corn and sugar beet offer higher energy densities than wheat or molasses and are available in large quantities, so sustainable production can be viable. Neither of these feedstocks are currently or likely to be available in sufficient quantities in Australia.

Whilst Australia's current biofuel supply uses first generation feedstocks, it is recognised that this is unlikely to be the case in the future[18] due to their limited availability and their alternative uses. Advances are being made into modifying these feedstocks to offer improved yields under particular climatic conditions but second generation (alternative) feedstocks are more likely to provide the scalability and sustainability needed, and may also come with further consequential environmental benefits. However, these feedstocks are typically unproven in Australia (although are proven elsewhere) and it is likely to be some time before they become sufficient proven here to attract investment.

Based on an assessment of the viability and availability of feedstocks in Australia, the following have been selected for assessment for the efficient cost production of ethanol production for new entrants:

- Sugar-based – sugar cane, molasses and sweet sorghum.
- Starch-based – wheat, sorghum and cassava.
- Cellulose-based – forest residues, mallee, cane and wheat trash.

2.5 Co-Products and Externalities

Co-products are secondary products derived from the production process that may be sold or re-used. In the case of ethanol production, the different processes produce a variety of co-products which are able to be used as inputs into the process (energy, waste etc), or sold on as an additional revenue stream. A summary of the co-products derived from the three ethanol production process pathways, and their potential uses, is provided at Table 1.

Table 1 Co-products from ethanol production

Co-Product	Process Type	Potential Uses
- Carbon Dioxide	- Sugar-Based - Starch-Based - Cellulosic-Based	- Beverage Products - Medical Products - Dry Ice - Heavy Industry – Oil & Gas, Power Generation
- Stillage (Dunder)	- Sugar-Based - Starch-Based	- Solids – Bio-active Fertiliser - Biogas – Electricity Co-Generation
- Vital Gluten	- Starch-Based	- Cooking - Animal Feed
- Bran / Germ	- Starch-Based	- Cooking - Vegetable Oil
- Distiller's Dried Grains with Solubles (DDGS)	- Starch-Based	- Stock Feed (value is a function of protein content)
- Lignin	- Cellulosic-Based	- Synthetic Fuels - Increased Ethanol Yield - Electricity Co-Generation

[17] An assessment of key costs and benefits associated with the Ethanol Production Grants program. Bureau of Resources and Energy Economics, Feb 2014
[18] Australian Government, Department of Industry, BREE, Australian Energy Resource Assessment, 2nd Edition, 2014

It should be noted that as a number of the feedstocks are themselves co-products of other product processes (e.g. molasses as a co-product from sugar production, or wood wastes as a co-product from forestry operations), the carbon dioxide and other greenhouse gases associated with growing and harvesting the feedstocks are attributed to the parent processes rather than the production of ethanol.

The stillage (or dunder) can be used to produce fertiliser and gasified to generate electricity. The lignin produced from cellulose based processes can be gasified to either increase ethanol production yield, produce synthetic fuels or used to generate electricity.

There is an opportunity to integrate this gasification and electricity co-generation facilities into the plant design. Onsite co-generation would make the plant more self-sufficient and could be used to offset the production costs of the plant by feeding excess electricity back into the grid.

2.6 Legislative and Regulatory Requirements for Ethanol Producers

There a number of legislative and regulatory requirements that a new entrant would need to observe. For a development in NSW, these may include:

- **Biofuel Production**

  For a biofuel to be eligible to meet the mandate, it must be compliant with the *Global Principles and Criteria for Sustainable Biofuels Production – Version Zero (Roundtable on Sustainable Biofuels)*.[19] This document sets out principles relating to:

  - Legislative requirements
  - Emissions
  - Land rights, human rights, labour rights and working conditions
  - Contribution to community development
  - Impact on ecosystems, biodiversity and conservation
  - Surface and groundwater management
  - Air pollution
  - Cost efficiency.

- **Commonwealth Planning Requirements**

  - *Environment Protection and Biodiversity Act 1999*

- **State Requirements**

  - *Coastal Protection Act 1979*
  - *Contaminated Land Management Act 1997*
  - *Environmental Planning and Assessment Act 1979*
  - *Environmental Planning and Assessment Regulation 2000*
  - *Fisheries Management Act 1994*
  - *Heritage Act 1977*
  - *Local Government Act 1993*
  - *Mine Subsidence Compensation Act 1961*
  - *National Parks and Wildlife Act 1974*
  - *Native Vegetation Act 2003*
  - *Noxious Weeds Act 1993*
  - *NSW Biodiversity offsets policy*
  - *NSW Road Noise Policy 2011*
  - *Protection of the Environment Operations (Clean Air) Regulation 2010*
  - *Protection of the Environment Operations (Noise Control) Regulation 2008*
  - *Protection of the Environment Operations (Waste) Regulation 2014*
  - *Protection of the Environment Operations Act 1997*
  - *Roads Act 1993*
  - *Rural Fires Act 1997*
  - *State environmental planning policies*
  - *The Aquifer Interference Policy 2012*
  - *The NSW State Groundwater Policy 1997*
  - *Threatened Species Conservation Act 1995*
  - *Waste Avoidance and Resource Recovery Act 2001*
  - *Water Act 1912 and Water Management Act 2000*
  - *Work Health and Safety Act 2011*

- **Standards and Codes**

  There are numerous Australian and International standards and codes relating to the planning, design and operation of a bioethanol plant. These have not been listed here but would be identified by a proponent as part of the design development process.

[19] http://www.fairtrading.nsw.gov.au/ftw/Businesses/Specific_industries_and_businesses/Biofuels_industry.page?

2.7 Risks

A sustainable feedstock is required in sufficient quantity and quality, and within close proximity of the proposed plant to minimise transport costs. The cost of feedstock is a large component of the cost of production. Unless proponents are vertically integrated and able to source their own feedstock or have long-term supply contracts, they will be exposed to price variation as a result of market forces that are essentially unrelated to fuel prices.

Conventional feedstocks typically have alternative uses and are part of an established food supply chain. These alternative markets are well established, offer potential increased return for growers, and diverting the feedstock for ethanol production may increase prices or force the use of imported substitutes. The low grade starch derived from wheat is currently entirely committed to the pulp and paper industry, for example, and it may not be possible in practice for a new entrant to secure enough supply to make a standalone wheat starch ethanol production facility viable.

Ethanol production can be self-sufficient in terms of energy, and needs water to makeup losses at up to 2 ML per annum per 100 ML of ethanol production capacity, so energy and water needs are unlikely to be barriers to entry.

The bioenergy market in Australia could be perceived as immature and a potential high commercial risk. Whilst Australia has significant capacity and history of financing infrastructure, it has a small venture capital market and institutional investors have been reluctant to fund higher risk early-stage technology companies. This is particularly important for technologies that are emerging, unproven or yet to be demonstrated at scale, including the advanced or second generation feedstocks. Proponents have noted that expansion of the industry is unlikely to underpin or incentivise investment without government intervention.[20]

2.8 Incentives for the Production of Ethanol

A variety of incentives applicable to ethanol production already exist:

- **Ethanol Production Grants Program**

  The Ethanol Production Grants (EPG) Program was introduced in 2002-03 as a short term (12 month) subsidy payable to eligible domestic ethanol producers, but was extended by successive Governments. It was designed to support production and deployment of ethanol as a sustainable alternative transport fuel in Australia by providing full excise reimbursement, at the excise rate, to ethanol producers using locally derived feedstock to produce ethanol for transport use in Australia.

  The EPG was terminated at the end of June 2015 after reviews concluded that the benefits of the program were modest, had come at a high cost, and that an expanded Australian ethanol industry based on market priced feedstock was considered unlikely to be commercially viable in the absence of the EPG rebate.

- **Ethanol Excise**

  The taxation treatment for ethanol is determined by the *Alternative Fuels Act*, as amended by the *Excise Tariff Amendment (Ethanol and Biodiesel) Act 2015*. Excise rates for domestically produced ethanol as a percentage of those for petrol were set at 0% on 1 July 2015, rising by 6.554% at the start of each financial year to 32.77% from 1 July 2020.

  The excise equivalent customs duty for imported ethanol remains 38.143 cents per litre.

- **Emissions Reduction Fund**

  This fund is administered by the Clean Energy Regulator with the broad objective of supporting initiatives that measure, manage, reduce or offset Australia's carbon emissions.

  The Emissions Reduction Fund is designed to support the reduction in Australia's emissions by providing an incentive to adopt new practices and technologies which reduce emissions, with the objective of helping Australia meet its emissions reduction target of 5% below 2000 levels by 2020.

  Organisations taking part can earn Australian carbon credit units (ACCUs) - one ACCU is earned for each tonne of carbon dioxide equivalent (tCO2-e) stored or avoided by a project. ACCUs can be sold to generate income, either to the Government through a carbon abatement contract, or on the secondary market.

[20] An Assessment of key costs and benefits associated with the Ethanol Production Grants programme, BREE, 2014

Allocation is usually made by way of an auction, the next one coming up in November 2016. Market sounding was due to close on 14 October 2016 to review alternative purchasing approaches to make it more attractive to large industrial projects.

- **Emissions Displacement Credit**

  Australia has implemented a range of schemes at the state and national level. These include the Renewable Energy Target (RET) and the New South Wales Energy Savings Scheme (ESS).

  Emissions displacement activities are where the consumption of a more emissions-intensive output is displaced with a less emissions-intensive output. The RET is based on the displacement premise, that is, additional renewable energy displaces more emissions-intensive generation from coal and gas.

  These types of activities include, for example, the displacement of fossil fuel-generated electricity with renewable energy, as could be the case with a new entrant ethanol producer. This also applies to fuel- or feedstock-switching where an emissions-intensive fossil fuel or feedstock is replaced by a less emissions-intensive alternative.[21]

- **National Grant and Financing Schemes**

  - Australian Renewable Energy Agency (ARENA)

    ARENA provides long-term financial assistance packages for renewable energy technology innovation with $215 million allocated and no minimum or maximum. It runs the Emerging Renewables Programme which funds the development, demonstration and early stage deployment of renewable energy technologies, and jointly funds the Southern Cross Renewable Energy Fund which selectively invests in Australian renewable energy companies.

  - RIRDC's Bioenergy, Bio products and Energy program

    This is focused on the development of sustainable and profitable bioenergy and bio-products industries. RIRDC invests in research and development that helps rural industries to be productive, profitable and sustainable.

  - The Clean Energy Finance Corporation (CEFC)

    CEFC operates like a traditional financier, working with co-financiers and project proponents to seek ways to secure financing solutions for the clean energy sector. The CEFC Act established the CEFC Special Account which is credited with $2 billion per year from 2013 to 2017. Projects span renewable energy, low-emissions technologies and energy efficiency. Using a full range of financial instruments, the CEFC co-finances and invests, directly and indirectly, in clean energy projects and technologies.

    The CEFC focuses on projects and technologies at the later stages of development which have a positive expected rate of return and have the capacity to service and repay capital. They can also look at earlier stage projects which have significant support and a risk profile appropriate for CEFC. The CEFC may provide concessional finance but does not make grants.

- **The NSW Regional Clean Energy Program**

  This part of the Office of Environment and creates opportunities throughout New South Wales to engage the community in local renewable energy initiatives, including bioenergy.

  This is a community focused initiative, and has grants available to support community initiated projects. Whilst this is unlikely to offer any direct financial support to a new entrant, it does promote community engagement in bioenergy.

[21] http://climatechangeauthority.gov.au/reviews/carbon-farming-initiative-study/key-characteristics-baseline-and-credit-schemes

3.0 The Production of Ethanol from Grain Feedstocks

Australia is a major producer of wheat and also produces sorghum, both of which can be (and are) used for ethanol production.

Wheat is used to produce flour for food purposes but it can be further processed to produce a wide variety of products including gluten and various grades of starch. Australia is one of the largest global exporters of wheat and is a significant exporter of gluten to the USA.

A key feature of the gluten production process is the co-production of various grades of starch. It is estimated that Australia consumes around 600,000 tonnes per year of starch in industrial, food and beverage applications and as a feedstock for ethanol. Of this, it is estimated that 480,000 tonnes per year is produced domestically. Sources of starch other than wheat include corn, potato and tapioca starch, most of which is imported.

The market price of the starch grades, as by-products, is not strongly influenced by wheat or gluten prices and reflects pricing comparable to imported starch.

We estimate that approximately 200,000 tonnes of co-product wheat starch is required to produce 100 ML of ethanol and various refinery co-products. To produce 300 ML, a refinery will require approximately 600,000 tonnes of low grade starch.

Grain (red) sorghum is predominantly grown for stockfeed, but has recently become an attractive feedstock for the production of baiju - a drinking alcohol - in China. There has been a rapid increase in sorghum grain exports to China, which may reduce the availability and increase the price of sorghum for local ethanol production.

3.1 The Grain Production Process

The ethanol production process using grain is similar to the sucrosic process but requires additional process steps. Grain de-husking is required, and the starch content requires enzymatic conversion to glucose prior to fermentation. Significant additional value can be gained by removing gluten protein from the de-husked flour, and in practice the value of gluten is such that gluten is the primary product and starch only a by-product.[22]

Sorghum and wheat both enable production of high protein stockfeed as a by-product. Electricity and steam can be produced from biogas using anaerobic treatment of soluble organics in the exiting process water.

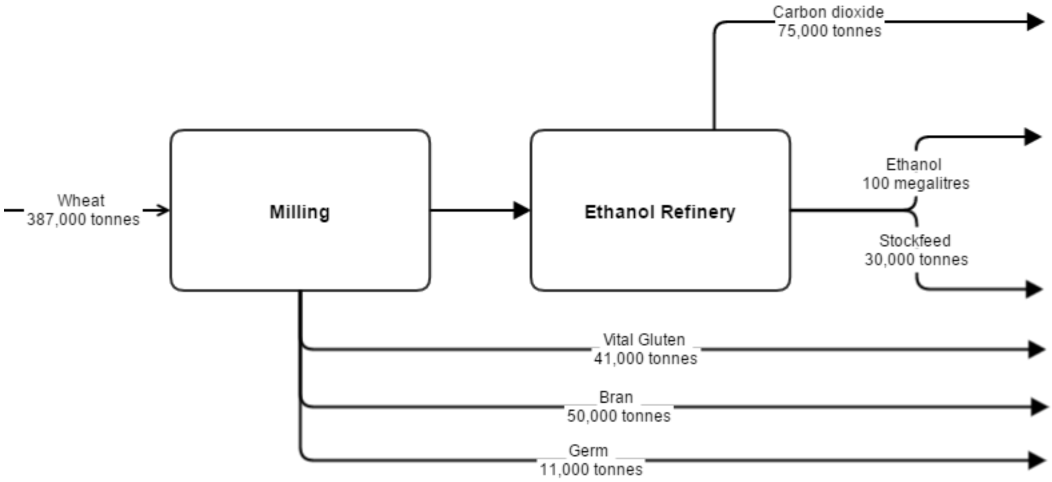


Figure 7 Relative material volumes used or produced in a gluten plant

The process pathway for a new entrant producer of ethanol from wheat would involve conventional dry milling to remove bran and germ and create flour, which would then undergo wet milling to separate the gluten and A-grade starch. The gluten would be washed and the B-grade starch removed, leaving C-grade starch residue which can be used to produce ethanol.

[22] The process design, equipment specification and costs used for this process have been developed by AECOM from a variety of sources. We have not had access to any production information from an Australian proponent.

A 100 ML capacity ethanol plant would require the low grade starch by-product from production of about 41,000 tonnes of gluten, which in turn would require about 387,000 tonnes of wheat. The plant would also produce about 30,000 tonnes of distillers grain solids (DDGS) used as stockfeed.

The starch would be converted to glucose through the application of heat and enzymatic action to hydrolyse (liquefy) and to convert (saccharify) the starch to glucose. Enzymes would be added to the starch during the hot liquefaction phase, and following liquefaction to convert starch to glucose prior to and during the fermentation process. The glucosic mash would be fermented in a series of large tanks operating continuously. Water and contaminants would be removed by distillation and rectification followed by a molecular sieve to increase concentration to 99.9% by weight of ethanol. A small amount of gasoline would be added to denature the ethanol prior to delivery to fuel blending sites.

The major refinery by-product would be distillers' grain solids (DDGS) which contains unfermented sugars, bio-active fermentation yeasts, proteins and minerals. Stillage from the ethanol refinery is concentrated by centrifugal decanters to separate solids from water, and the solids stream is dried in a rotary kiln using process steam.

The water stream containing soluble organics is biologically treated in a biogas plant to recover biogas and reduce the organic load. The biogas would be used to generate electricity for the facility, and the hot exhaust used to produce process steam. Carbon dioxide production is expected to be very low due if internally generated biogas is used to provide energy.

The process is similar for sorghum grain, but dry milling is more difficult compared to wheat. Ethanol refining of sorghum carries a higher non-fermentable load than wheat, leading to higher quality DDGS (with a higher protein and fat content). Wheat can be substituted for sorghum, offering some flexibility for a sorghum-based refinery.

3.2 Feedstock Availability in Australia

There are two viable grain-based feedstocks available in Australia, and several with some potential:

Wheat	Large and increasing quantities of wheat are exported by Australia. Wheat is used to produce gluten, which is also exported, and starches, which are available as a feedstock for ethanol production. There is a commercial plant in operation (Manildra).
Red Sorghum	Red Sorghum is sufficiently available (export and stockfeed markets) for ethanol production. There is a commercial plant in operation (Dalby).
Maize	Corn is the major feedstock used globally, especially in North American and Brazil. There is insufficient feedstock for ethanol production in Australia.
Rice	There is insufficient feedstock for ethanol and food production in Australia, and variable production due to El Nino drought cycles.
Cassava	There is currently insufficient feedstock for ethanol production in Australia. However, cassava chip is readily available as an import and there are trial plantations in progress in the Burdekin and Laura regions that currently export cassava chips to China for ethanol production.
Potato	There is insufficient feedstock for ethanol and food production in Australia.
Bananas	There is insufficient feedstock for ethanol and food production (but there is waste available).

3.2.1 Wheat

Wheat production in Australia has been increasing as a result of favourable growing conditions (Figure 8). Australia exported about 16.5 million tonnes in 2015, approximately 4 million tonnes of which was produced in NSW.

Export volumes have been increasing at about 2% a year. Global grain markets are currently over-supplied, which has put downward pressure on wheat prices.

Australia provides about 40% of the gluten imported by the United States.

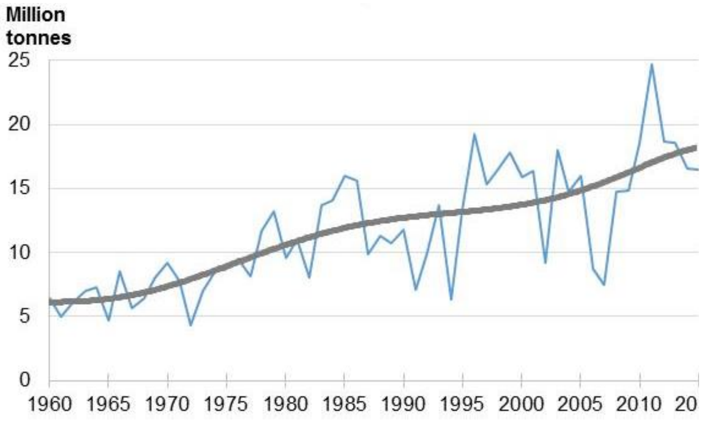


Figure 8 Australian wheat exports

The wheat price available to growers varies by distance from a port. Growers near a major port currently have access to prices around $230 per tonne, whereas more remote growers may only be able to sell at $160 per tonne (APW1 daily data sourced from the Australian Wheat Board), the 30% difference reflecting transport costs.

Feedstock availability in NSW is estimated as indicated in Figure 9.

Potential Annual Production	Wheat		
	Crop Area '000 ha	Yield ('000 tonnes pa)	Ethanol (ML)
Moree	550	880	316
Walgett	352	563	202
Nyngan	530	848	305
Wyandra	308	493	177
Riverina	538	861	309
Total	**2,278**	**3,645**	**1,309**

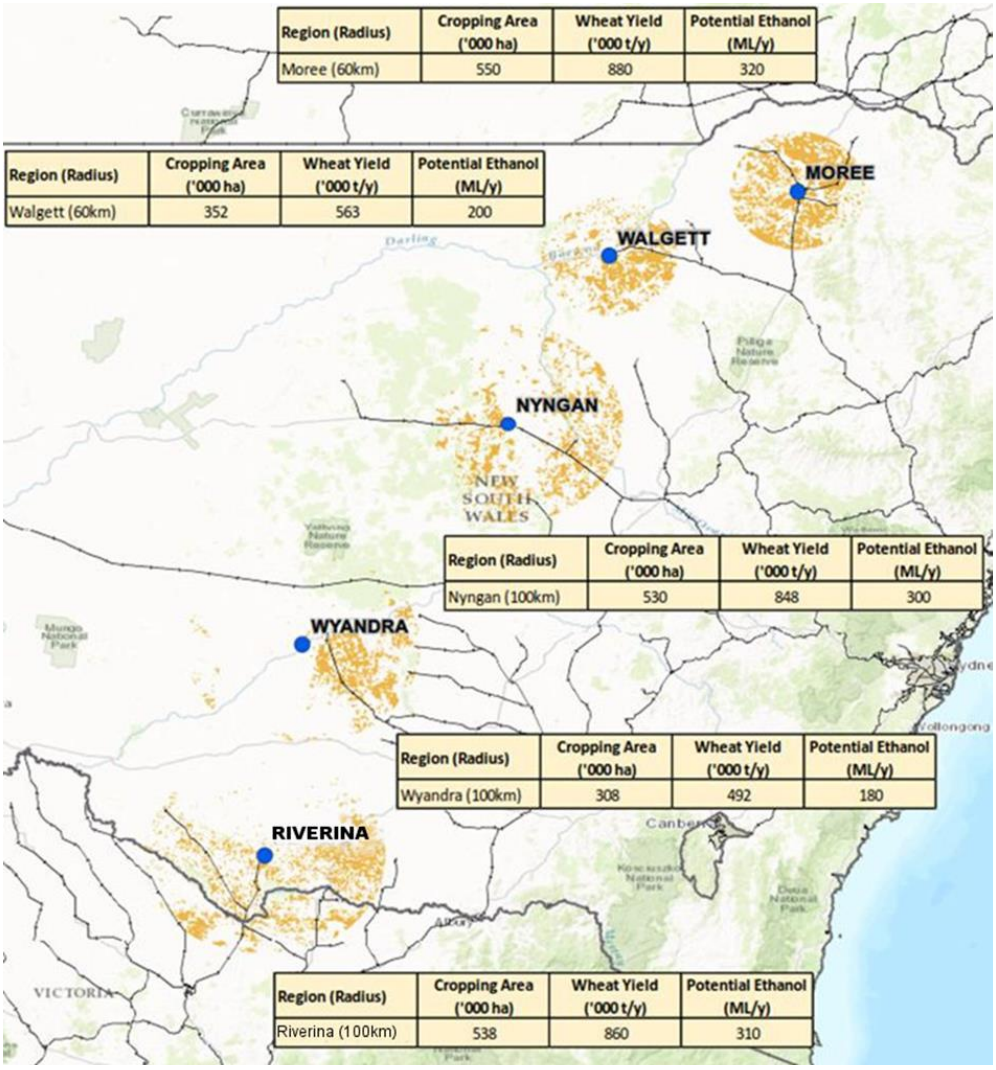


Figure 9 Wheat feedstock availability and yield

Deregulation of the Australian grains industry has prompted changes at a farm level. High transportation costs encourage growers to seek local markets such as stock feeding, and they have tended to increase on-farm storage to expand their marketing options, cater to different freight modes and adjust to seasonal variability, particularly in response to high cattle prices which motivate intensive cattle finishing (and the need for stock feed).

Large grain users such as flour mills and ethanol refineries can make use of this trend by locating in wheat producing regions. Experience in North America suggests that feed lotting could be attracted to ethanol production plants and locate nearby to take advantage of DDGS available from these facilities.

3.2.2 Sorghum

The annual Australian grain sorghum crop is around 2.2 million tonnes per year, largely produced in Queensland.

Sorghum has historically been grown for cattle feed, offering growers a low risk, low yield, dry cropping option.

A strong market has recently developed in China for sorghum for production of drinking alcohol, and approximately 50% of the crop is now being exported (Figure 10).

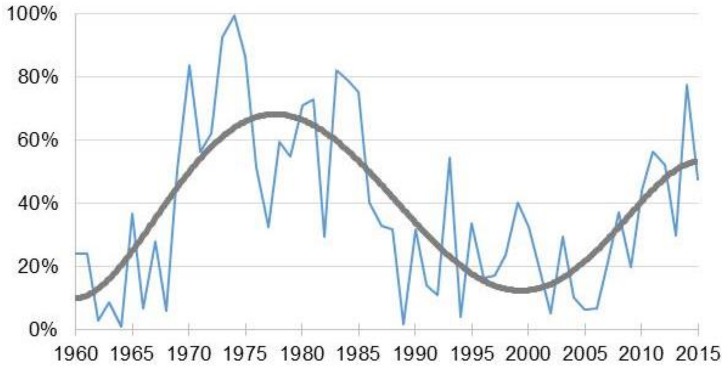


Figure 10 Proportion of Australia's sorghum crop that is exported

Production of sorghum increased 70% between 2014 and 2015, reflecting the increase in demand. Prices have moved slightly lower in Australian dollar terms, with the decline in exchange rate over the period cushioning growers from downward global market price movements (Figure 11).

Figure 11 Grain sorghum indicator prices, Sydney (ABARES)

Price variability has been approximately ±30% over the past three years (with current prices at the low end of the range). The risk in relation to sorghum availability and price may be a disincentive for new entrants intending to produce ethanol from sorghum.

3.3 Current and Proposed Grain-based Ethanol Producers

3.3.1 Wheat

Four companies produce the majority of flour in NSW. One of these, Manildra, has the only integrated milling and refining facility in Australia. This facility, located at Nowra-Bomaderry, has an estimated equivalent wheat processing capacity of 1.2 million tonnes per year, which is used to produce an estimated:

- 150,000 tonnes per year of gluten (as the primary product);
- A quantity of starch A and B, produced as a by-product from gluten manufacture, which is sold primarily to Australian markets; and
- 300,000 ML per year of ethanol derived from the starch by-product from gluten production (current production is about 170,000 ML per annum).

Dongmun Greentec has a proposal to construct a wheat-based non-integrated 115 ML per year ethanol plant at Deniliquin, 200 kilometres northwest of Albury. This proposal involves bran removal using dry milling followed by ethanol refining and drying of DDGS and solubles, using reticulated power and gas. The site in Deniliquin has rail access and good highway access to the Port of Melbourne.

As a potentially viable alternative, the wheat price disadvantage for growers in remote areas offers a strategic opportunity for a new entrant to produce ethanol in those areas, where a local plant developed to produce gluten could ensure sufficient low grade starch for ethanol production, and be competitive in both markets.

An integrated facility could demonstrate a highly profitable business model, combining flour milling, gluten production, ethanol refining and DDGS production in rural areas for local use in new feedlots. This option relies on wheat diverted from export (in a period of excess supply).

This type of facility would provide considerable economic growth to rural areas, and the scale of wheat production capacity suggests that there could be significant economies of scale advantages.

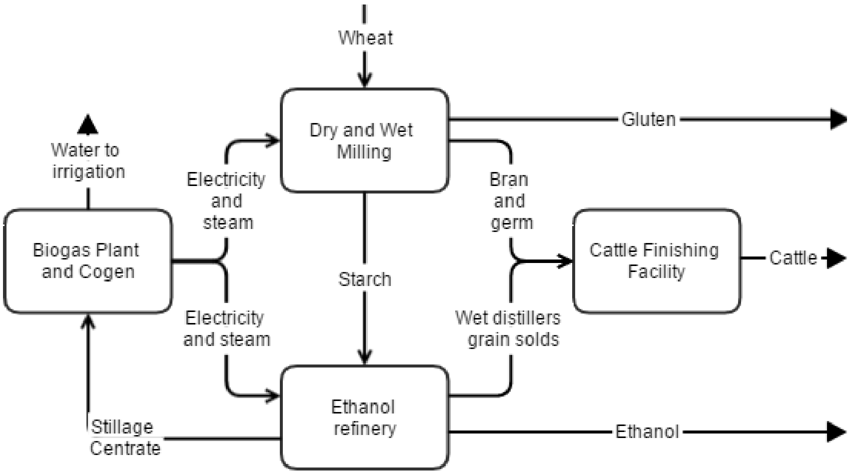


Figure 12 Sketch of a possible integrated production facility

3.3.2 Sorghum

Around 220,000 of the 2.2 million tonnes of sorghum grain currently being produced per year is used by Dalby Bio-ethanol to produce around 76 ML per year of fuel alcohol and 160,000 tonnes per year of DDGS.

The production process is very similar to that used for wheat starches (Figure 7). The current producer is integrated with a fuel wholesaler/retailer, allows the owner to capture the full value of the ethanol. There appears to be sufficient supply to support a new entrant, but if the price of sorghum recovers the cost of feedstock may become an issue. As is now the case with wheat, supply may exceed demand in the future, which would force grower prices down and provide an incentive to find an alternative market for the grain.

3.4 Production Costs and Logistics

3.4.1 Wheat (starch)

A new entrant ethanol plant with production capacity of 100 ML of ethanol per annum using C-grade starch feedstock is estimated to require an investment of approximately $147 million. Production at full capacity would involve:

- Purchase of starch feedstock estimated to cost $40 million, based on an assumed cost of $200 per tonne (price data is not publically available), assuming that sufficient quantities are available for purchase;
- $16 million in direct costs associated with ethanol production in central NSW, including utilities, staff, freight of ethanol to Sydney, etc;
- Maintenance and indirect (overhead) costs totalling about $9 million;
- A return on assets of approximately $15 million (using a post-tax real WACC of 7.3% as advised by IPART and assuming that 25% of the capital is debt-funded); and
- Production of co-products that could be sold to earn approximately $13 million in revenue (used to offset production costs).

Sales and marketing costs are not provided for, assuming that sales would be direct to a fuel wholesaler under contract.

This scenario would produce ethanol at about $0.69 per litre delivered to Sydney from central NSW. It may not be possible to secure supply of sufficient low grade starch, however, so a standalone facility relying on purchased starch may not be practical.

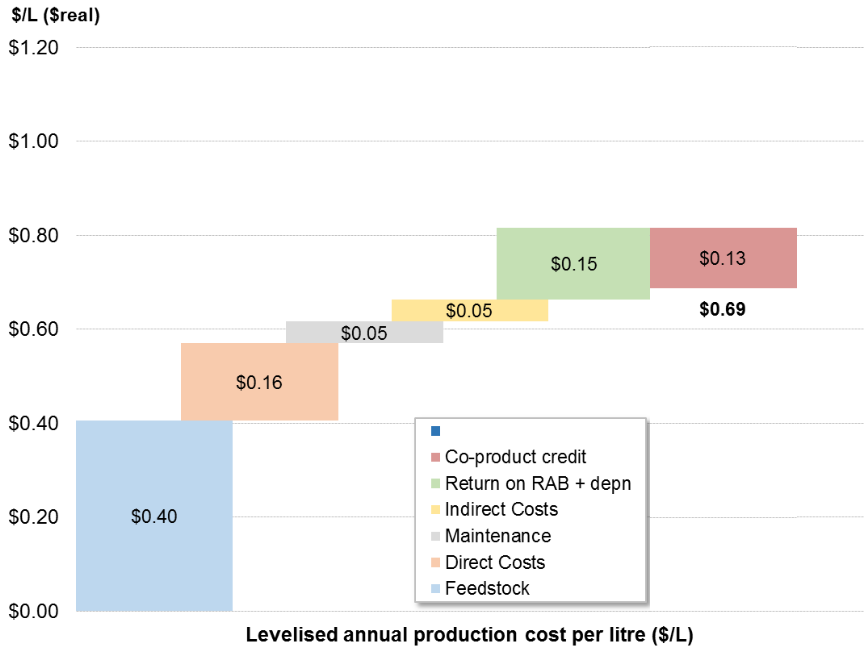


Figure 13 Levelised cost of ethanol production from purchased starch

A more comprehensive summary of production assumptions is included in Appendix C and of cost estimates used in Appendix D. A detailed breakdown of all costs incurred is included in the operational and financial model developed during this study.

The cost of feedstock is 50% of the total production cost of ethanol (excluding co-product credit), and financial performance is very sensitive to changes in this cost. The cost of starch is influenced by seasonal factors affecting wheat production, which therefore pose a significant risk to both financial performance and the cost of the ethanol. This risk may be mitigated by long-term supply contracts.

A 10% increase in feedstock cost would increase the cost of the ethanol by $0.04 per litre.

The offsets available include sale of stock feed products and credits for renewable energy generation, both of which tend not to be as volatile as the cost of starch.

3.4.2 Integrated gluten / ethanol production

Access to low grade wheat-based starch may be difficult for a new entrant, since there is currently only one significant supplier and an established market for the product. We consider that the most viable option to produce ethanol from wheat is to adopt and adapt the integrated model shown in Figure 12. This would involve making use of lower wheat prices available in central NSW to locate an integrated gluten and ethanol production facility close to the source of the crop and to establish long-term supply contracts with the local farmers.

The scope of this study does not include a review of the cost of gluten manufacturing. We have therefore considered how the standalone production facility reviewed in Section 3.4.1 would differ if it was associated with a gluten plant rather than attempt to allocate costs between integrated gluten and ethanol production facilities.

We consider that the ethanol part of the proposed integrated facility would be likely to benefit in two ways when compared to a standalone ethanol production plant that must purchase and source its starch:

- We noted in page 13 that the wheat price differential between a rural centre and a port is as much as 30%. Not all this difference would accrue to the cost of the starch produced by a gluten plant located at the rural centre. We have assumed that the cost of the wheat used will be approximately 33% of the cost of gluten/starch production, implying that the cost of the starch produced could be 10% lower than it would be otherwise. The standalone facility reviewed in 3.4.1 has therefore been adjusted to allow for the lower cost of starch.
- Indirect (overhead) costs could be reduced if these are spread over both the gluten and the ethanol facilities. We consider that this could reduce the overheads applicable to the ethanol plant by as much as 30%.

With these two assumptions, the cost of ethanol delivered from an integrated new entrant gluten and ethanol production facility with 100 ML per annum capacity would be lower than the cost from a standalone facility by about $0.05 per litre of ethanol, or an estimated $0.64 per litre delivered to Sydney from central NSW.

This cost structure for ethanol production from an integrated gluten and ethanol production facility located in central NSW is illustrated in Figure 14, which presents the costs on a per-litre of ethanol basis.

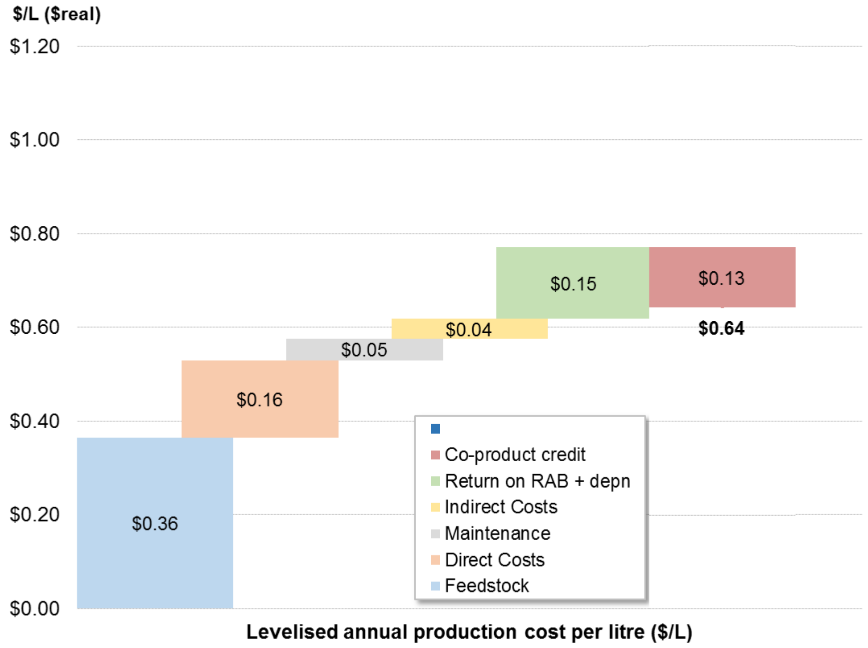


Figure 14 Levelised cost of ethanol production from an integrated facility located in central NSW

It should be noted that this option would enable avoidance of transport costs that would otherwise be required to move the wheat to port, and reduce transport-related emissions.

A more comprehensive summary of production assumptions is included in Appendix C and of cost estimates used in Appendix D. A detailed breakdown of all costs incurred is included in the operational and financial model developed during this study.

The cost of feedstock would be 47% of the total production cost of ethanol (excluding co-product credit), and financial performance is very sensitive to changes in this cost. The cost of starch is influenced by seasonal factors affecting wheat production, which therefore pose a significant risk to both financial performance and the cost of the ethanol. This risk may be mitigated by long-term supply contracts.

A 10% increase in feedstock cost would increase the cost of the ethanol by $0.04 per litre.

The offsets available include sale of stock feed products and credits for renewable energy generation, both of which tend not to be as volatile as the cost of starch.

3.4.3 Imported starch (cassava chips)

The upper price limit for domestic sources of starch would be equivalent to the lowest landed cost of a suitable alternative, so for completeness a review of the production of ethanol using imported starch has been included. The two forms of starch mostly widely traded are cassava chips and tapioca starch, both widely produced in large quantities in Asia and the Pacific. The lowest cost option is the cassava, which is currently trading at around US$180 per tonne but has varied between +60% and -40% of current prices (Figure 15 and Figure 16).

Current prices are close to the mean of the past ten years, so this option has assumed a cost of feedstock of $285 per tonne for cassava chips landed at a possible facility built adjacent to the Port of Newcastle (selected for this comparison based on its proximity to Sydney).

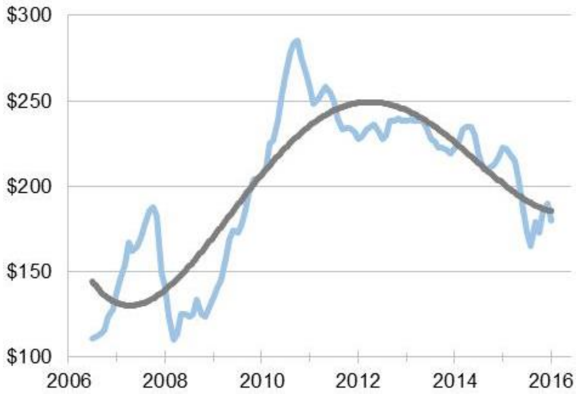


Figure 15 Cassava chip prices US$ FOB Bangkok

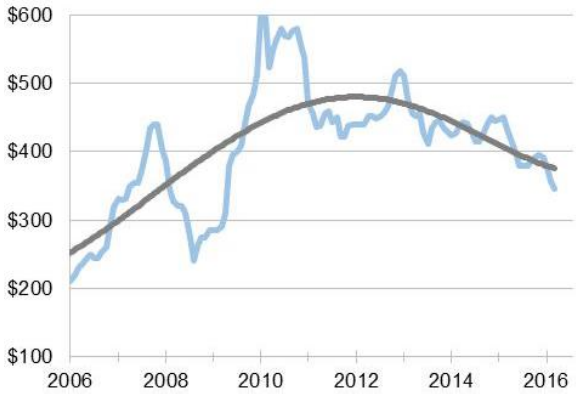


Figure 16 Native Tapioca prices US$ FOB Bangkok

Cassava is being trialled as a commercial crop in Queensland but there is unlikely to be sufficient feedstock for use by an ethanol production facility for several years. The availability of local cassava chips may provide a cost advantage for a local ethanol plant if a long-term supply contract is in place.

A new ethanol plant with production capacity of 100 ML of ethanol per annum using imported cassava is estimated to require an investment of approximately $144 million. Production at full capacity would involve:

- Purchasing and importing feedstock estimated to cost $64 million (at current import prices);
- $9 million in direct costs associated with ethanol production at Newcastle, including utilities, staff, freight of ethanol to Sydney, etc;
- Maintenance and indirect (overhead) costs totalling about $9 million;
- A return on assets of approximately $15 million (using a post-tax real WACC of 7.3% as advised by IPART and assuming that 25% of the capital is debt-funded);
- Production of co-products that could be sold to earn approximately $7 million in revenue (used to offset production costs).

Sales and marketing costs are not provided for, assuming that sales would be direct to a fuel wholesaler under contract.

This scenario would produce ethanol at about $0.90 per litre delivered to Sydney. This cost structure is illustrated in Figure 17 which presents the costs on a per-litre of ethanol basis.

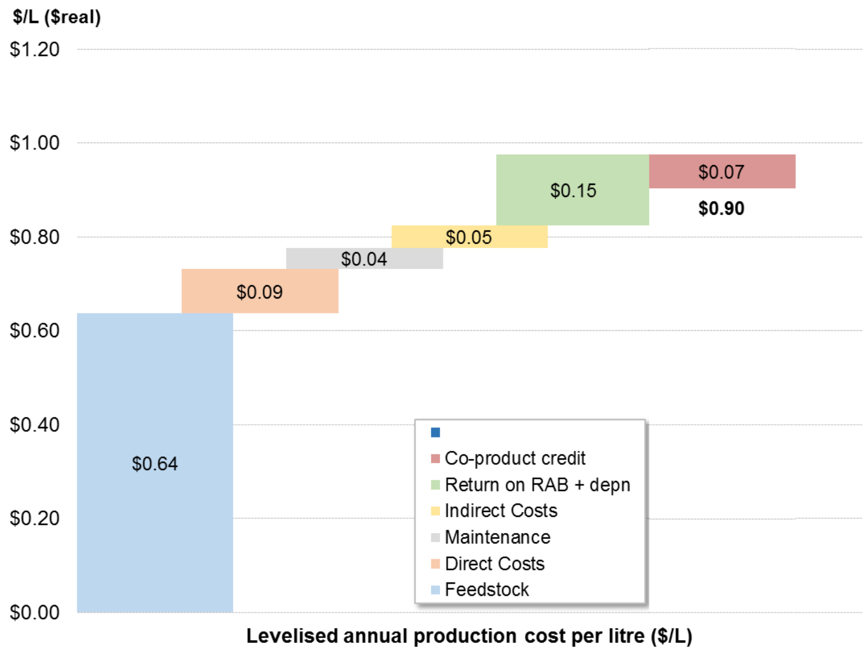


Figure 17 Levelised cost of ethanol production at Newcastle using imported starch (cassava)

This may be the most viable option for onshore production of ethanol from imported feedstock. At the price indicated, it would not be an attractive option to pursue, but it is readily scalable. The cost of feedstock would be 66% of the total production cost of ethanol (excluding co-product credit), and financial performance would be very sensitive to changes in this cost. Cassava is traded in bulk, and the cost is determined by global prices.

A 10% increase in feedstock cost would increase the cost of the ethanol by $0.07 per litre.

An on-shore cassava-based ethanol production facility located on-farm could have access to feedstock produced at a cost estimated to be about $0.32 per litre of ethanol (benefiting from the very attractive yields available in the Burdekin). This outcome could make use of locally grown cassava for ethanol production an attractive proposition.

Pilot plantations have been established in Queensland, but it is too early to estimate the likely cost of Australian-grown cassava if dedicated for ethanol production.

3.4.4 Sorghum

An ethanol plant with production capacity of 100 ML of ethanol per annum using sorghum is estimated to require an investment of approximately $180 million. Production at full capacity would involve:

- Purchasing of feedstock estimated to cost $47 million at August 2016 prices ($172 per tonne in Darling Downs);
- $17 million in direct costs associated with ethanol production in Darling Downs, including utilities, staff, freight of ethanol to Sydney, etc;
- Maintenance and indirect (overhead) costs totalling about $12 million;
- A return on assets of approximately $19 million (using a post-tax real WACC of 7.3% as advised by IPART and assuming that 25% of the capital is debt-funded);
- Production of co-products that could be sold to earn approximately $18 million in revenue (used to offset production costs).

Sales and marketing costs are not provided for, assuming that sales would be direct to a fuel wholesaler under contract.

This scenario would produce ethanol at about $0.77 per litre delivered to Sydney. This cost structure is illustrated in Figure 18 which presents the costs on a per-litre of ethanol basis.

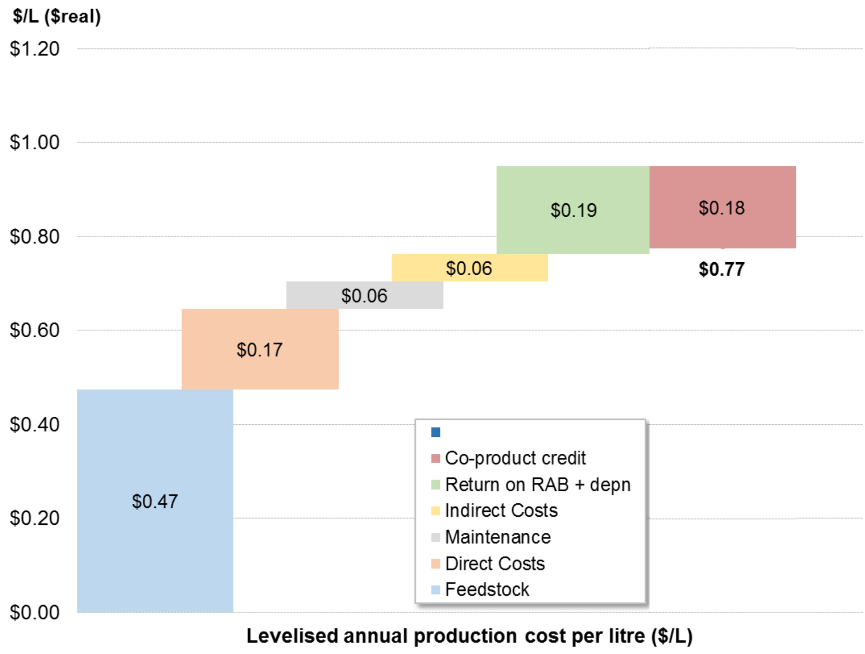


Figure 18 Levelised cost of ethanol production from sorghum

The availability and cost of sorghum feedstock is increasingly being driven by demand from China, and current expectations are that feedstock costs are likely to increase significantly in the short to medium term. Every 10% increase in feedstock price would add another $0.05 per litre to the delivered cost of the ethanol.

The cost of feedstock would be 50% of the total production cost of ethanol (excluding co-product credit), and financial performance is sensitive to changes in this cost. The cost of sorghum is influenced by demand from China. This risk could be mitigated with long-term supply contracts.

3.5 Externalities

Grain-based ethanol production would be self-sufficient in terms of energy.

Exporting of wheat incurs a high transport and storage cost, and relatively high levels of transport-based carbon dioxide emissions. The process involves a number of transacting parties that produce little added value to the grain.

Production of ethanol from grain based would displace wheat as an export commodity, which may have impacts on the export market for wheat and Australia's terms of trade.

Specific co-products relating to the production of ethanol from grain-based feedstocks include:

- Stillage (or dunder), which can be used to produce fertiliser and gasified to generate electricity; and
- DDGS, which is a high quality stockfeed.

3.6 Issues and Constraints

Three possible starch-based feedstocks have been reviewed. Of the three:

- Wheat offers a large and increasing quantity of feedstock, where wheat would be diverted from export and used locally, benefitting from minimisation of transport costs and associated externalities. Grade C starch is a residue from gluten production, and may not be readily available to a new entrant standalone ethanol producer.
- Sorghum prices are being driven by demand from China for the feedstock. This issue could be overcome through use of an integrated production business model or long-term supply contracts.

- Cassava is not likely to be attractive if ethanol production relies on imported feedstock, but current indications are that dedicated cassava cropping for ethanol production would be an attractive proposition (and pilot crops have been planted in the Burdekin).

The most promising opportunity at this time is the use of wheat. The cost of feedstock can be managed by locating ethanol production in remote rural areas (near to a railhead) to take advantage of lower wheat prices there, and by developing to produce and sell gluten, the higher value starches, ethanol produced from the lower value starches) and DDGS for local use as stockfeed. The opportunity suits a cooperative business model, with equity available for the local farmers.

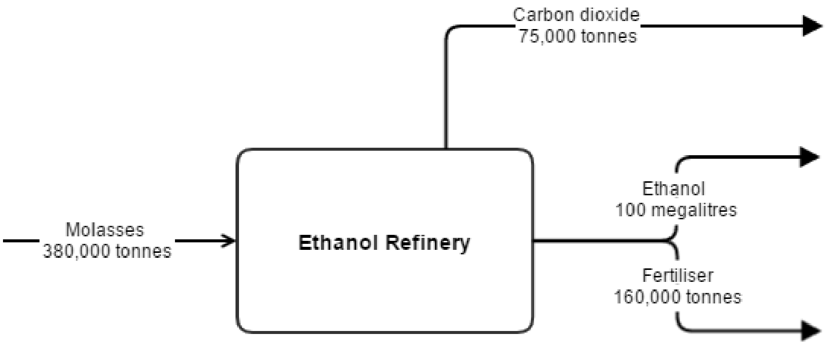
4.0 The Production of Ethanol from Sugar-based Feedstocks

In Australia, the sucrosic or sugar-based pathway relies on molasses, a sugar milling by-product. Plant located adjacent to existing sugar mills offers established utilities, laboratories, labour and administration and transport which can lower the cost of ethanol production.

4.1 The Sucrosic Production Process

Molasses is produced as a by-product from the crystallisation process of a raw sugar mill.[23]

It is produced as three syrups (A, B and C), one of which (the C-syrup) is the residue from which it is no longer economic to extract sugar. The combined "sugars" content in Australian molasses is about 50% by weight, and the fermentable content is typically around 47% (compared to 52% and 60% for A and B-syrup respectively).



C-syrup is currently used mainly in the fermentation (ethyl alcohol, yeast, lysine and monosodium glutamate) and stockfeed industries, and approximately 33% is exported, although exports decline during periods of drought when stockfeed demand is high. When used for ethanol production, the C-syrup is pumped or trucked from sugar mills to an ethanol refinery, where it is held in large underground bladders for processing through the year. The syrup is fermented in a series of large tanks and water and contaminants removed using distillation and rectification followed by a molecular sieve to increase concentration to 99.9% by weight of ethanol. A small amount of gasoline is added to denature the ethanol prior to delivery to fuel blending sites.

The process would produce a major by-product called dunder, which contains unfermented sugars, bio-active fermentation yeasts and mineral content. The dunder is centrifuged to separate solids from water and soluble organics which are biologically treated in a biogas plant to recover biogas and reduce the organic load.

The residual high nutrient water would be used for nearby farm irrigation, and the biogas used to generate electricity. The hot exhaust would be used to produce process steam. The solids from centrifugation would be blended with nutrients to produce a bio-active fertiliser for cropland or used in stockfeed.

4.2 Feedstock Availability in Australia

There are three sucrosic feedstocks available in Australia, and at least one other with potential:

Sugar Cane	Sugar cane is an established crop and can be used to produce ethanol at greenfield sugar mills. A pilot production plant is currently under construction at Pentland in North Queensland.
Molasses	Molasses is a by-product of sugar production. It is currently being used to produce ethanol and alcohol at Wilmar’s Plane Creek Ethanol Refinery, the Rocky Point Sugar Mill’s Ethanol refinery, Diageo’s Bundaberg Rum Distillery and Finesucre’s Millaquin Sugar Mill in Bundaberg.
Sweet Sorghum	Sweet Sorghum is a desirable feedstock for dedicated, greenfield ethanol refineries co-located on-farm. It generates a high yield and has a simple processing route. There are currently trial plantations in progress and pilot plants are being constructed (Pentland Bioenergy Plant Project, Kimberly Agricultural Investments).
Agave	Agave typically used to produce tequila, which has higher commercial value than ethanol. There is currently not enough feedstock for ethanol production in Australia. Agave generates a high yield with a minimal reliance on water, and is a promising feedstock. AusAgave currently has trial plantations in progress.

[23] The process design, equipment specification and costs used for this process have been developed by AECOM from a variety of sources. We have not had access to any production information from an Australian proponent.

The major sucrosic opportunity is molasses (C-syrup), produced at about 2.8% of the cane harvest during the crushing season. B-syrup can also be used, and contains around 2.5 times the fermentable sugars that C-syrup has, but unlike C-syrup, its value is linked to the price of sugar. This makes it a more expensive, albeit more abundant feedstock.

Production in Australia is linked to sugar cane grown from northern NSW to north of Cairns. Total production has increased from 700,000 tonnes in 2010 to 900,000 tonnes in 2015, but is constrained by drought.

Molasses availability can be assumed to be approximately as indicated in Figure 19.

Potential Annual Production	**Molasses C Syrup**		**Molasses B Syrup**	
	Tonnes	Ethanol (ML)	Tonnes	Ethanol (ML)
North QLD	280	74	690	200
Burdekin	240	63	590	170
Central QLD	250	66	600	175
less Wilmar	*-230*	*-60*		
South (SEQ+NNSW)	135	35	330	100
Total	**675**	**178**	**2,210**	**645**

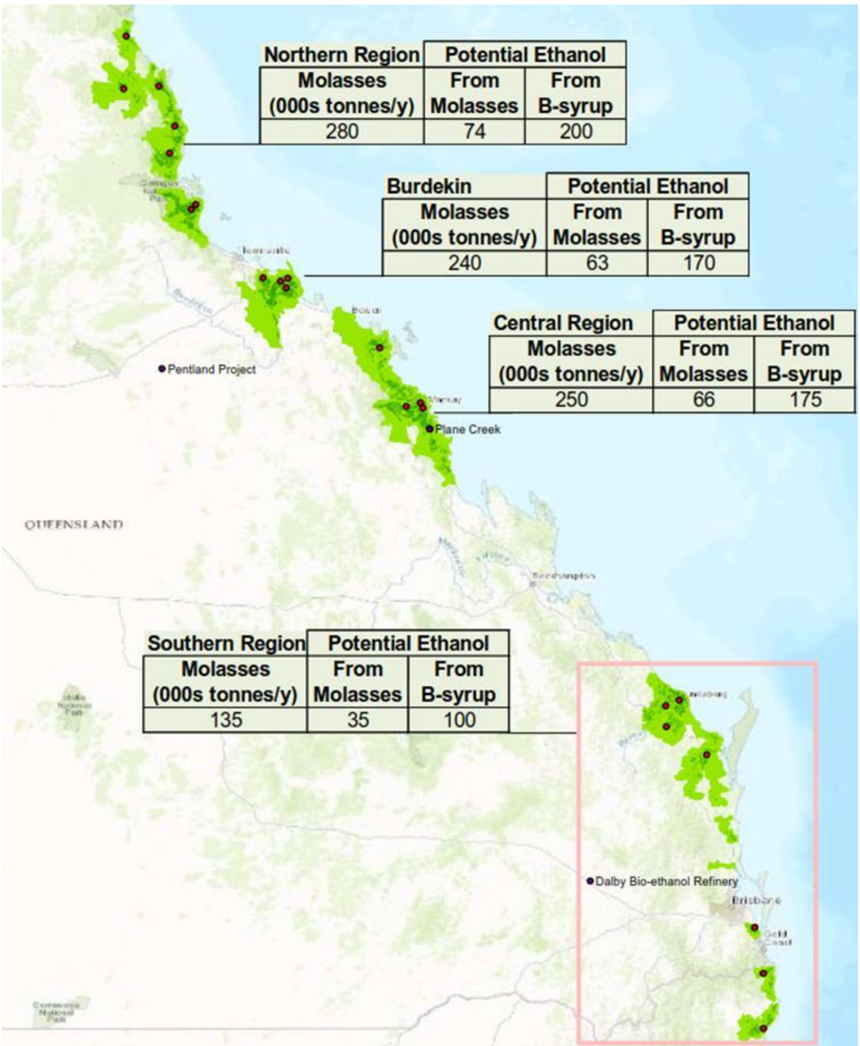


Figure 19 Molasses availability and ethanol yield

4.3 Feedstock prices

Sugar mills require certainty that molasses will be sold and removed from site. Large capacity storage has been developed at various ports to accommodate holding of molasses prior to shipping to export markets.

The C-syrup price is typically in the range of $100 to $130 per tonne, and is influenced by:

- Seasonality:
    - Availability is high during mill crushing and low prior to the start of harvesting;
    - Demand is low during wetter periods when grass and grain stockfeed is available; and
    - Demand increases during dry periods and is very high during drought conditions.
- Exchange rates (a weak exchange rate promotes exports).

A and B-syrup prices are determined by the international price of sugar, which depends on Brazilian regulated ethanol price and their exchange rate as well as climatic conditions arising from El Nino/La Nina perturbations. Prices are currently above $550 per tonne as sugar moves into short supply, but it was traded at close to $320 per tonne at the bottom of the cycle earlier this year (Figure 20, which uses US cents per pound). The price variability over the three years shown is approximately ±30%.

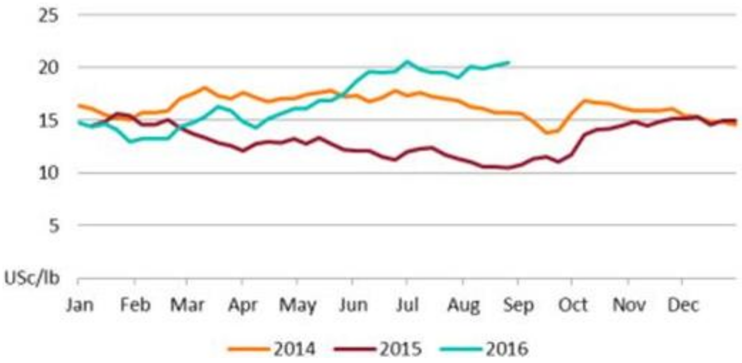


Figure 20 Global sugar prices (ABARE)

At low sugar prices, ethanol production may offer a better outcome for B-syrup, particularly where a fuel ethanol floor price is mandated like Brazil. As noted, the price of C-syrup is not closely linked to sugar prices.

4.4 Current and Proposed Sucrosic Ethanol Producers

Three organisations currently produce ethanol from molasses:

- Wilmar Sugar Mills operates an ethanol refinery at Plane Creek (and sugar mills in the Herbert, Burdekin and Mackay regions). The refinery has a production capacity of 117 ML but is currently producing only 60 ML of ethanol.
- Other producers include Diageo in Bundaberg located at Bundaberg Sugar's Millaquin Sugar Mill, which has a production capacity of 12 ML and is currently producing 8 ML.
- Rocky Point Sugar Mill also operates a small sugar mill and is at full capacity producing 1.5 ML of ethanol.

Organisations that have either been running pilot plant or have announced their intention to invest in molasses-based ethanol production include:

- **NQ Bioenergy (NQBE)**

  NQBE has gained access to cane production area in the district which will provide the required minimum amount of feed stock (2.5 to 3 million tonnes of cane per season) with growers having signed binding contractual cane supply agreements.

  Feedstock outside the sugar cane harvesting season will be drawn from fallow crops such as sweet sorghum, timber off-cuts, and council green waste.

- **Renewable Developments Australia (RDA)**

  RDA has commenced a feasibility study to support financing arrangements for a greenfield irrigated 19,000 ha sugar farm and 190 ML per year ethanol refinery located near Pentland. Renewable Developments Australia has negotiated an off-take arrangement for ethanol through CHS, a global ethanol trader. The agreement is based on the export of ethanol to meet regional demand for ethanol primarily to the Philippines, implying that the refinery expects to operate profitably and compete with international ethanol prices – currently at $0.49 USD per litre as reported in “Biofuels Digest”[24]. This is equivalent to a production cost of $0.65 AUD, excluding delivery.

  The proposed Pentland facility will use cane juice as the source of fermentation material, avoiding the high cost of sugar milling into crystal. The juice is recovered by shredding the cane with juice extracted using a diffuser and clarified prior to fermentation. By-products include electricity. Minimal processing of dunder is required as it is used on the cane fields around the ethanol refinery, and process water is re-used for irrigation.

  Based on a cane farm producing and delivering 120 tonnes per hectare at $4,000 per hectare, the fermentables are estimated to cost around $0.39 per litre of ethanol.

  Higher yields are potentially available using other plant varieties, and RDA has invested in the development of a strain of super sweet sorghum that should suit their growing conditions and could increase yields by a factor of two, and is now piloting plantations. The super sweet sorghum would cost more to grow and store, but the cost of the super sweet sorghum-based ethanol feedstock is still expected to be significantly lower than cane-based feedstock.

4.5 Production Costs and Logistics

An ethanol plant with production capacity of 100 ML of ethanol per annum using molasses C-syrup is estimated to require an investment of approximately $148 million. Production at full capacity would involve:

- Purchasing C-syrup feedstock at an estimated $46 million;
- $27 million in direct costs associated with ethanol production in the Burdekin, including utilities, staff, freight of ethanol to Sydney, etc;
- Maintenance and indirect (overhead) costs totalling about $9 million;
- Require a return on assets of approximately $15 million (using a post-tax real WACC of 7.3% and assuming that 25% of the capital is debt-funded);
- Produce co-products that could be sold to earn approximately $25 million in revenue (used to offset production costs).

Sales and marketing costs are not provided for, assuming that sales would be direct to a fuel wholesaler under contract.

This scenario would produce ethanol at about $0.72 per litre delivered to Sydney. This cost structure is illustrated in Figure 21 which presents the costs on a per-litre of ethanol basis.

[24] http://www.biofuelsdigest.com/bdigest/2016/10/20/philippines-boosts-january-monthly-ethanol-allocation-to-75835-cu-m/

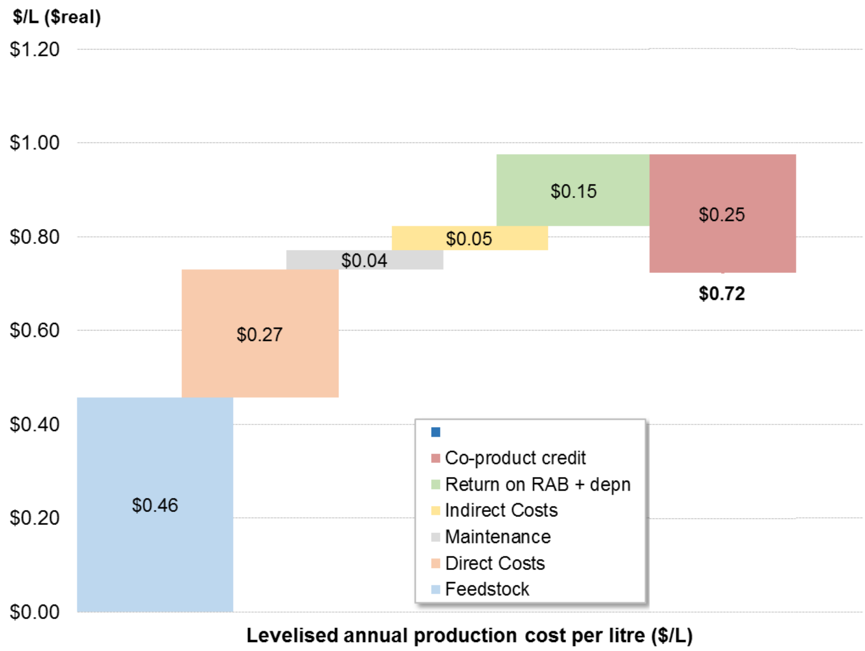


Figure 21 Levelised cost of ethanol production, using molasses C-syrup

A more comprehensive summary of production assumptions is included in Appendix C and of cost estimates used in Appendix D. A detailed breakdown of all costs incurred is included in the operational and financial model developed during this study.

The cost of feedstock would be 47% of the total production cost of ethanol (excluding co-product credit), and financial performance would be very sensitive to changes in this cost. The cost of molasses is strongly influenced by seasonal factors, which therefore pose a significant risk to both financial performance and the cost of the ethanol. This risk could be mitigated by long-term supply contracts.

A 10% increase in feedstock cost would increase the cost of the ethanol by $0.05 per litre.

The offsets available include sale of stock feed products and credits for renewable energy generation, both of which tend not to be as volatile as the cost of molasses.

If the plant were to rely on B-syrup, the cost of production would change to reflect the higher cost feedstock, implying a cost structure as presented in Figure 22. This scenario would produce ethanol at about $1.02 per litre delivered to Sydney.

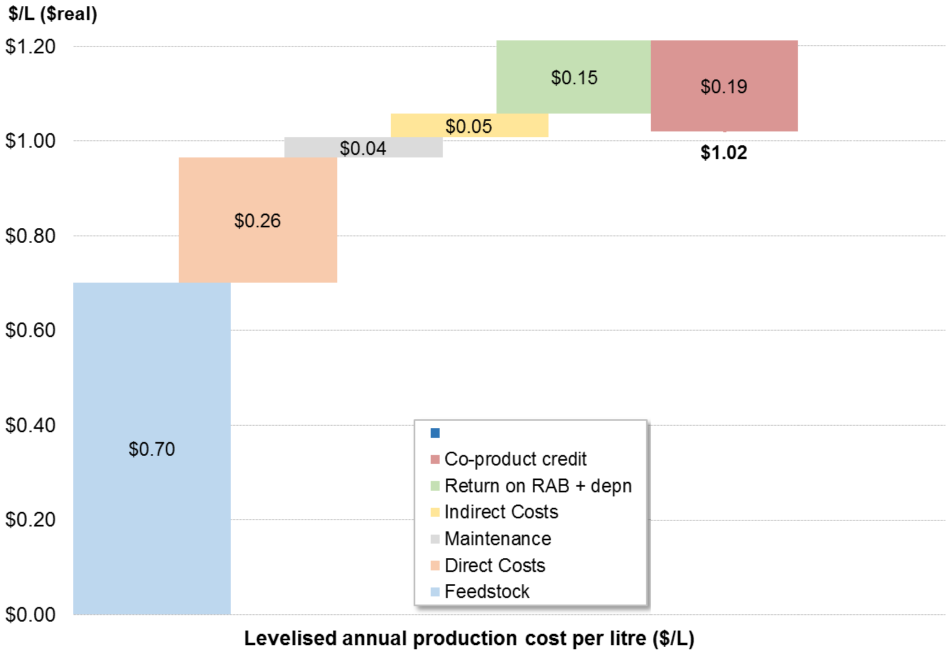


Figure 22 Levelised cost of ethanol production using molasses B-syrup

The cost of feedstock would be 58% of the total production cost of ethanol (excluding co-product credit), and financial performance would be very sensitive to changes in this cost. The cost of molasses is strongly influenced by seasonal factors, which therefore pose a significant risk to both financial performance and the cost of the ethanol. This risk could be mitigated by long-term supply contracts.

A 10% increase in feedstock cost would increase the cost of the ethanol by $0.07 per litre.

4.6 Externalities

The feedstock used is derived from by-products from sugar extraction, and tailpipe emissions from growing and harvesting sugar cane are attributed to the primary product (raw sugar).

Emissions associated with ethanol are largely related to the fermentation process which loses around 49% of the mass of fermentable material as a very pure form carbon dioxide, and generation of biogas which is converted to carbon dioxide.

Displacing molasses as a stockfeed may create additional externalities related to cattle-carrying / fattening capacity. Specific externalities relating to the production of ethanol from sugar based feedstocks that have been identified include:

- Displacement of molasses as a commodity, which may have an impact on the local and export markets for sugar, and on Australia's terms of trade.
- Replacement of molasses with dunder as a stockfeed, which may have impacts on the stockfeed market and result flow on effects from replacing molasses with a different stockfeed

Onsite power co-generation would make the plant self-sufficient and could be used to offset the production costs of the plant by feeding excess electricity back into the grid.

4.7 Issues and Constraints

There is potential to improve yields by growing cane specifically for ethanol production, encouraging fibre rather than sugar content. There are fibre cane varieties used in Brazil that could be imported, but are subject to a two year quarantine period and trial plantings to prove viability. North Australia has large tracts of flat land suitable for intensive cropping and sustainably harvestable water, which makes it ideally suited for fibre cane production.

Use of fibre cane could increase yields by as much as a factor of two (making it similar to super sweet sorghum), removing price and availability constraints currently imposed by the sugar and stock feed markets.

5.0 The Production of Ethanol from Cellulose-based Feedstocks

Australia has substantial reserves of cellulosic feedstocks, including forestry and milling residues, trash remaining from cane, wheat, cotton and rice production, and other sources of green waste. Most of this residue currently has no value, and a significant proportion is burned to remove it.

5.1 The Cellulosic Production Process

The cellulosic process is substantially based on a two stage, low acid pre-treatment process followed by enzymatic hydrolysis.[25][26]

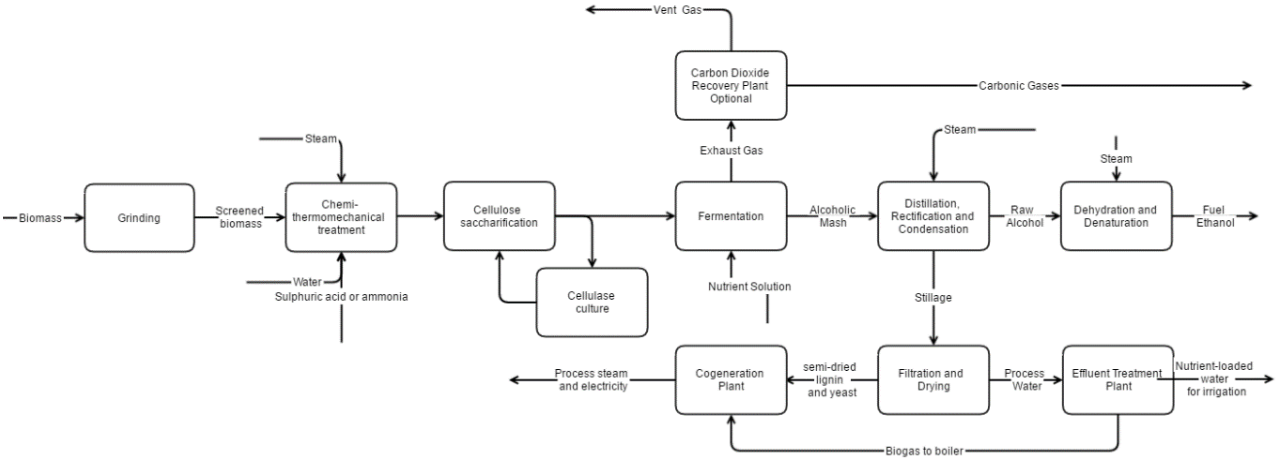


Figure 23 Schematic of the cellulosic production process

Forest residues and thinnings would be chipped in-forest and screened prior to delivery to site in side-tipping B-double trucks. The stockpile at site would be built by trucks discharging onto the stockpile with a dozer and extended pushing blade. Cane trash and mallee eucalypt would be supplied using the same method.

Chemi-thermomechanical treatment is required to breakdown the biomass, to convert hemi-cellulose to soluble sugars such as xylose and to soften and solubilise lignin to enhance cellulose availability, taking care to avoid excessive degradation of the hemi-cellulose and cellulose to avoid sugar degradation products which reduce yield and subsequently act against enzyme activity.

Following the pre-treatment step, cellulose and xylose from hemi-cellulose would be converted to glucose by enzymatic action. The conversion occurs simultaneously with the fermentation of glucose to ethanol. This process occurs in staged tanks over a period of five days. As glucose is fermented and removed, the enzymatic conversion of cellulose and xylose to glucose is encouraged.

The major cost in lignocellulosic ethanol is the cost of production of sufficient enzyme to convert cellulose to glucose and hemi-cellulose to xylose for subsequent conversion to ethanol. The enzymes can be purchased or produced in-house, but it is likely that in-house production will be more cost-effective. The option modelled for this study therefore involves a co-located enzyme production facility, built and owned by a specialist enzyme producer, with enzymes purchased across the fence to supply the needs of the ethanol refinery. This approach would secure:

- The lowest cost enzyme production;
- Skilled process design and management; and
- State of the art enzymes.

The enzyme reactors use glucose to promote enzyme production. The glucose syrup required can be purchased or manufactured on-site (if the refinery has co-located starch production).

[25] "Process Design and Economics for Biochemical Conversion of Lignocellulosic Biomass to Ethanol: Dilute-Acid Pretreatment and Enzymatic Hydrolysis of Corn Stover", NREL, 2012.
[26] The process design, equipment specification and costs used for this process have been developed by AECOM from a variety of sources. We have not had access to any production information from an Australian proponent.

Following fermentation, conventional distillation, rectification and drying of the ethanol stream would be used to produce fuel ethanol. A small amount of gasoline would be added to denature the ethanol prior to delivery to fuel blending sites

Unlike sugar or grain based ethanol, the stillage produced from the bottom of the distillation column is not suitable for stockfeed or use as a fertiliser. Instead, the stillage would be filtered to remove lignaceous solids and combusted in a boiler to produce steam for generation of electricity and process needs.

The combination of lignin solids and biogas would generate excess electricity which would be sold into the grid to generate income. Additional large generator credits would be available for all renewable electricity generated.

The filtrate containing soluble organic would be pumped to the biogas plant which produces methane biogas. The nutrient-loaded, bio-active water from the biogas plant could be used for irrigation.

5.2 Feedstock Availability in Australia

Key potential feedstocks include:

- Eucalypt forest residues, thinnings and pulpwood;
- Mallee used in farm stabilisation and productivity improvement;
- Radiata pine forest residues, thinnings and pulpwood; and
- Sugar cane trash. Other opportunities such as bagasse and wheat stubble are substantially committed for electricity production and soil amelioration respectively.

Crop stubbles may be available where double cropping occurs and growers seek a quick turnaround time to prepare their field for the next crop or when the presence of crop stubble causes issues. For example, cotton trash can hold over diseases and pests.

The primary cellulosic feedstocks available in Australia are likely to include:

Forest Residues and Waste	There is sufficient feedstock for ethanol production as forest residues, and waste is currently either left to degrade after harvesting or is direct burnt.
Oil Mallee Trees	There is insufficient feedstock for ethanol production in Australia, but recent technology and plantation development in WA indicates industry interest in growing more Oil Mallee Trees. There is a trial plantation in NSW that will be used to supplement the feedstock of the Broadwater Bioenergy Power Plant.
Municipal Green Waste	Municipal green waste is currently sent to landfills. The market for mulch and fertiliser based on this waste stream is saturated, but there may not be sufficient quantities available within range of a new plant to make this resource viable.
Almond & Macadamia Shell	There is sufficient feedstock for ethanol production as almond and macadamia shells are currently either discarded or used to produce garden mulch, and the ethanol production.

5.2.1 Forest Residues

Data on forest biomass in NSW is not currently readily available, so estimates have been made for the purposes of this study. The indications are that there are regions with a total of approximately 1,560 HA of planted forest able to support an ethanol production facility located locally, with potential for a total production capacity of around 974 ML of ethanol per annum (Figure 24).

Two other resources identified (Nyngan and Griffith) are likely to be too small to be viable.

Mallee eucalypts are one of the predominant groups of perennial species utilised to address salinity issues affecting 11 million hectares of agricultural land across Western Australia, South Australia, Victoria and NSW. Because of the scale of the problem, it was always recognised that this revegetation would need to be very extensive and would need to sustain itself economically as a crop in its own right.

In some cases, there are additional cellulosic feedstocks such as wheat trash available locally that could also be processed.

Potential Annual Production	**Forest Residues**		
	Forest Area (HA)	Residue ('000 tonnes)	Ethanol (ML)
QLD / North NSW			
Inglewood	430	1,520	270
Richmond Range	170	600	107
Grafton Forest Area	140	490	87
Central NSW			
Pillaga	300	1,060	188
Nyngan	50	160	29
ACT / South NSW			
Griffith	30	110	20
Tumut	230	810	143
Eden	210	740	131
Total	**1,560**	**5,490**	**974**

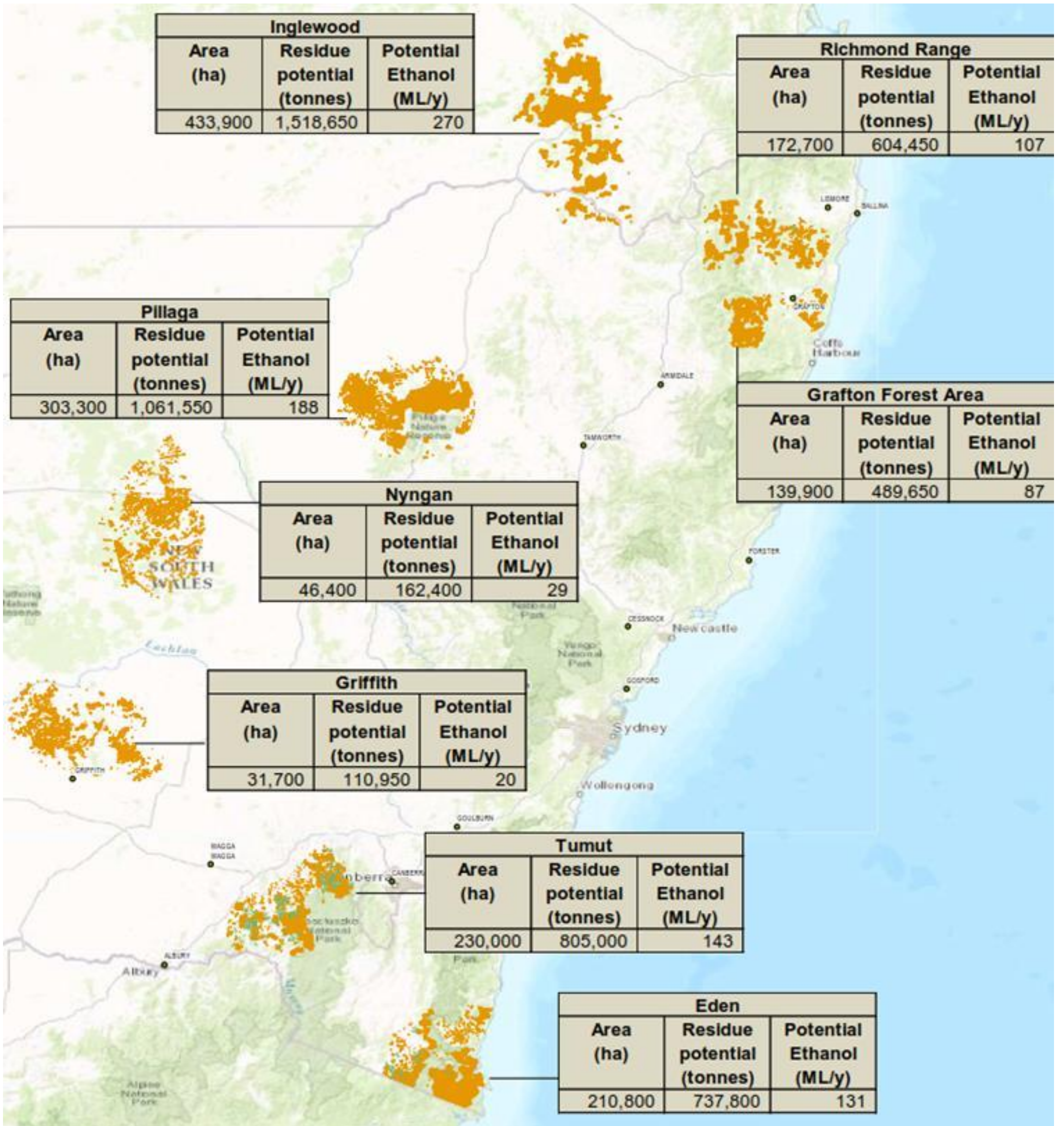


Figure 24 Potential plantation feedstock availability and ethanol yields

5.2.2 Cane trash

Cane trash is the dried leaf material that the growing cane stem sheds as it grows, and represents around 10% of the cane harvested. Pre-harvest burning is required for agronomic purposes in the Burdekin and Northern NSW. Beneficial use of the trash rather than burning is attractive to growers and the community alike in these regions.

The availability of cane trash is indicated in Figure 25. Harvesting of the trash will incur additional costs, but will create additional revenues for growers, harvesting and haulage contractors.

Potential Annual Production	Cane Trash	
	Tonnes	Ethanol (ML)
North QLD	1,000	276
Burdekin	800	221
Central QLD	850	235
South (SEQ+NNSW)	500	138
Total	**3,150**	**869**

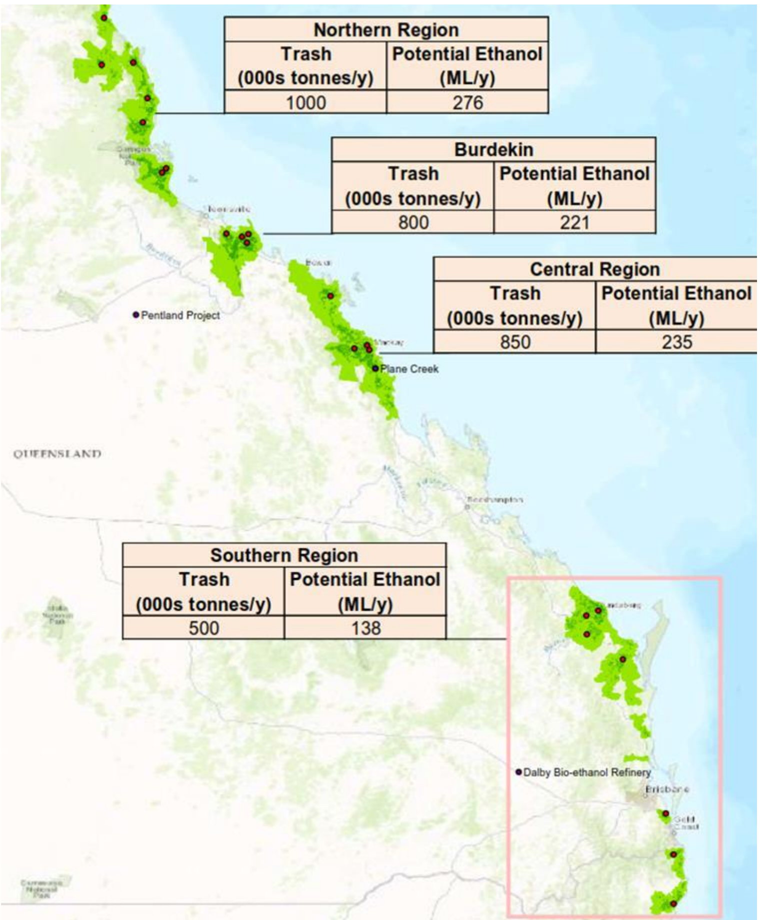


Figure 25 Cane trash availability and ethanol yield

5.3 Current and Proposed Cellulosic Ethanol Producers

Cellulosic ethanol facilities in Australia are limited to pilot plants including:

- **Mackay Renewable Bio-commodities Pilot Plant**

  In 2007, the Queensland University of Technology (QUT) received funding from the Australian and Queensland Governments to construct a pilot research and development facility for the production of bioethanol and other renewable bio commodities from biomass including sugarcane bagasse. This facility has been built on the site of the Racecourse Sugar Mill in Mackay, Queensland and is known as the Mackay Renewable Bio commodities Pilot Plant (MRBPP). This research facility is capable of processing cellulosic biomass by a variety of pre-treatment technologies and includes equipment for enzymatic saccharification, fermentation and distillation to produce ethanol. Lignin and fermentation co-products can also be produced in the pilot facility.

- **Ethtec**

  Ethtec's pilot plant at Harwood Sugar Mill to evaluate and develop new cellulosic technologies based on licensed technology from Apace Research Limited.

  Ethtec has a world-wide exclusive licence from Apace Research Limited ("Apace Research") to further develop and commercialise technologies developed by and under the direction of Apace Research for the production of ethanol from lignocellulosic material.

  Over the past 25 years Apace Research has received a number of Australian Federal Government grants to develop new technologies for the production of ethanol from lignocellulosic material. In collaboration with the University of Southern Mississippi (United States of America), the Tennessee Valley Authority (United States of America) and the University of New South Wales (Australia), Apace Research has developed and demonstrated this technology at laboratory and mini-pilot plant scale.

  Ethtec intends to construct a full-scale plant in the Ingham alongside NQ Bio-energy Corporation's proposed sugar mill in Ingham, which has environmental impact approvals but is yet to be constructed.

  Ethtec's technology is unique and adapted to high ethanol yield at a minimum cost. It takes a new approach across the ethanol refining process which has the potential to lead to new processing arrangements for conventional ethanol refineries.

- **Microbiogen**

  Microbiogen is currently focussed on yeast development to support cellulosic ethanol and improved strains for convention ethanol and other products.

  Microbiogen is an industrial biotechnology company that specialises in the development, licensing and deployment of improved industrial strains of Saccharomyces cerevisiae yeast.

  The company has developed new and novel yeast strains that can lead to improved production from traditional fuel ethanol facilities and lignocellulosic ethanol facilities amongst others. The company's strategy is to focus on its core competitive advantage of yeast strains development and then partner and license its enhanced yeast strains to large corporations that can incorporate these breakthroughs into large scale, capital intensive bio-refineries. The partnering and license strategy is believed to be the best way to have world leading home grown Australian technology deployed globally and locally in Australia.

Further development is proposed by:

- **Renewable Development Australia (Pentland Project Stage 2)**

  RDA has proposed to use Italian group, Beta Renewables Proesea technology which is operating in a full scale facility in Cresentino, Italy.

  The first stage of the Pentland Project, currently in pre-construction, is based on 190 ML of ethanol from sugar cane. The second stage will convert to sweet sorghum to provide additional biomass for cellulosic ethanol to be produced.

- **NQ Bio-energy Corporation Limited (Ingham Sugar and Bio-Energy Project)**

5.4 Production Costs and Logistics

5.4.1 Forest Residues

An ethanol plant with production capacity of 100 ML of ethanol per annum using forest residue and similar feedstocks is estimated to require an investment of approximately $287 million. Production at full capacity would involve:

- An estimated $29 million to collect and transport the forest residue to the plant;
- $40 million in direct costs associated with ethanol production near Tumut, including utilities, staff, freight of ethanol to Sydney, etc;
- Maintenance and indirect (overhead) costs totalling about $18 million;
- A return on assets of approximately $30 million (using a post-tax real WACC of 7.3% as advised by IPART and assuming that 25% of the capital is debt-funded);
- Production of co-products that could be sold to earn approximately $10 million in revenue (used to offset production costs).

Sales and marketing costs are not provided for, assuming that sales would be direct to a fuel wholesaler under contract.

This scenario would produce ethanol at about $1.07 per litre delivered to Sydney. This cost structure is illustrated in Figure 26 which presents the costs on a per-litre of ethanol basis.

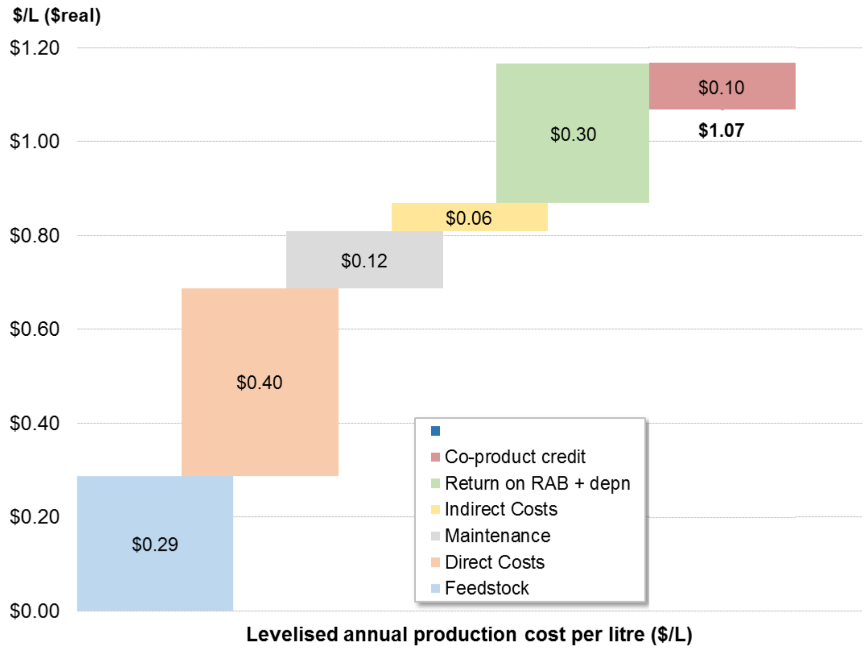


Figure 26 Levelised cost of ethanol production from forest residues

A more comprehensive summary of production assumptions is included in Appendix C and of cost estimates used in Appendix D. A detailed breakdown of all costs incurred is included in the operational and financial model developed during this study.

The cost of feedstock would be 25% of the total production cost of ethanol (excluding co-product credit). In the case of cellulosic feedstocks, the major cost driver is the chemicals used, so the cost of ethanol is not sensitive to changes in feedstock costs.

A 10% increase in feedstock cost would increase the cost of the ethanol by $0.03 per litre.

The offsets available include sale of and credits for renewable energy generation, and possible carbon credits for avoided burning of cane trash or forest residues.

5.4.2 Cane Trash

An ethanol plant with production capacity of 100 ML of ethanol per annum using cane trash is estimated to require an investment of approximately $292 million. Production at full capacity would involve:

- A cost estimated at $13 million to collect and transport the cane trash to the plant;
- $49 million in direct costs associated with ethanol production in the Burdekin, including utilities, staff, freight of ethanol to Sydney, etc;
- Maintenance and indirect (overhead) costs totalling about $18 million;
- A return on assets of approximately $30 million (using a post-tax real WACC of 7.3% as advised by IPART and assuming that 25% of the capital is debt-funded);
- Produce co-products that could be sold to earn approximately $5 million in revenue (used to offset production costs).

Sales and marketing costs are not provided for, assuming that sales would be direct to a fuel wholesaler under contract.

This scenario would produce ethanol at about $1.06 per litre delivered to Sydney. This cost structure is illustrated in Figure 27 which presents the costs on a per-litre of ethanol basis.

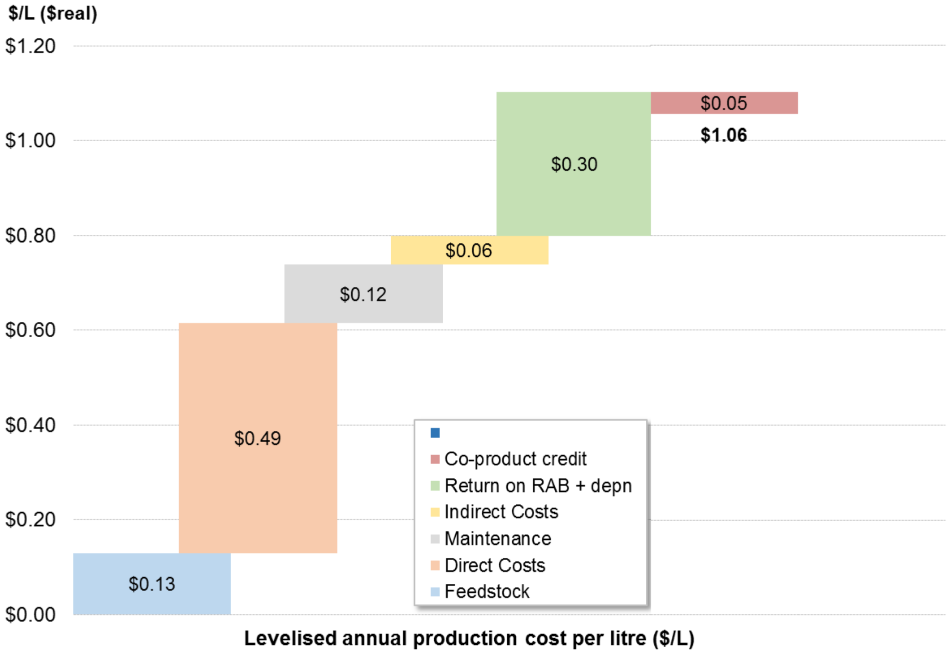


Figure 27 Levelised cost of ethanol production from cane trash

A more comprehensive summary of production assumptions is included in Appendix C and of cost estimates used in Appendix D. A detailed breakdown of all costs incurred is included in the operational and financial model developed during this study.

The cost of feedstock would be 12% of the total production cost of ethanol (excluding co-product credit). In the case of cellulosic feedstocks, the major cost driver is the chemicals used, so the cost of ethanol is not sensitive to changes in feedstock costs.

A 10% increase in feedstock cost would increase the cost of the ethanol by $0.01 per litre.

The offsets available include sale of and credits for renewable energy generation, and possible carbon credits for avoided burning of cane trash or forest residues.

5.5 Externalities

The use of forest-based feedstocks for ethanol production could:

- Displace current use of forestry residues and wastes from niche uses such as panel board manufacture;
- Displace forestry residues and wastes from natural use as part of the sites biodiversity;
- Displace some pulp wood from paper production;
- Increase demand for currently unused products that would otherwise be disposed of, such as oil mallee trees, forestry residues and wastes;
- Act as a driver for the development and improvement of forestry equipment and techniques to more efficiently harvest waste products and oil mallee trees.

Some forestry waste is left on the ground after the harvesting process to help maintain soil structure and nutrients, and aid soil water retention for future plantations. Excess waste can be burned. The removal of biomass could therefore result in the loss of nutrient capital and organic matter that would impact the plantation sites ecological function, productivity and ground stability. Only larger sized forestry residues and wastes are generally harvested for bioenergy production for this reason, and smaller products such as fine branches, woody debris and needles are left.

Cane trash is not wanted by sugar cane growers, and is generally burned to clear the ground for the next planning cycle.

Cellulose-based feedstocks provide lignin as a by-product, which can readily be gasified to increase ethanol production yield, produce synthetic fuels or generate electricity. An excess of electricity after plant consumption is available from cellulosic production of ethanol, and this renewable energy can be sold on the grid, therefore benefiting local power users.

Collection of forest and other residues for ethanol production provides relatively better employment opportunities in regional areas than other methods.

5.6 Issues and Constraints

Cellulosic production is relatively capital and production intensive, and is only likely to be viable for large plant, which is capital intensive. The ethanol produced is relatively high cost compared to other methods of production, but has more significant environmental and economic benefits than other forms.

With high production costs, the opportunity to realise greater value from the cellulosic process and reduce the cost of ethanol produced relies on the ability to increase yields from the feedstocks available.

The yield available from the feedstock varies according to the type of tree involved. Pinus radiata is most often used in North America, where it is the predominant planted tree, but eucalyptus variants are used in Brazil and elsewhere because they have higher energy density and will yield more ethanol per unit mass than pine.

Australia has several high energy variants of eucalyptus available, and spotted gum in particular has been identified by the Queensland Alliance for Agricultural Innovation (QAAFI) as a particularly promising feedstock because of its energy content and because it can be grown well in marginal land areas. Use of spotted gum as a feedstock would require the economics to be proven and plantations to be established, so this option is a medium to long-term one.

6.0 Efficient Costs for New Entrants

The cost structure for any ethanol producer involves:

- An investment in plant;
- Acquisition of feedstock, which will generally be by purchase using market prices (unless the producer is vertically integrated);
- Ongoing operational, overhead and finance costs, and delivery of ethanol to Sydney; and
- Production of co-products that can be sold to offset ethanol production including energy, renewable energy certificates and stock feed. The use of some feedstocks for ethanol production would reduce carbon emissions (and could potentially attract revenue under Carbon Credits (Carbon Farming Initiative) Rule 2015).

6.1 Comparative Delivered Ethanol Costs

The modelling suggest that the method of ethanol production that would offer the lowest efficient cost of production (for a standardised 100 ML per annum plant capacity) is the use of grade C starch either directly via purchase at market prices or at a plant associated with a gluten manufacturing facility.

While the sucrosic options appear to be a higher cost that partly reflects the distance the ethanol must be transported. If the molasses-based ethanol were only transported to Brisbane, for example, the delivered cost would be very similar to the cost of starch-based ethanol delivered to Sydney.

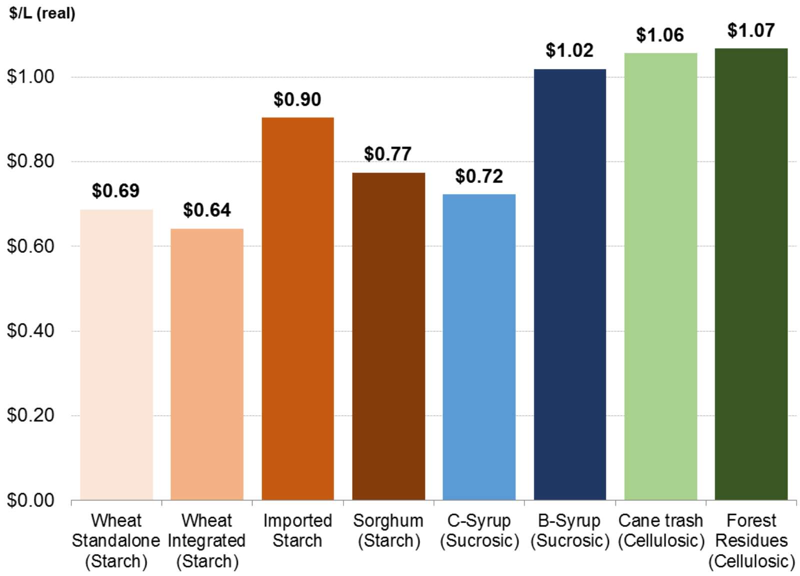


Figure 28 Comparative efficient costs of ethanol production by feedstock

This analysis has used a standardised 100 ML per annum production facility. Economies of scale are available, and the extent of this opportunity is addressed below.

Variations of feedstock prices will have a direct impact on the production cost of ethanol as indicated in these charts, which are expressed as per litre costs.

To illustrate this comparison further, a number of cost drivers have been used to compare costs for a new entrant ethanol production by feedstock type.

6.1.1 Feedstock

The cost of feedstock is the main driver for all forms of sucrosic and grain-based ethanol production. The primary reason why starch-based production methods deliver ethanol at a lower cost is that the cost of the feedstock is lower than it is for sucrosic options (Figure 29). The starch-based methods rely on processing of a primary product (gluten) which removes the need for front-end processing that would otherwise be needed.

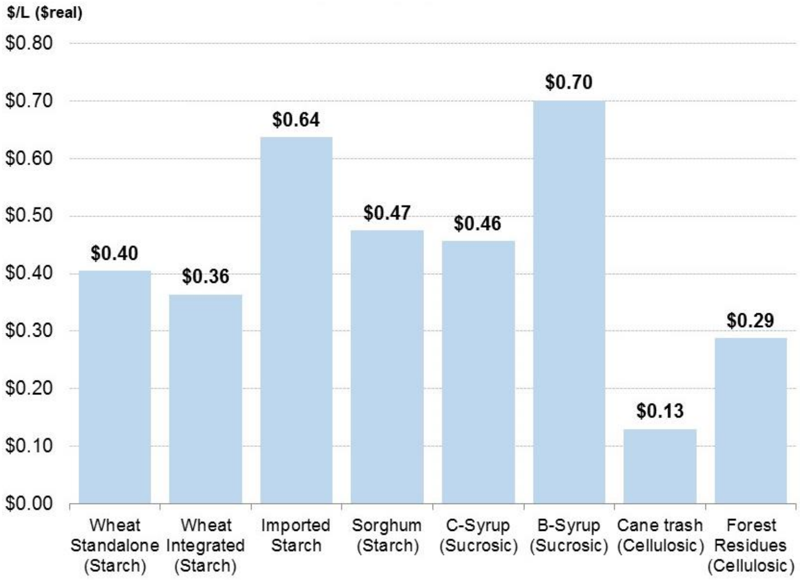


Figure 29 Feedstock costs per litre of ethanol produced

Any change in feedstock cost would increase the cost of the ethanol in proportion to the costs shown in Figure 30.

6.1.2 Production (direct) costs

Production costs for a new entrant vary considerably by pathway, with the cellulosic process being the most costly to operate and the starch-based processes the least cost to operate (Figure 30).

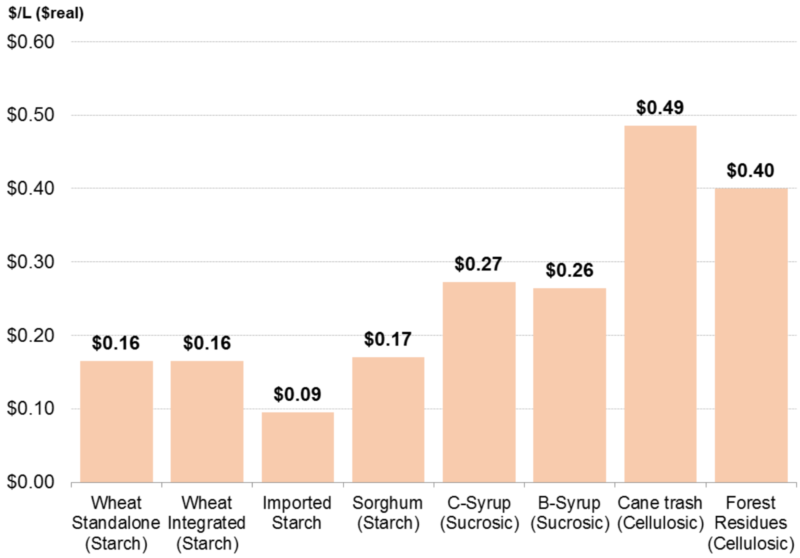


Figure 30 Production (direct) costs per litre of ethanol produced

6.1.3 Capital Costs

The capital investment needed is lowest for sucrosic and sorghum based ethanol production for the standardised 100 ML per annum plant (Figure 31),[27] and the return on investment appears to be more attractive for these methods. For modelling purposes, return of capital has been assumed to be straight line, and a weighted average cost of capital (WACC) has been used as advised by IPART.

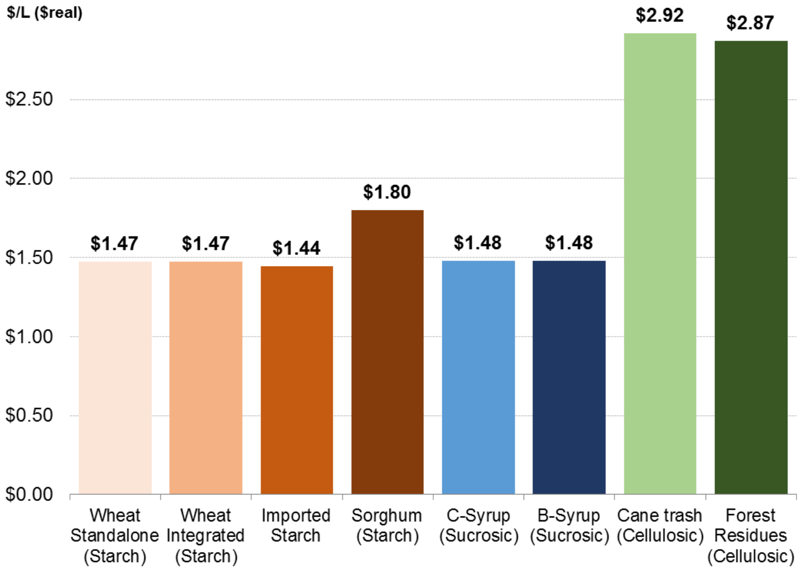


Figure 31 Capital costs required per litre of ethanol production capacity

It should be noted that the return on asset base approach used by IPART is intended to apply to capital-intensive industry, and may understate the revenue required by manufacturers for whom operational costs are a relatively high proportion of production costs (and are therefore less capital-intensive). The model developed for this study allows the use of a margin on costs as an alternative mechanism to investigate efficient production costs.

6.1.4 Co-products and offsets

The value of co-products (such as DDGS, energy and renewable energy certificates) has been used to offset the production cost of ethanol. These co-products are most significant for sucrosic production methods (Figure 32).

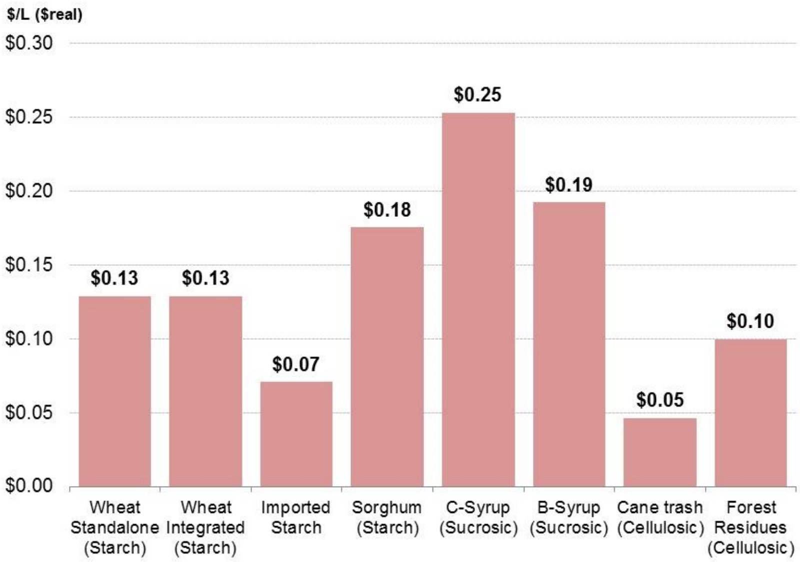


Figure 32 The value of by-products and offsets by feedstock type per litre of ethanol produced

[27] The process design, equipment specification and costs used for this process have been developed by AECOM from a variety of sources. We have not had access to any production information from an Australian proponent.

6.2 Indicative Development Timetables

There are a number of factors that affect the time it is likely to take for a new entrant to reach full production:

- All new investments will go through funding, approvals and construction phases, each of which could potentially take about 12 months. Where commercial crops already exist for a specific feedstock, it has been assumed that there will be no need for increased cropping.
- In some cases, pilot or trial plantings are already in place, and, assuming that the feedstock is proven, only the development of full commercial production of the feedstock is required. This period varies depending on the nature of the plant.
- Where a possible feedstock has not yet been trialled, a pilot stage may be required and in some cases, imported varieties will require successful progress through mandatory quarantine. Super sweet sorghum is grown from seed, so quarantine is not required, and the crop is able to be expanded faster than other crops.

Consideration of these factors for all feedstocks reviewed suggests a possible development timetable as indicated in Figure 33.

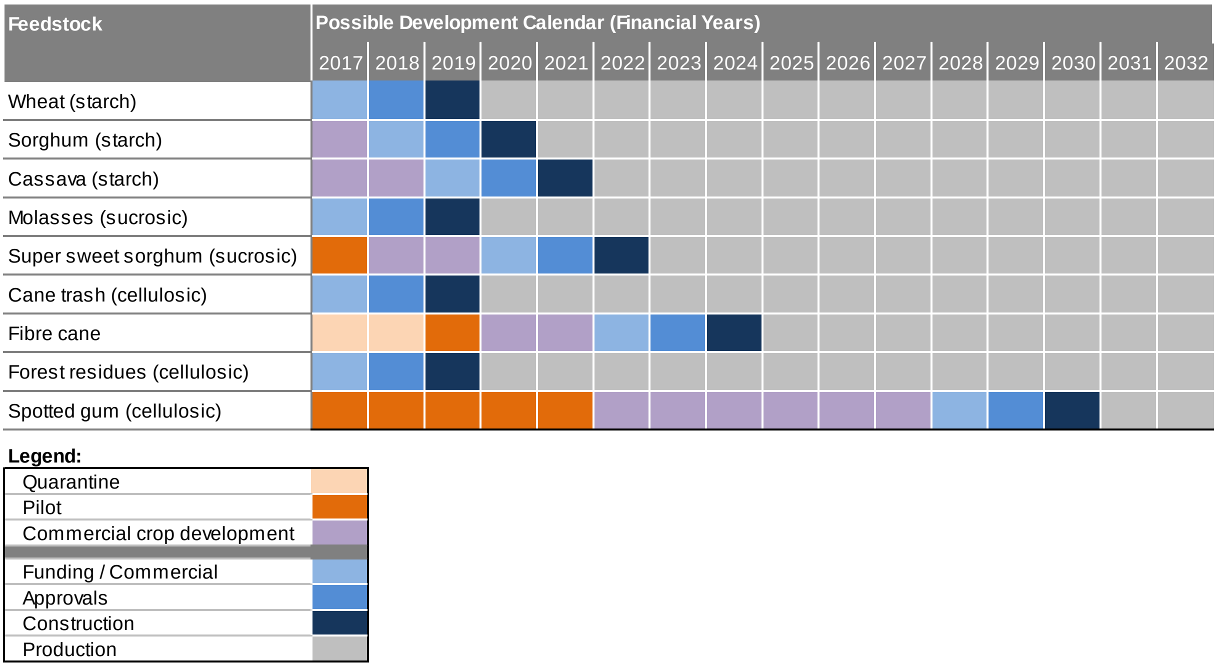


Figure 33 Indicative development timetable for new entrants

It should be noted that the development program for a specific investment is likely to vary from the indicative one shown for a variety of reasons.

Spotted gum has been included in Figure 33 only because it has been nominated as a potentially viable high yielding and relatively low cost source of cellulosic feedstock. The possible program for development of a spotted gum resource is likely to be typical for other potential native forest-based cellulosic feedstocks that are not currently available in sufficient quantities in Australia.

7.0 Conclusions

This section includes a number of observations and conclusions reached after consideration of the findings presented in this report.

7.1 Efficient New Entrant Cost of Ethanol Production

The modelling suggests that the method of ethanol production that would offer the lowest efficient cost of production (for a standardised 100 ML per annum plant capacity) is the use of starch C either directly (via purchase at market prices or at a plant associated with a gluten manufacturing facility.

The sucrosic options appear to be a higher cost, but that partly reflects the distance the ethanol must be transported. If the molasses-based ethanol were only to be transported as far as Brisbane, for example, the delivered cost would be very similar to the cost of starch-based ethanol delivered to Sydney.

Among the pathways reviewed, the lowest efficient cost of ethanol production for a new entrant delivered to Sydney is $0.53 per litre of ethanol for a 310 ML wheat integrated facility in central NSW. There are two other pathways that offer a slightly higher cost.

7.2 Cost and Availability of Feedstock

This study has shown that feedstock costs would range between 12% and 66% of total production costs, and, except for forest residues and cane trash, would be the largest component of a new entrant's ethanol production cost structure.

Feedstocks other than the cellulosic have value in their own right, and are tradeable within Australia or able to be exported. Use of these feedstocks involves an opportunity cost, in that a new entrant would have to compete with existing users for access to the feedstock. This is particularly an issue with sorghum, which is in high demand in Asia.

The lack of security of supply of feedstock would be a significant risk for new entrant ethanol producers. There appear to be two principal strategies available to mitigate this risk:

- Vertical integration, so that the ethanol producer is able to control supply of feedstock, or long-term supply contracts with growers, which could potentially include equity arrangements; and
- Ethanol production using feedstocks that are a by-product of another process and therefore do not need to be sold or purchased on the open market (the use of wheat is a good example, where the primary product is gluten and the starch used for ethanol production is a by-product.

Both of these strategies are likely to provide cost relief as well, in that feedstocks could be transferred to ethanol production at cost.

It should be noted that local use of feedstock would reduce or eliminate transport costs otherwise required to move product to population centres or ports for shipment. The ethanol producer would therefore compete with export prices less transport costs.

Availability of feedstocks also varies:

- Molasses is primarily produced in central and north Queensland, and there is potential to use the C-syrup and B-syrup feedstock currently available to produce up to about 800 ML of ethanol per annum in up to four locations.
- Wheat is primarily produced in NSW, and there is potential to produce more than 1,000 ML per annum (by removing wheat from export) in up to five locations.
- Cane trash is produced largely in Queensland and is mostly burnt at this time. There is enough material to produce up to about 870 ML of ethanol, in four locations.
- There is enough forest residue to enable production of about 920 ML of ethanol in six locations.

The analysis provided in this report expresses production costs as a value per litre of ethanol produced. Variations in the cost of feedstocks (for a specific installed plant capacity) will have a proportional impact on the cost of the ethanol. This is illustrated in Figure 34.

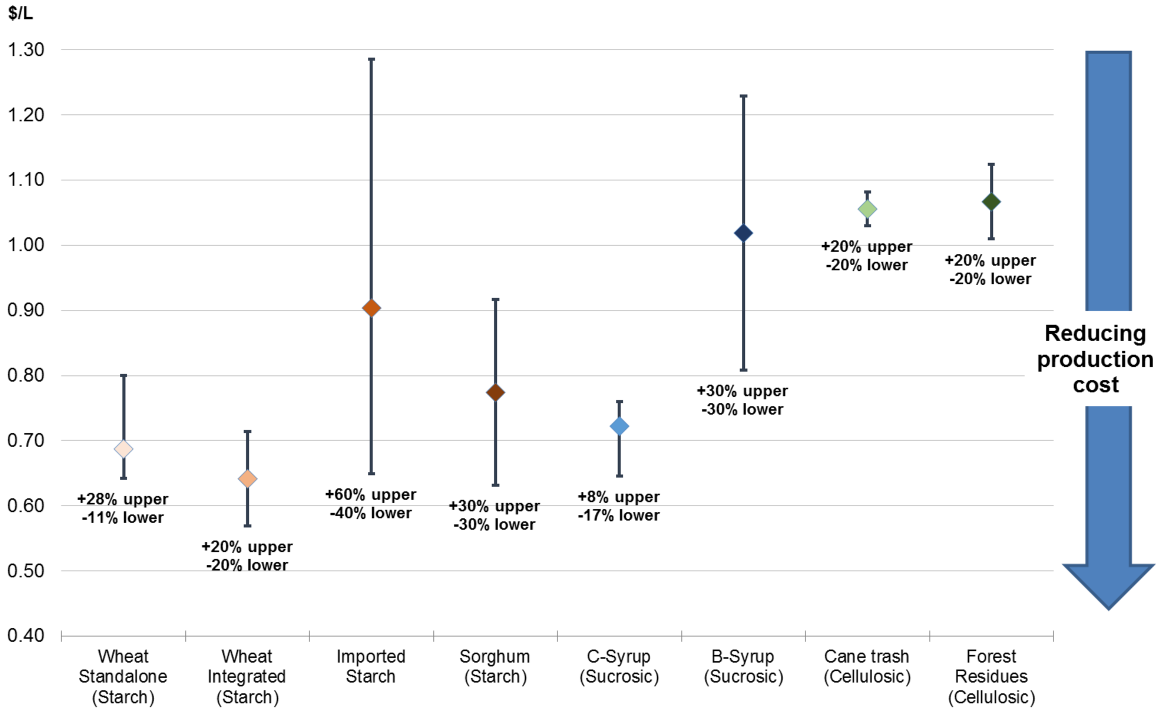


Figure 34 The impact of feedstock cost variation on the delivered cost of ethanol (for 100 ML plant)

Cellulosic production is least sensitive to variations in feedstock costs (feedstock is a lower proportion of total production cost than for other pathways).

7.3 Co-Products

Use of sugar and starch-based feedstocks enable co-production of DDGS, which has value as stockfeed. Revenues available from the sale of co-products can offset a proportion of the production costs, and can therefore make the main product (ethanol) more viable.

The core process used for ethanol production enables waste materials to be used for production of electricity, and the process will generally be at least self-sufficient in terms of energy requirements. The cellulosic process produces lignin as a by-product and enables a surplus of energy to be generated, which can be sold to offset production costs. The production of electricity using renewable materials also enables ethanol production to qualify for renewable energy certificates (RECs), and these have value in their own right. Sales of the RECs earned are included in the production cost models as an offset cost.

Finally, use of two feedstocks in particular, cane trash and forest residues, would reduce the scale of current burn-offs of these waste materials and therefore avoid carbon emissions, enabling the ethanol producer to participate in the Australian Emissions Trading Scheme.

The cost model developed for this study has assumed a value of $10 per tonne of carbon dioxide emissions avoided, and treated this as an offset to production costs for those processes that use an eligible feedstock. It should be noted that the next Emissions Reduction Fund auction will be held in November 2016, and the outcome will set the cost of carbon abatement for the next period which at this stage appears likely to be higher than $10 per tonne. If that occurs, the offset available for ethanol producers using eligible feedstocks will increase proportionally.

7.4 Scalability

Like many production processes, the cost base of ethanol production does not increase linearly with scale. There are economies of scale available for ethanol producers using all feedstocks, with the cost advantage decreasing as transport costs increase to move feedstock from further away to feed a large plant.

Optimisation of plant size depends on assessment of a range of factors, and is beyond the scope of this study. Use of the operational and financial model developed during this study does, however, enable the impact of scaling up production capacity to be assessed. This is illustrated in Figure 35, which shows the assessed cost for a standardised 100 ML capacity plant, together with costs for plants with capacity of 50 ML and 200 ML.

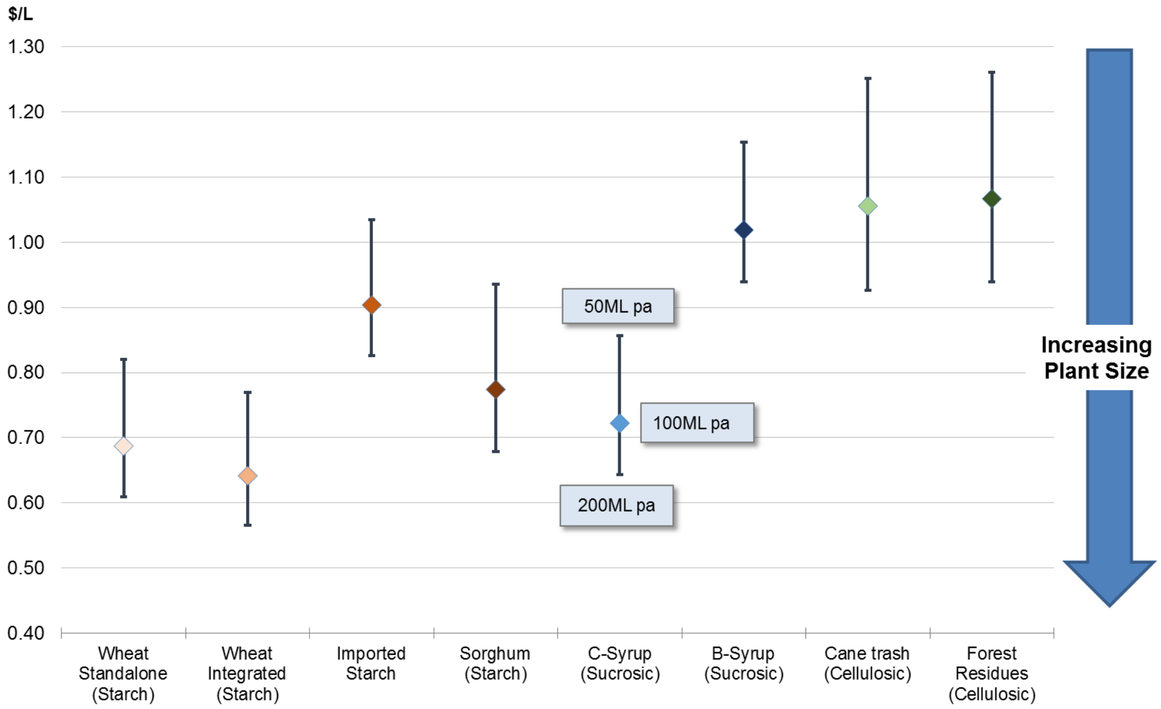


Figure 35 Impact of plant size on the delivered cost of ethanol

This review has indicated probable maximum plant sizes at specific locations. Figure 36 shows the calculated range of unit cost prices for ethanol for each feedstock, for plant production capacities that match the yield currently considered to be available within useful range of each possible production facility as indicated in Figure 19 (for sucrosic feedstocks), Figure 9 (for grain feedstock), Figure 24 and Figure 25 (for plantation and cane trash feedstocks respectively):

- The calculated ethanol price is shown on the vertical axis, with the lowest cost of production shown at the top of the chart;
- Plant size is shown on the horizontal axis, with the largest plant sizes on the right;
- Curves are shown based on the calculated efficient cost of production for a range of plant sizes for each feedstock type, showing a reducing cost per litre as plant size is increased; and
- Production options in the top right corner of the chart are the most attractive (lowest cost of ethanol production).

It should be noted that some feedstock sources are not considered to be available in sufficient quantity at a particular location to support a viable plant.

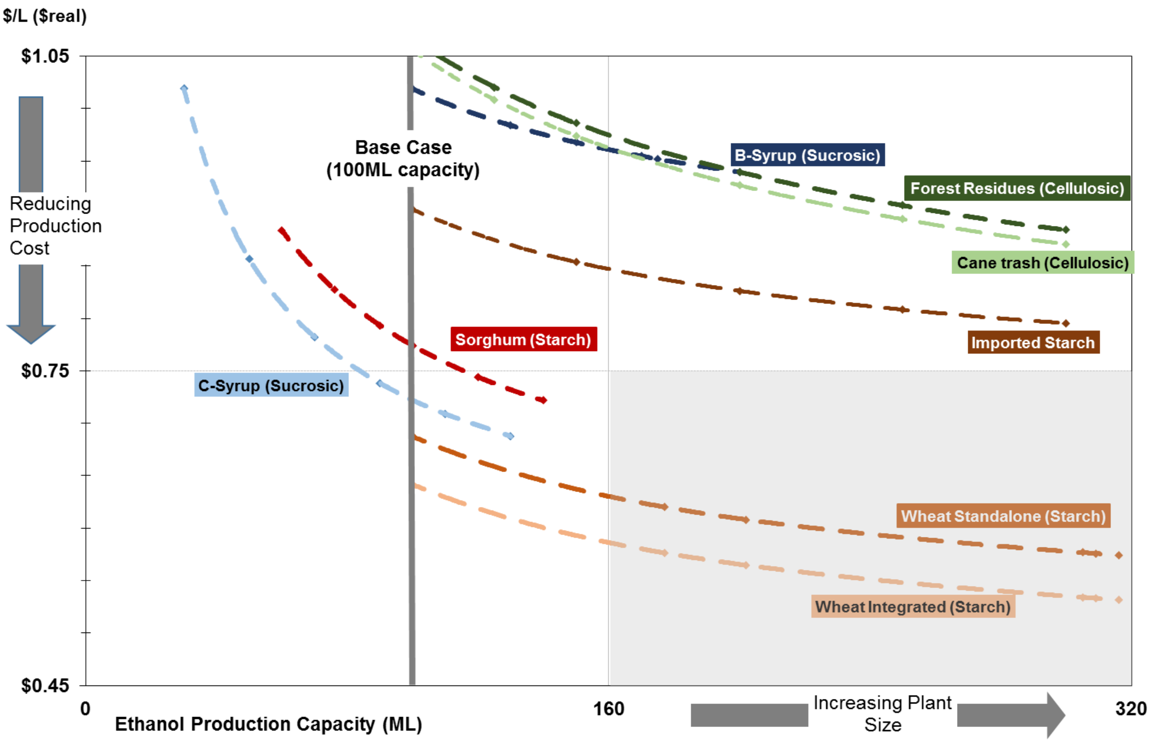


Figure 36 Impact of scale of production on the delivered cost of ethanol by feedstock

It is clear that scale has a significant impact on the delivered cost of ethanol, and that the impact varies considerably by feedstock:

- Large integrated production plants with capacity at 300 ML or higher using wheat-based starch offer the lowest cost ethanol;
- Mid-sized plant with capacity of around 120 ML using C-syrup or sorghum-based starch are the most competitive alternative to starch-based production; and
- Cellulosic production plants are not likely to be competitive even at a large scale unless chemical and capital costs can be reduced.

In general, a plant with four times the production capacity of another will produce ethanol at approximately 60% of the unit cost of the smaller plant, other factors being equal. A larger facility will therefore provide lower cost ethanol and a better return on investment than a smaller one.

7.5 The Production Cost Curve for Ethanol in Australia

The analysis summarised in Sections 4.2, 3.2 and 5.2 provides an estimate of the total yield estimated to be currently available in Australia. This, together with the calculated weighted production cost, enables a production cost curve to be produced for ethanol production in Australia (Figure 37).

This analysis suggests that a maximum of about 1,300 ML of ethanol could potentially be produced from wheat starch, at a weighted average cost of $0.59 per litre of ethanol delivered to Sydney. This quantity is sufficient to enable the current mandate to be met.

A higher mandate would require additional production using the next lowest price feedstock (molasses C-syrup, produced in central Queensland), which could provide up to an additional 240 ML of ethanol at a weighted average cost of $0.81 per litre of ethanol delivered to Sydney. Up to about 220 ML of ethanol could be produced from sorghum, at about $0.83 per litre delivered to Sydney.

Additional demand would require progressively higher ethanol costs as lesser cost feedstocks are exhausted.

It should be noted that the quantity and production cost estimates are based on a range of assumptions, and any particular investment will have its own specific performance outcomes that may be different to the estimates developed by this study.

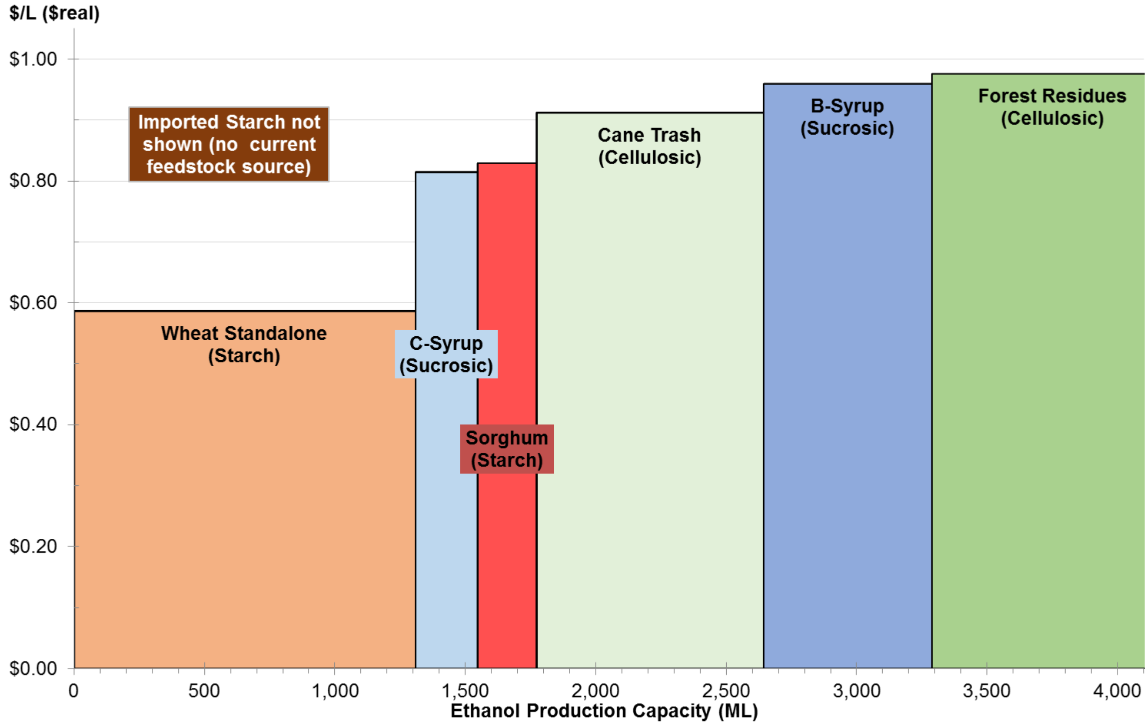


Figure 37 Production cost curve for ethanol in Australia

7.6 Plant Location

The feedstocks are generated where the crop is grown, and the cost of transport for bulk feedstock would be such that there would be significant advantage in locating a processing plant close to the source of the feedstock.

The yield of crops useable as feedstock for ethanol production is latitude-dependent, and a block of land in Northern Queensland could produce twice the yield of a similar block in Central NSW. A new entrant ethanol producer that relies on purchasing feedstock would find it easier to scale up production in northern latitudes than in the south, because a greater quantity of feedstock can be obtained within a given radius from the plant in the north. It is therefore likely to be more cost effective for some feedstocks types to produce ethanol in the north.

It should be noted that forest reserves in Northern Queensland are very limited in scale compared to those in NSW, and therefore that use of this feedstock is largely limited to the southern states. Cane-based feedstocks, however, are primarily available in Queensland.

The cost modelling presented in this report involves transport of ethanol to Sydney for blending and use in NSW (and generally assumes that backhaul will be available along the East coast, but not inland, so delivery of ethanol from inland locations is assumed to include the cost of the return journey).

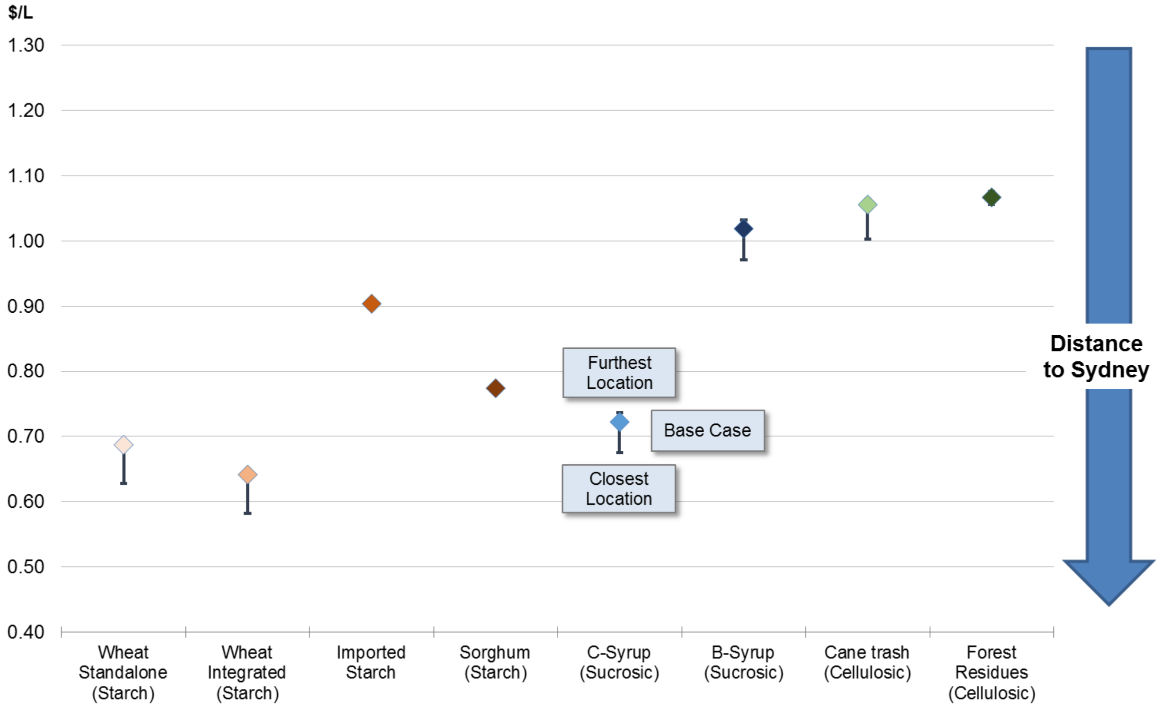


Figure 38 Impact of plant (feedstock) location on the delivered cost of ethanol (for 100 ML plant)

Where production is based in Queensland and a potential market exists in Brisbane or the larger regional cities in the north, the delivered cost of ethanol to Brisbane would be lower by approximately $0.05 per litre than the delivered cost to Sydney. If petrol prices are assumed to be similar in the two cities, the cost reduction would be sufficient to make the Brisbane market more attractive than the Sydney market.

This is therefore a risk for NSW, in that if Queensland increases its E10 mandate, northern producers will find it more profitable to ship ethanol internally in Queensland rather than to Sydney.

7.7 Issues and Constraints

There are a number of issues to consider:

- The capital investment involved is significant, and some form of market security is likely to be necessary to encourage investments in ethanol production;
- Proponents have noted that some form of market security would encourage the investment required;
- Security of access to feedstocks is already an issue and may become more significant if market prices for those feedstocks increase. This risk could be mitigated through long-term supply contracts, grower participation in ethanol production directly, or via co-operatives;
- Development of the biofuels sector would encourage economic development in the rural communities around each plant; and
- The cost of ethanol production may reduce in the future as technology improves, and cellulosic production in particular may become more attractive. This form of production is considered a medium to long term option.

Appendix A

Reference Documents and Bibliography

Appendix A Reference Documents and Bibliography

Author	Reference
Ag Scientia	'East Coast Supply and Demand, Advisory & Compliance Workshop' Presentation, 25 July 2016.
AG Wired	http://energy.agwired.com/2016/07/28/epure-strengthen-the-framework-for-sustainable-ethanol/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+DomesticFuel+%28Domestic+Fuel%29 http://energy.agwired.com/2016/07/29/ai-bio-funds-13m-for-biomass-based-bioproducts/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+DomesticFuel+%28Domestic+Fuel%29
Agricultural Marketing Resource Centre	http://www.agmrc.org/renewable-energy/ethanol/
Almond Growing Regions	Image
Alternative Energy News	http://www.alternative-energy-news.info/waste-to-energy-gains-steam/ http://www.alternative-energy-news.info/synthetic-fuel-co2-solar-energy/ http://www.alternative-energy-news.info/technology/biofuels/ethanol-fuel/
APAC biofuel Consultants	'Australian Biofuels 2015 – 2016 Client Report Study', 2016.
Applied Cleantech	http://www.appliedcleantech.com/index.php?dir=site&page=articles&op=category&cs=3004&langpage=eng&parent=0
Asia-Pacific Economic Cooperation	'Biofuel Costs, Technologies and Economics in APEC Economics', APEC Energy Working Group, December 2010.
AUSAGAVE	'AGAVE Sugars & Fibre feedstock for advanced bio-fuels / bio-energy / bio-chemicals', June 2015.
Australian Agricultural and Resources Economics Society Conference	'The impact of Australian ethanol policy on agriculture: examining limiting factors'. AARES 2012 Conference Paper, February 2012
Australian Competition and Consumer Commission (ACCC)	Report on the Australian petroleum market – December Quarter 2015, February 2016
Australian Government Australian Renewable Energy Agency	'Project report: Advancing Established and Integrated Marine Microalgae Biofuel to Commercialisation', Muradel Report, February 2015

Author	Reference
Australian Government Australian Renewable Energy Agency.	'Biomass to bio-crude: Producing advanced drop-in fuels for Australia', August 2016
Australian Government Australian Renewable Energy Agency.	Project report: Production of Generation 2 Ethanol, High Nutrition Feed and Green Coal from Sugarcane Bagasse, April 2012
Australian Government Australian Renewable Energy Agency.	'An assessment of key costs and benefits associated with the Ethanol Production Grants program', A Report for the Department of Industry, Bureau of Resources and Energy Economics, February 2014.
Australian Government Australian Renewable Energy Agency.	'Australian Energy Resource Assessment', Second Assessment, 2014.
Australian Government Australian Renewable Energy Agency.	'The Australian Renewable Energy Mapping Infrastructure (AREMI) Project', August 2014.
Australian Government Australian Renewable Energy Agency.	'The Australian biomass for bioenergy assessment project, August 2016.
Australian Government Australian Renewable Energy Agency.	Bioenergy Projects http://arena.gov.au/projects/bioenergy/
Australian Government Bureau of Resources and Energy Economics	'An assessment of key costs and benefits associated with the Ethanol Production Grants program', Department of Industry, 2014.
Australian Government Department of Industry and Science	'Australian Energy Update', Office of the Chief Economist', 2015.

Author	Reference
Australian Government Rural Industries Research and Development Corporation	'Eucalypts for Biofuel Production in Northern Australia', Identifying species from current and future testing programs. RIRDC Pub. No. 11/064, June 2011
Australian Government, Department of Agriculture and Water Resources	'Agricultural commodities', Researched by the Australian Bureau of Agriculture and Resource Economics and Sciences, June 2016.
Australian Lot Feeders Association	'Briefing Note Ethanol', October 2015
Australian National Audit Office	'The Ethanol Production Grants Program', Department of Industry and Science, The Auditor-General ANAO Report No.18 2014 -2015, Performance Audit, 2015.
Biofuels Associated of Australia	Ethanol in Australia http://biofuelsassociation.com.au/biofuels/ethanol/ethanol-in-australia/
Biofuels Digest	http://www.biofuelsdigest.com/bdigest/2016/07/31/aemetis-a-major-market-opportunity-in-cellulosic-ethanol/ http://www.biofuelsdigest.com/bdigest/2016/10/20/philippines-boosts-january-monthly-ethanol-allocation-to-75835-cu-m/
Bionenergy Australia	http://www.bioenergyaustralia.org/pages/policy-and-biofuels-info.html
Brear, M	'Comparison of emissions and fuel consumption of a passenger vehicle on two fuels', A report prepared for the Manildra Group of Companies. University of Melbourne / ACART, May 2015
Chambers D, and Holtum J.A.M	'Feasibility of Agave as a Feedstock for Biofuel Production in Australia', Australian Government, Rural Industries Research and Development Corporation, November 2010.
Chu. J	'Biofuel from Sewage', Business, www.technologyreview.com, 13 October 2009
Coote. D	'Review of commercial wood-fuelled electricity and heat generation technologies'. CRC for Forestry, Harvesting and Operations Program. Bulletin 7, April 2010.
Cuevas, C	'The impact of Australian ethanol policy on agriculture. Examining limiting factors'. Presentation based on ANU Masters Thesis, 2010.
Department of Energy and Water Supply, Queensland.	'Queensland Biofuels Pathway ', APAC biofuel consultants, September 2015
Department of Industry, Innovation and Science	Australian Petroleum Statistics, Issue 239, www.industry.gov.au/oce, June2016

Author	Reference
Department of the Environment, Water, Heritage and the Arts.	'The full cost of landfill disposal in Australia', BDA Group Economics and Environment, July 2009
Dongmum Greentec	'Deniliquin Ethanol Plant, Environmental Impact Statement', Volume 1. Prepared by AECOM for Dongmum Greentec Ltd. Pty., October 2015
École Polytechnique Fédérale de Lausanne	Roundtable on Sustainable Biofuels – Global Principles and Criteria for Sustainable Biofuels Production Version Zero,
Energy and Research Centre of the Netherlands	ECN Phyllis2 biomass database https://www.ecn.nl/phyllis2/
Ethanol Producer Magazine	http://www.ethanolproducer.com/
Farine, D.R et al	'An assessment of biomass for bioelectricity and biofuel, and for greenhouse gas emission reduction in Australia', GCB Bioenergy (2012) 4, 148–175, 2012
Forestry Corporation	'Planted Forest Regions of NSW'. Figure, August 2016
Furtado et al	'Modifying plants for biofuel and biomaterial production'. Plant Biotechnology Journal (2014) 12, pp. 1246–1258, 2014
Ghaffariyan.M.R	'Eurpoean biomass harvesting systems and their application in Australia', CRC for Forestry. Harvesting and Operations Program. Bulletin 10, September 2010.
Ghaffariyan.M.R	'Assessment of harvest residues from different harvesting operation sites in Australia', CRC for Forestry. Bulletin 31, September 2012.
Ghaffariyan.M.R	'Natural drying and optimising a forest residue supply chain to reduce the total operating costs: A case study in Western Australia', AFORA and CRC for Forestry. Industry Bulletin 3, April 2014.
Ghaffariyan.M.R and Andorocski.V	'Bundling harvest residue in shining gum plantations', CRC for Forestry. Bulletin 31. Bulletin 15, February 2011.
Ghaffariyan.M.R and Apolit.R	'Assessment of residues from whole-tree and cut-to-length harvesting in Southern Pine plantations, Toolara, south-east Queensland', AFORA and CRC for Forestry. Industry Bulletin 17, March 2016.
Ghaffariyan.M.R and Wiedemann.J	'Harvesting low productivity eucalypt plantations for biomass', CRC for Forestry. Harvesting and Operations Program. Bulletin 19, July 2011.
Ghaffariyan.M.R Spinelli.R and Brown.M	'Harvesting residual woody biomass in Pine Plantations in South West, August 2014, .
Ghaffariyan.M.R Spinelli.R and Brown.M	'Analysing the effect of five operational factors on the operating costs of a biomass supply chain: A case study in Western Australia', AFORA and CRC for Forestry. Industry Bulletin 12, September 2014.
Ghaffariyan.M.R,	'The natural drying process of logs and harvesting residues – preliminary results', AFORA and CRC for Forestry. Industry Bulletin 2, March 2013.

Author	Reference
Ghaffariyan.M.R, Spinelli.R and Brown.M	'Forwarding technologies to collect harvesting residues for bioenergy use', CRC for Forestry. Bulletin 32, October 2012.
Global Agricultural Information Network	'Biofuels Annual, EU Biofuels Annual 2016', USDA Foreign Agricultural Service. GAIN Report No. NL6021, June 2016.
Grain Growers	'State of the Australian Grains Industry 2016', 2016.
Healey.A.L Et al	'Effect of aging on lignin content, composition and enzymatic saccharification in Corymbia hybrids and parental taxa between years 9 and 12', Biomass and Bioenergy 93 (2016) 50 - 59. Elsevier Scientific Publishing Company, 2016.
Henry.R.J (Association of Applied Biologists)	'Evaluation of plant biomass resources available for replacement of fossil oil', Plant Biotechnology Journal (2010) 8, pp. 288–293, 2009
HoustonKemp Economists	'Maximum price for wholesale fuel-grade ethanol', 1 August 2016.
IOWA State University	Ethanol Profitability Model https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiW7PL8mOjOAhXJkZQKHXN9A70QFggfMAA&url=https%3A%2F%2Fwww.extension.iastate.edu%2Fagdm%2Fenergy%2Fxls%2Fd1-10ethanolprofitability.xlsx&usg=AFQjCNHViNveeM-Yjd4oYfQ45RSqWyBRzA&sig2=6qEuVOVRxu72fvruKn-8AA&bvm=bv.131286987,d.dGo
IPART	'Review of Ethanol Supply and Demand'. Independent Pricing and Regulatory Tribunal of New South Wales 2012, May 2012
IPART	' Review of a maximum price for wholesale ethanol in automatic fuel blends', Other - Issues Paper. Independent Pricing and Regulatory Tribunal of New South Wales 2016, June 2016
IPART	'Fact Sheet – Review of a maximum price for wholesale ethanol', June 2016
IPART	'Ethanol Supply and Demand in NSW', Other Industries – Final Report. Independent Pricing and Regulatory Tribunal of New South Wales 2012, March 2012
IPART New Entrant Ethanol Procedures	'AECOM Phone Discussion with Professor Mark Brown', 19 August 2016,
L.E.K Consulting	'Advanced Biofuels Study', Strategic Direction for Australia, Summary Report, 14 December 2011
Manildra Group	'Manildra Group Public Submission Issues Paper'. Letter, 1 August 2016,
Manildra Group	http://www.manildra.com.au/products/fuel/ http://e10thegoodfuel.com.au/how-we-make-e10/
McIntosh. S, et al	2012, Ethanol production from Eucalyptus plantation thinnings. Bioresour. Technol. (2012), doi:10.1016/ j.biortech.2012.01.114
Mera Chemicals	'Indicative pricing for bulk chemicals – ethanol production'. Email correspondence, 22 August 2016

Author	Reference
National Renewables Energy Laboratory	'Process Design and Economics for Biochemical Conversion of Lignocellulosic Biomass to Ethanol'. U.S Department of Energy, Technical Report NREL/TP-5100-47764, May 2011
Ngh Environmental	' Scoping study to support SSD DGR Request', Deniliquin Ethanol Plant, December 2013
North West Forestry Investment Group	'Economic Aspects of Growing Softwood Plantations on Farms in the New England Region', May 2002.
North West Forestry Investment Group	'Economic Aspects of Growing Hardwood Plantations on Farms in the New England Region', May 2002
Novozymes	https://www.novozymes.com/en
NSW Department of Fair Trading	Biofuels Market Place data http://www.fairtrading.nsw.gov.au/ftw/Businesses/Specific_industries_and_businesses/Biofuels_industry/Biofuels_marketplace_data.page
NSW Department of Primary Industries Lands	'Timber Plantations North Coast NSW. Figure. March 2016
NSW Department of Primary Industries Lands	'Timber Plantations in NSW. Figure. March 2016,
NSW Government, Department of Industry Resources and Energy.	'Renewable energy resources of New South Wales', Geological Survey of New South Wales, 2016
NSW Government, Department of Primary Industries Lands	'Timber Plantations North Coast NSW'. NSW Government, March 2016
NSW Government, Department of Primary Industries Lands	'Timber Plantations NSW'. NSW Government, March 2016
Oak Ridge National Laboratory (ORNL)	Summary of High-Octane, Mid-Level Ethanol Blends Study, ORNL/TM-2016/42, July 2016
Parliament of Australia	'Fuel Ethanol-Background and Policy Issues. Current Issues Brief No. 12 2002-03, 2003
Qteros	http://www.qteros.com/vision/economic-viability/
Queensland Government Information Service	'Red Sorghum growing regions and long term median yield in Queensland'. Figure, August 2016

Author	Reference
Queensland Government Information Service	‘Wheat growing regions and long term median yield in Queensland’. Figure, August 2016
Renewable Fuels Association	‘Going Global 2015 Ethanol Industry Outlook, 2015.
Renewable Fuels Association	‘Pocket Guide to Ethanol 2015’. USA, 2015
ResearchGate	‘Substitution of fossil fuels with bioenergy from renewable biomass resources’. National Research Flagships Sustainable Agriculture, January 2009
Rural Industries Research and Development Corporation	Biomass Producer http://biomassproducer.com.au/markets/bioenergy-markets-in-australia/ethanol/#.V8Tntfn5i71
S&P Global	Market Data Biofuels http://www.platts.com/products/market-data-biofuels
U.S Department of Energy	‘U.S Billion-ton Update, Biomass Supply for Bioenergy and Bioproducts Industry’, August 2011
U.S Department of Energy	‘Peer review Report, Review Panel Summary Report and Project Results’, Bioenergy technologies office, February 2014
U.S Department of Energy	‘Biomass Conversion’, Energy Efficiency and Renewable Energy, Bioenergies Technology Office, June 2016.
U.S Department of Energy	‘Ethanol the complete energy lifecycle picture’, Energy Efficiency and Renewable Energy, 2007.
U.S Department of Energy	‘Ethanol Feedstocks’, Alternative Fuels Data Center. Energy Efficiency and Renewable Energy, July 2016.
U.S Department of Energy	Alternative Fuels Data Center http://www.afdc.energy.gov/fuels/ethanol.html
U.S Department of Energy	Bioenergy Technologies Office http://www.energy.gov/eere/bioenergy/bioenergy-technologies-office
U.S Department of Energy	Knowledge Discovery Framework https://bioenergykdf.net/billionton2016/overview
U.S Grains Council	‘A Guide to Distiller’s Dried Grains with Solubles (DDGS)’ Third Edition, 2012
U.S. Department of Agriculture	Brazil’s Ethanol Industry: Looking forward, Constanza Valdes, BIO-02, June 2011
U.S. Department of Agriculture	Australia Biofuels Annual, 2015, Gain Report Number AS1516, 8 March 2015
U.S. Department of Agriculture	Biofuel Feestock and CoProduct Market Data http://www.ers.usda.gov/topics/farm-economy/bioenergy/biofuel-feedstock-coproduct-market-data.aspx

Author	Reference
University College London	‘Bioethanol Production from Municipal Solid Waste’, Department of Civil Engineering and Environmental Engineering. Presentation, 2003.
Walsh. D and Strandgard. M	‘Productivity and cost of harvesting a stemwood biomass product from integrated cut-to-length harvest operations in Australian Pinus rediata plantations’. Biomass and bioenergy, July 2014
Walsh.d, Wiedemann.J, Strandgard.M, Ghaffariyan.M.R and Skinnell.J	‘’FibrePlus’ study: Harvesting stemwood waste pieces in pine clearfall’, CRC for Forestry. Bulletin 31. Bulletin 18, February 2011.
Willington.I.P and Marten.G.G	‘Options for Handling Stillage waste from Sugar-based Fuel Ethanol Production’, *Resources and Conservation,* 8 (1982) 111-129 111 Elsevier Scientific Publishing Company, 1981.

Appendix B

Stakeholders Consulted

Appendix B Stakeholders Consulted

Organisation	Date of Discussion
Discussions with	
ARENA	4 August 2016
Ethtec	25 August 2016
QAAFI	19 August 2016
Bioenergy Australia	18 August 2016
Manildra	24 August 2016
Queensland University of Technology	11 August 2016
RDA	11 August 2016
NSW Forestry Corporation	25 August 2016
Department of Primary Industry	9 August 2016 22 August 2016 24 August 2016
Contacteded, no discussion	
BREE	5 August 2016, followed by voicemail

Appendix C

Ethanol Production Data by Feedstock

Appendix C New Entrant Ethanol Production Data by Feedstock

C1 Sucrosic Refinery

This section summarises key points relevant to the production of ethanol in Australia from sucrosic feedstocks.

Introduction

The sucrosic pathway is the simplest and cheapest source of ethanol when combined with sugar milling by-product such as molasses (C-syrup) or even diverted sugar – A and B-syrup. Location adjacent to existing sugar mills offers established utilities, laboratories, labour and administration and transport which lowers the cost of production.

Molasses is produced as a by-product from the crystallization process of a raw sugar mill. It consists of sugars, organics, minerals and other residues. Other A and B syrups also occur as a by-product of raw sugar processing although Australian sugar millers strive to maximize the extraction of raw sugar leaving only the molasses.

Australian cane molasses is currently used mainly in the fermentation (ethyl alcohol, yeast, lysine and monosodium glutamate) and stockfeed industries. Approximately 1/3 of Australia's annual molasses production is exported, although this has varied and exports decline during periods of drought when stockfeed demand is high.

Molasses is an agricultural by-product of sugar milling and it varies in quality according to seasonal and regional conditions.

About 6 to 8% of the sucrose which arrives in cane is left behind in molasses. Apart from sucrose, molasses also contains other sugars and salts. The combined "sugars" content in Australian molasses is about 50% of the weight of molasses and the fermentable content is typically around 46.5% which compares to 52% and 60% for A and B molasses respectively.

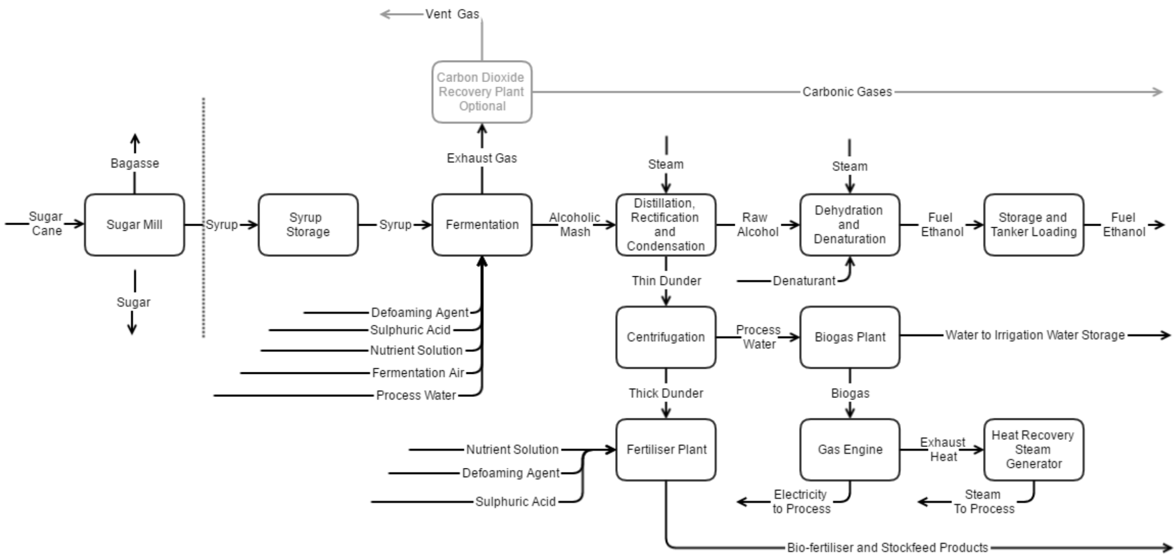


Figure 39 Sucrosic refining block diagram

The refinery process is depicted in the Process Block Model in Figure 39. It includes:

- Molasses receival and storage
- Screening and transfer
- Fermentation
- Distillation, rectification and condensation
- Dehydration
- Anhydrous alcohol transfer and storage system
- Dunder handling, storage and disposal system

- Biogas plant
- Steam and electricity
- Reagent storage and handling

Sucrosic Ethanol Plant Process Description

Storage and supply of molasses

Molasses (C syrup) or B syrup is supplied from sugar mills as syrup during the crushing season which operates for around 20 weeks in the year. Typically, the ethanol refinery would be co-located with one sugar mill and draw molasses from other sugar mills. Co-location is attractive as the sugar mill can provide important infrastructure required for ethanol production such as steam and electricity, water, weigh bridge, maintenance facilties, laboratory and administration centre as well as personnel with experience in operating plants.

For example, molasses from Broadwater mill in New South Wales could be pumped directly to an adjacent ethanol refinery. Additional molasses from Condong and Harwood sugar mills could be trucked to the site and discharged to a 100,000 litre in-ground bladder storage. Excess daily syrup received over and above the capacity of the refinery would be diverted to underground storage bladders and pumped to the ethanol refinery when the sugar mill is not operating.

The molasses is produced at around 2.84% of sugar cane delivered to a sugar mill. Its composition is typically:

Component	Units	Typical Composition
Total solids	%	78
Total reducing sugars as invert sugars	%	50.7
Unfermentable sugars	%	4.3
Fermentable sugars	%	46.4
Total Inorganics	%	11.2
Specific gravity	kg/m^3	1.48

The molasses is pumped from the bladder via filters to the storage tank where it is heated using a hot water tube to maintain the molasses in a fluid state at a controlled temperature. The molasses is pumped to the fermentation section under flow control using a flowmeter and variable speed pump.

The process below is largely relevant for sucrosic, starch and cellulosic feedstocks following conversion of starch and cellulose/hemicellulose to sugars and the fermentation, distillation, rectification and dehydration. The front end and back end stillage/vinasse/dunder treatment is dependent on the feedstock and is discussed in the relevant sections of this report related to each feedstock.

Fermentation

Syrup at controlled temperature is pumped to fermentation tanks where nutrient is added to promote fermentation. The system consists of a pure yeast fermenter, pre-fermenter and the five fermentation tanks. Yeast is cultured in the laboratory then to a yeast fermenter and to the pre-fermenter to sustain optimum yeast activity.

Additional refrigerated yeast vessels are installed to maintain yeast cream at optimum conditions to supplement yeast activity following shutdown and cleaning events by direct addition to the fermenters.

Fermentation is initiated in the first fermenter in batch mode prior to it being switched to continuous mode by continuous addition of molasses to pre-fermenter and first fermenter. Dilution water, sulphuric acid and nutrient solutions are also added to these fermenters. The nutrient solution consists of phosphate and nitrates. Sulphuric acid is dosed to control pH.

The fermenting mash is pumped to the next fermenter. Each fermenter is agitated to ensure settling of yeast does not occur.

Heat generated by fermentation is removed by recirculation of the mash through external heat exchangers. Aeration of the pre-fermenter and first fermenter is aerated to promote yeast growth.

Fermented mash leaving the fifth fermenter is fed to the Beer Tank which supplies the distillation section. The mash has an alcoholic content of 10% (by volume) in the final fermenter although variations can occur depending on raw material quality.

Air from the fermenters is collected in a central header and fed to the waste air scrubber. Process water used to scrub the air of alcohol is added into the Beer Tank. Approximately half the dry mass of molasses is released during fermentation as carbon dioxide. It is vented to atmosphere or collected, dried and compressed for external sales, subject to market demand. Purer carbon dioxide, if needed, is drawn from the final fermentation tanks.

Distillation, Rectification and Condensation

- Beer Preheat Train

  The 10% (by volume) Beer is pumped from the Beer Tank through a series of heat exchangers to raise the temperature. Heat is sourced from the:

  - dehydrated vapour from the Molecular Sieve Unit.
  - Beer column bottoms (thin dunder)

  Periodic cleaning of this heat exchanger is required and is achieved using clean-in-place systems.

  The Beer Preheater / Molecular Sieve Unit Product Condenser is a shell and tube heat exchanger with the beer on the tubeside and dehydrated alcohol vapours on the shell side. The Beer/Thin Dunder shell and tuber exchangers operate with two on-line units and one unit in standby or undergoing a cleaning cycle. The fouling tendency is high and CIP systems are hard-piped for efficient cleaning.

- Beer Column, degassing column and sludge column

  The Beer Column has 22 trays with rising vapor in contact with liquid. It strips alcohol and carbon dioxide gas from the beer.

  Beer enters the top of the Degasssing Column which is heated by some of the alcohol/water vapor generated in the beer column. The acid gas containing carbon dioxide is drawn from the top.

  The thin dunder leaving the bottom of the Beer Column at 10% dry solids contains less than 100 ppm by weight of alcohol.

  The stripped alcohol is drawn of tray 22 as a vapour and passes to the Rectifying Column.

- Degas Condenser and vent gas scrubbing

  These vapours are fed to the Degas Condenser where the gas is cooled and most of the alcohol/water is collected and condensed in the Degas Condensate Drum.

  The gas leaving the Degas Condenser is mostly CO_2 with some residual alcohol and water. This stream is sent to the Beer Column Vent Scrubber for recovery of alcohol. This scrubber consists of 6 metres of packing over which the alcohol-laden gas is counter-currently contacted with water. This scrubber removes 98 to 99% of the residual alcohol in the carbon dioxide rich vapour before it is vented.

  The scrubbed water leaves the bottom of the scrubber and is pumped to the Degas Condensate Drum.

- Beer Column Reboilers

  The Beer Column reboilers generate the steam that is used in the Beer Column for stripping the alcohol vapour and dissolved gases from the beer. There are two reboiler circuits – each with 100% capacity.

  The thin dunder side of the boiler (tube side) must be cleaned every one or two days.

- Dunder cooling and handling

  The thin dunder from the bottom of the Beer Column is pumped through the Beer Dunder heat exchanger to cool the thin dunder stream. The cooled thin dunder is pumped to the Thin Dunder Tank at about 10% dry solids.

- Rectifying column

  The Rectifying column is a 33 tray column that receives alcohol/water streams from:

  - The Beer Column stripping section which enters below tray 1 with around 43% alcohol content

- The wet alcohol recycle stream from the Molecular Sieve Unit. This liquid stream contains around 66 weight% alcohol.

The Rectifying Colum produces alcohol at 93.5% by volume. Vapour distillate is drawn off tray 30 and is fed to the Molecular Sieve Unit.

The water separated from the alcohol is recovered at the bottom of the column and contains around 6.5 weight% alcohol which is processed in the Stripping Column.

Vapour above tray 30 is collected, condensed in the Rectifying Column Condenser and returned to tray 33 as reflux. Pressure controllers maintain the operating pressure on the top of the Rectifying Column.

Non-condensible, carbon-dioxide-rich gases with residual alcohol vapours are carried through the Rectifying Column Condenser to the Rectifying Column Gas Cooler where the gas is further cooled and condensed to recover alcohol. Remaining non-condensible gas is routed to the vacuum pump.

Two other vapour side-draws:

- Fusel oil vapour is removed from tray 2 or 4
- Technical vapor stream is drawn from tray 6 or 7.

These heavy alcohols and organics are removed to avoid build-up. They are passed forward to the Molecular Sieve Unit.

- Stripping Column

The 6.5 weight% bottoms stream is pumped to the top of the Stripping Column. Alcohol is stripped and returns it to the Rectifying Column via the Stripping Column overhead vapour line.

Steam to the Stripping Column is a combination of 6 bar steam and flash vapour from the Residue Water Flash Drum. The steam is used as the motive steam for the Stripping Column Thermocompressor which pulls flash vapour from the flash drum. The water from the bottom of the Stripping Column is discharged on level control to the Residue Flash Water Drum producing the low pressure steam to the Stripping Column Thermocompressor.

Dehydration using a molecular sieve

The Molecular Sieve Unit receives the net Rectifying Column overhead at about 93.5 vol% and dries the stream down to less than 0.1weight% water.

The stream is dried by passing the vapour through a vessel filled with molecular sieve beads that selectively absorb water vapour. There are two byproducts from the Moelcular Sieve Unit.

- Wet alcohol recycle stream
- Non-condensible vapour stream

The net Rectification Column Distillate is first heated to 113 °C in the Superheater to prevent condensation of vapours on the molecular sieve beads to avoid the liquid blinding the bead pores. The superheated vapour is then passed through one of the molecular sieve beds. About 15 to 20% of the anhydrous alcohol leaving the bed is used as purge gas to regenerate the other bed. The remainder is returned to the Distillation Area as product.

Regeneration of the Molecular Sieve Unit is achieved using pressure swing adsorption. Adsorption occurs at a pressure slightly above atmospheric pressure and desorption takes place under vacuum. Dropping the pressure on the unit after an adsorption cycle, the molecular sieve releases the water it has adsorbed. Using anhydrous alcohol as the carrying vapour serves three purposes:

- It sweeps the water vapor from the sieve material
- The dry alcohol shifts the equilibrium to maximize the dryness of the sieve material.
- It compensates for the energy loss from water desorption. Maintaining temperature ehnaces the desorption rate.

The purge gas is reheated to 113 °C before it enters the regenerating bed which adds further heat for water desorption.

The wet purge vapour leaving the bed contains around 66 weight% alcohol and 33weight% water vapour. This vapour is condensed in the Molecular Sieve Unit Purge Condenser. The condensate is collected and in the Molecular Recycle Drum and pumped back to the Rectification Column via the Recycle Preheater.

- Vacuum system

  The Vacuum System provides the source of vacuum for the Molecular Sieve Unit regeneration system and as a means of removal of carbon dioxide from the Rectification Column overhead system and the dehydrated alcohol recovery system.

  The vapour from the Dehydrated Alcohol Gas Cooler which is rich in alcohol vapour is normally routed back to the Molecular Sieve Purge Condenser which condenses most of this vapour and reduces the load on the vacuum system.

  The Rectifying Column Gas Cooler outlet gas which contains minimal alcohol is routed back directly to the vacuum pump suction header.

- Dehydrated alcohol recovery

  Dehydrated alcohol vapours are sent to the Distillation Area where the vapours are condensed in the either the Molecular Sieve Unit Product Condenser/Beer Preheater on in the Molecular Sieve Unit Product Condenser.

  To avoid carbon dioxide build-up in the condensers and potentially high product acidity, about 3% of the alcohol vapour is drawn off the outlet of the condensers and router to the Moelcular Sieve Product Gas Cooler. The steam is partially condensed to recover as much alcohol as possible. The non-condensibles from the Dehydrated Alcohol Gas Cooler are returned back to the vacuum system where it is recompressed and sent with the other Molecular Sieve Unit non-condensibles back to the Beer Column Vent Scrubber.

  The condensed alcohol is collected in the Dehydrated Alcohol Receiver and pumped by the Alcohol Product Pumps to storage by way of the Rectifying Column Feed Preheater where it preheats the Molecular Sieve Unit wet alcohol recycle. The dehydrated alcohol is then cooled in the Alcohol Product Cooler before being sent to the Alcohol Product Storage Tanks (x3).

  A truck load-out facility is included to fill B-double road tankers for delivery to customer blending facilities in Newcastle.

Dunder handling

The dunder is the underflow from the Beer Column. This is typically 10 to 16% solids by weight. It is pumped through the Beer / Thin Dunder Preheater and into the Thin Dunder Tank.

The Thin Dunder is transferred to a header supplying two ANDRITZ D7-series decanter centrifuges. Each one is capable of handling the full Thin Dunder flow. The liquid phase passes to the biogas plant as Wastewater for reduction of COD/BOD. Some of the liquid phase is returned to the thin dunder tank to control solids content to maintain a consistent feed to the centrifuges,

The Thick Dunder at 35 to 40% solids content is conveyed to a covered stockpile. Thick dunder is withdrawn from the stockpile by a front end loader which feeds a moving floor bin that supplies Thick Dunder to the Fertiliser Plant. Thick Dunder is conveyed to a blending tank where dry nitrogenous and phosphate fertiliser is added along with water to drop the solids to 30 to 35%.

The nutrient streams are received in bulk and are unloaded into open-faced, lined-concrete hoppers. Nutrient is recovered from each hopper by the front end loader which transfer each nutrient to a separate live bottom bin feeding nutrient to the Blending Tank.

- Urea - 145 kg per tonne of dunder
- Ammonium sulphate - 40 kg per tonne of dunder
- Di-ammonium phosphate - 47.5 kg per tonne of dunder

The liquid fertiliser high nitrogen and phosphorous blend is pumped to a storage tank. Tankers are loaded from the storage tank at a Tanker loading facility and delivered to customers on demand and pumped directly onto farmers cropping rows subject to field access and forecast rainfall.

Blending is used to increase the product value and create a range of fertilisers that are suitable for regional cropping needs.

Biogas plant

Cooled wastewater from the Andritz Centrifuge is pumped to the Preacidification Tank. The Preacidification Tank will provide an environment to encourage the acidification of the wastewater as well as equalize the reactor influent. The Preacidification Tank reduces the filamentous bacteria population in the anaerobic bacteria consortium. The Preacidification Tank receives recycle from the Bio-reactor to encourage bacterial growth.

The Preacidification Tank contents will flow by gravity to the front-end of the in-ground covered Bio-reactor where a low-rate upflow sludge blanket process is deployed via the use of a distribution header-lateral piping network along the bottom of the Bio-reactor.

The high COD wastewater passes upward through the sludge blanket and microorganisms digest the feed, destroying BOD, COD, and TSS, while generating biogas. The treated anaerobic effluent will exit the reactor through the floating tube settlers and effluent header piping located at the back-end of the Bio-reactor as the biogas generated begins to separate from the treated wastewater and the anaerobic sludge starts to settle.

The final effluent containing around 1,200 mg/L COD will flow by gravity to the irrigation pond where it will be held until used to irrigate the surrounding cropland.

The Bio-reactors will be completely sealed with a floating, insulated geomembrane cover, such that the system can operate under a slight vacuum pressure and allow for collection of biogas, temperature control, and positive odor control. Negative odors caused by hydrogen sulfide in the biogas will not be released to the atmosphere, eliminating the discharge of foul odors. The anaerobic digestion process continuously produces biogas, which is collected underneath the Bio-reactor cover and transmitted, via biogas blowers, to a gas engine or a back-up biogas flare for disposal.

Bio-sludge is allowed to accumulate and is removed annually during a refinery shutdown. The nutrient-rich biosludge is used as fertiliser supplement.

Steam and Energy

Steam and energy is required for process purposes.

Biogas containing around 60% of methane is recovered from the biogas plant. This is collected in a holding tank at 5 barg pressure. The biogas is supplied to a 2.5 megawatt gas engine which provides electricity. LPG tanks are provided as a backup fuel.

Exhaust heat is recovered from the engine and used to generate process steam at 9 barg (180 deg C). A steam drum accumulator is used to hold steam to handle process upsets.

Offices and Laboratory

Office and laboratory facilities are integrated with plant operations and maintenance facilities in a single building.

Cost assumptions[28]

- Utilities and services considered include raw water, process water, demineralised water, steam, electricity, fuel oil, and effluent treatment.
- Cost of utilities and services were based upon our historical and quoted data.
- Chemicals and reagents required include water treatment chemicals, sulphuric acid, caustic soda, nitric acid, defoamer, phosphate, urea, and yeast.
- Annual cost of maintenance has been taken as 3 % of the total plant installed capital investment. Lubricants, safety equipment, etc is included in the cost of maintenance and repairs.
- Allowance has been made for 2 part-time laboratory staff. Laboratory establishment cost have been included in Non-process buildings.
- Office operating supplies costs such as stationary and related supplies and cleaning have been included.

[28] The process design, equipment specification and costs used for this process have been developed by AECOM from a variety of sources. We have not had access to any production information from an Australian proponent.

- Technology licensing fees are covered in the capital cost estimate.
- Insurance includes Material Damage and Loss of Production, Public Liability cover and Motor Vehicle insurance. An allowance of 0.3 % of the total installed capital cost has been allowed to cover this item.
- An allowance of 20% has been used to cover payroll tax, workers compensation insurance, holiday loadings and shift loadings. All overheads have been included in operating labour and supervision or executive salaries under general expenses.
- Personnel requirements are based on standard process plant operating practices, handling and administration requirements.

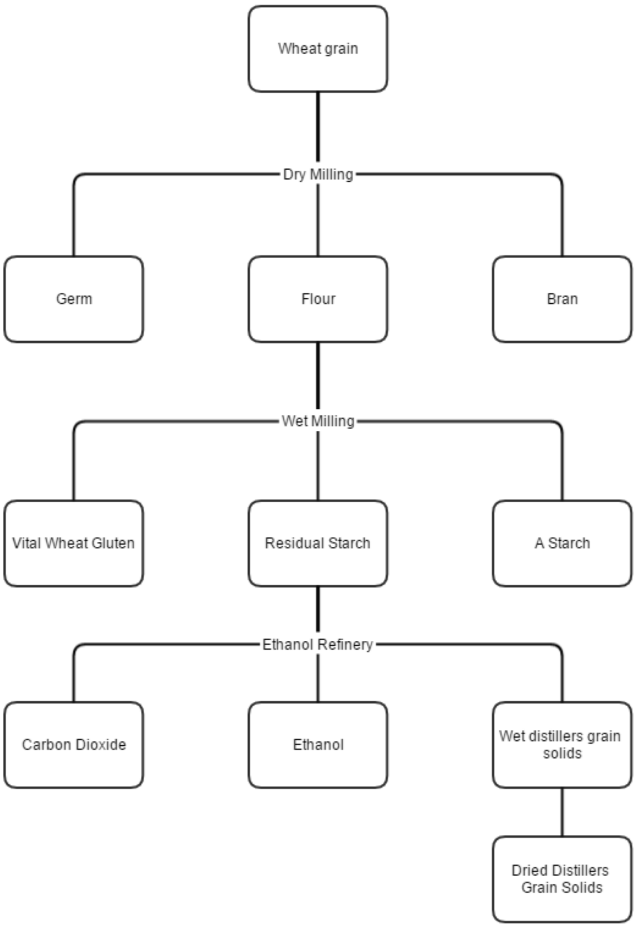
C2 Starch Refinery

Introduction

Australia has substantial wheat production capacity and exceeds local demand resulting in Australia being one of the largest exporters of wheat in the world with up to 80% exported in some years.

Wheat is the second largest agricultural sector in NSW with a turnover of close to $2 billion – more than twice the next largest sector.

Wheat farming in western NSW is constrained by high freight costs. Existing and new growers of wheat can be benefit from a large wheat consumer located in the western regions of wheat belt. Access to lower cost wheat also favours production of ethanol in these areas in conjunction with co-located intensive cattle finishing. .



Major products of wheat processing into ethanol include gluten, stock feed (wet and dry high protein distiller grain solids), biogas and electricity, bran and wheatgerm.

The refinery process is depicted in the Process Block Model on the following page. It includes:

- Wheat receival and storage
- Dry milling to produce bran, pollard and germ
- Wet milling – to produce gluten and starch
- Liquefaction and Saccharification
- Fermentation
- Distillation, rectification and condensation
- Dehydration
- Anhydrous alcohol transfer and storage system
- Distiller Grain Solids handling, storage and disposal system
- Biogas plant
- Steam and electricity

Substantial credits from gluten, bran and distillers grain solids can be extracted from wheat. Consequently, the facility design would be based on:

- Dry milling to extract bran and germ by-products
- Wet milling to extract gluten but not A-starch or B-starch – all of which is used along with C starch to produce ethanol.
- Starch-based ethanol refining
- Dried distiller’s grain solids but not including solubles which are used to generate biogas and electricity

Starch Ethanol Plant Process Description

Grain Receival

A new entrant producer would consume around 280,000 tonnes of grain annually to produce 100 million litres per year of ethanol. A target of 10.5% minimum protein is used to maintain a balance of gluten and ethanol production. A stockpile is included in the capital cost to enable the ethanol refinery to purchase wheat during the relatively short harvesting period. This enables growers to supply directly to the ethanol refinery directly during harvest or from farm storage.

Grain would be received in B-doubles through the weighbridge where it is automatically sampled. The trucks unload adjacent or onto the stockpile. The stockpile would be built using front end loaders with large grain buckets.

The 150,000 tonne stockpile would be covered by tarpaulins that are drawn forward or back by wire rope carriers along the edges and mobile equipment using ropes connected to the Tarpaulin front.

Dry Milling Plant

Wheat grain would be loaded from the stockpile to a bin feeding a wheat screen/cleaner. The coarse rejects (sticks/stones are dumped, whilst finer rejects would be added to the wet grain solids. Those accepted pass to a mixer where water would be sprayed onto the wheat grain surface to increase the moisture content to around 15%. This enhances processing consistency and consolidates the outer grain layer to increase breakage size during subsequent dry milling.

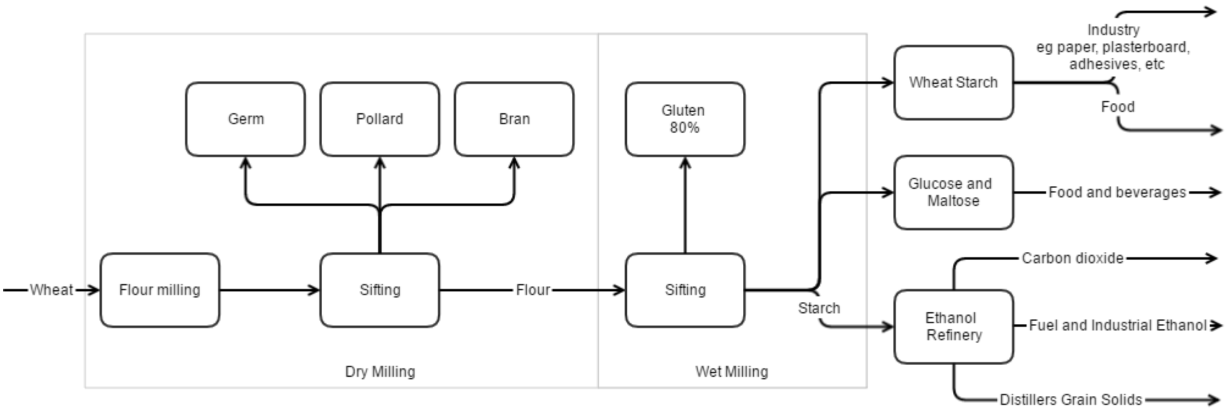
The moistened grain would be mechanically elevated by bucket to a silo with a 24 hour storage capacity where it would be held prior to processing on a first-in, first-out basis. A second silo would be also provided to enable grain quality management and processing reliability. The wheat would be metered and conveyed from the bottom of the silo to the Dry Mill where it would be separated into bran, germ and flour.

The dry milling process uses a series of breaking and separation rollers, air-assisted gyratory sifters and reduction rollers with secondary gyratory sifters.

Coarser bran would be removed by air separation and a gyratory sifter following the Grain Breaker Roller. It would be further processed through a Bran Reducing Roller and Bran Sifter to recover the finest fraction which is returned to the flour line. The remaining Millrun Bran would be transferred to a receival bin in the Feed Plant.

The Coarse Flour Underflow from the Grain Breaker Roller Sifter would be processed through Flour Reducing Rollers and separated by the Flour Gyratory Sifter into Flour and Germ. The coarser Germ fraction would be processed through Germ Rollers and fine flour would be recovered and sent back to the Flour Underflow. The Germ would be sent to the Feed Plant for conditioning, pelletising and packaging.

The Reduced Flour Underflow from the Flour Gyratory Sifter would be conveyed to the Wet Mill for separation of starch and gluten.



Wet Milling Plant

Several process options exist for wet milling supported by technology vendors and complete supply and install packages. The GEA Process is discussed below.

The wet mill separates the gluten and starch into A-starch, gluten and B-starch with additional C-starch in the wash water stream. The starch streams are recombined and pumped to the Ethanol Refinery. The Wet Milling Plant would be focused on gluten removal and gentle drying to produce high value gluten.

- Dough Preparation

  After the Dry Mill process, flour would be received in the Wet Milling Plant Flour Silo (12 hours capacity). The Flour would be metered from the Flour Silo to a dough mixer where water is added. A high pressure homogenizer encourages agglomeration of particles for maximum gluten separation. Intense mixing create a lump free dough and proteins agglomerate under the high shear forces. Further hydration occurs during time in the maturation tank.

- A-stage Separation

  The flour slurry would be pumped to the 3 Phase Decanter Centrifuge which produces A-starch and combined gluten and B-starch and a liquid phase. The A-starch would be recombined with the centrifuged liquid phase and B-starch after it is separated from gluten in the extraction step below.

- Gluten Extraction, Finishing, Dewatering and Drying

  The B-starch-gluten would be transferred to the Gluten Finisher. The plate and knives in the Finisher ruptures cells to promote extraction of the starch from the gluten. Washing separates the starch from the gluten. The starch wash-water stream would be centrifuged and mixed with A-starch and pumped to the Ethanol Refinery.

  Solids content of the B-starch stream would be increased by centrifugation to 35% solids. The liquid phase would be forwarded to the fermentation tanks for dilution of the Saccharified Mash.

  Entrained water would be removed from the gluten using bent screens. The gluten would be transferred to a screw press to remove more moisture and increase the gluten stream solids to 35% solids.

  A ring dryer would be used to dry the gluten. The gluten would be continuously extruded through a “fish tail” feeder across the dryer’s rotor. The shredded gluten would be mixed with a recycled stream of dry gluten to improve heat transfer and powder quality. The dryer creates internal recirculation of the semi-dried material. Larger particles have a higher retention time which improves drying.

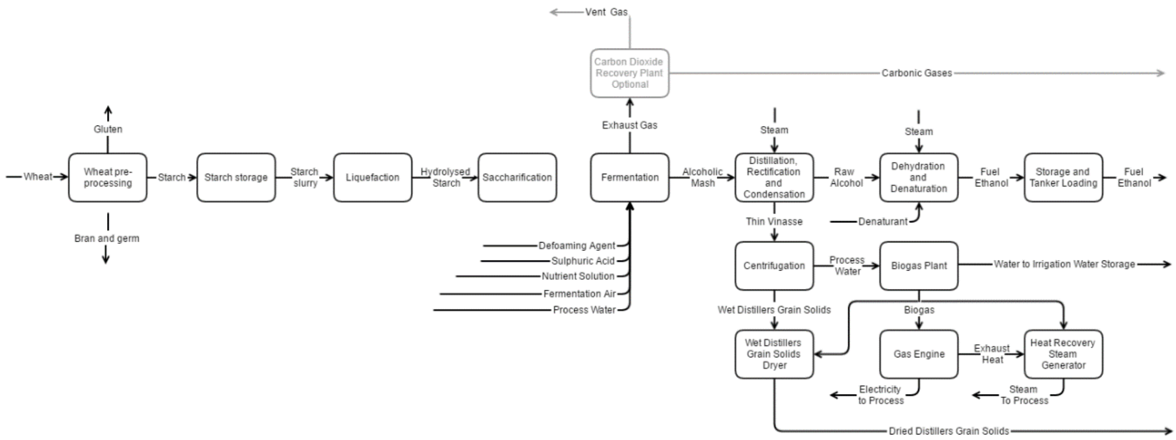
  The drier would be heated using biogas from the Biogas Plant.

The final moisture content of the gluten power would be 7%. It would be sifted. Oversize particles would be milled and re-sifted. The sifter underflow would be pneumatically conveyed through the air cooler which uses ambient, humidity adjusted air to the packing plant receiving silo. The gluten would be packed in one tonne FIBC bags and consolidated in a warehouse before loaded to a curtain-sided B-double truck for transfer to an export container port.

Ethanol Refinery

- Liquefaction and saccharification

Liquefaction and saccharification is the conversion of starch molecules into fermentable sugars. Liquefaction begins by heating the starch slurry in a stirred tank to around 110 degrees Celsius for 30 minutes to achieve partial hydrolyses of the starch slurry. A portion of the alpha-amylase required for full hydrolysis would be added. Heating of the incoming starch slurry is achieved by using Distilelrs Dried Dried Grain Solids evaporator condensate.



The pH is adjusted to 5-6.5 by adding caustic.

Gelatinisation would be completed by passing the partially liquefied slurry through the Mash Jet Cooker which takes the temperature to 121 degrees Celsius and holds it for around 15 minutes. The Mash would be expanded in a vacuum to lower the temperature to less than 89 degrees Celsius and the vapour blow-off would be forwarded to the Distillation and Evaporators.

The remaining alpha-amylase would be added and held in a mixed tank for five hours to complete the liquefaction process.

- Saccharification

The Mash would be pumped to the Pre-saccharification tanks and the enzyme gluco-amylase would be added to complete the conversion of starch to glucose. The residence time of the holding tank would be five hours prior to transfer to the Pre-fermentation Tank. Saccharification continues and would be completed in the Fermentation Tanks.

- Fermentation

The Mash at controlled temperature (31 to 33 degrees Celsius) would be pumped to fermentation tanks where nutrient would be added to promote fermentation. The system consists of a pure yeast fermenter, pre-fermenter and the five fermentation tanks. Yeast would be cultured from laboratory to yeast fermenter to pre-fermenter to sustain optimum yeast activity.

Additional refrigerated yeast vessels would be installed to maintain yeast cream at optimum conditions to supplement yeast activity following shutdown and cleaning events by direct addition to the fermenters.

Fermentation would be initiated in the Pre-fermenter in batch mode prior to it being switched to continuous mode by continuous addition of Mash to pre-fermenter and first fermenter. Dilution water, sulphuric acid and nutrient solutions are also added to these fermenters. The nutrient solution consists of phosphate and nitrates. Sulphuric acid would be dosed to control pH.

The fermenting mash would be pumped to the next fermenter. Each fermenter would be agitated to ensure settling of yeast does not occur.

Heat generated by fermentation is removed by recirculation of the mash through external heat exchangers. Aeration of the pre-fermenter and first fermenter is aerated to promote yeast growth.

Fermented mash leaving the fifth fermenter would be fed to the Beer Tank which supplies the distillation section. The mash would havean alcoholic content of 10% (by volume) in the final fermenter although variations can occur depending on raw material quality.

Air from the fermenters would be collected in a central header and fed to the waste air scrubber. Process water used to scrub the air of alcohol would be added into the Beer Tank. Approximately half the dry mass of glucose converted to ethanol would be released during fermentation as carbon dioxide. It would be vented to atmosphere or collected, dried and compressed for external sales, subject to market demand. Purer carbon dioxide, if needed, would be drawn from the final fermentation tanks.

- Auxiliary equipment

Auxiliary equipment includes:

- Storage, dilution and dosing of sulphuric acid
- Storage and dosing of caustic and chlorine cleaning agents
- Dilution and dosing of nutrients
- Dosing of defoamers

Distillation, Rectification and Condensation

- Beer Preheat Train

The 10% (by volume) Beer would be pumped from the Beer Tank through a series of heat exchangers to raise the temperature. Heat is sourced from the:

- dehydrated vapour from the Molecular Sieve Unit.
- Beer column bottoms (thin vinasse)

Periodic cleaning of these heat exchanger would be required and achieved using clean-in-place systems.

The Beer Preheater / Molecular Sieve Unit Product Condenser would be a shell and tube heat exchanger with the beer on the tubeside and dehydrated alcohol vapours on the shell side. The Beer/Thin Vinasse shell and tuber exchangers operate with two on-line units and one unit in standby or undergoing a cleaning cycle. The fouling tendency is high and CIP systems are hard-piped for efficient cleaning.

- Beer Column, degassing column and sludge column

The Beer Column has 22 trays with rising vapor in contact with liquid. It strips alcohol and carbon dioxide gas from the beer.

Beer enters the top of the Degasssing Column which would be heated by some of the alcohol/water vapor generated in the beer column. The acid gas containing carbon dioxide would be drawn from the top.

The thin vinasse leaving the bottom of the Beer Column at 10% dry solids contains less than 100 ppm by weight of alcohol.

The stripped alcohol would be drawn of tray 22 as a vapour and passes to the Rectifying Column.

- Degas Condenser and vent gas scrubbing

These vapours are fed to the Degas Condenser where the gas would be cooled and most of the alcohol/water collected and condensed in the Degas Condensate Drum.

The gas leaving the Degas Condenser would be mostly CO_2 with some residual alcohol and water. This stream would be sent to the Beer Column Vent Scrubber for recovery of alcohol. This scrubber consists of 6 metres of packing over which the alcohol-laden gas is counter-currently contacted with water. This scrubber removes 98 to 99% of the residual alcohol in the carbon dioxide rich vapour beforebeing vented.

The scrubbed water leaves the bottom of the scrubber would be pumped to the Degas Condensate Drum.

- Beer Column Reboilers

  The Beer Column reboilers generate the steam that would be used in the Beer Column for stripping the alcohol vapour and dissolved gases from the beer. There are two reboiler circuits – each with 100% capacity.

  The thin dunder side of the boiler (tube side) would require cleaning every one or two days.

- Dunder cooling and handling

  The thin vinasse from the bottom of the Beer Column would be pumped through the Beer Vinasse heat exchanger to cool the thin vinasse stream. The cooled thin vinasse would be pumped to the Thin Vinasse Tank at about 10% dry solids.

- Rectifying column

  The Rectifying column would be a 33 tray column that receives alcohol/water streams from:

  - The Beer Column stripping section which enters below tray 1 with around 43% alcohol content
  - The wet alcohol recycle stream from the Molecular Sieve Unit. This liquid stream contains around 66 weight% alcohol.

  The Rectifying Colum produces alcohol at 93.5% by volume. Vapour distillate is drawn off tray 30 and is fed to the Molecular Sieve Unit.

  The water separated from the alcohol would be recovered at the bottom of the column and contains around 6.5 weight% alcohol which is processed in the Stripping Column.

  Vapour above tray 30would be collected, condensed in the Rectifying Column Condenser and returned to tray 33 as reflux. Pressure controllers maintain the operating pressure on the top of the Rectifying Column.

  Non-condensible, carbon-dioxide-rich gases with residual alcohol vapours would be carried through the Rectifying Column Condenser to the Rectifying Column Gas Cooler where the gas would befurther cooled and condensed to recover alcohol. Remaining non-condensible gas would be routed to the vacuum pump.

  Two other vapour side-draws:

  - Fusel oil vapour would be removed from tray 2 or 4
  - Technical vapor stream would be drawn from tray 6 or 7.

  These heavy alcohols and organics would be removed to avoid build-up. They would be passed forward to the Molecular Sieve Unit.

- Stripping Column

  The 6.5 weight% bottoms stream would be pumped to the top of the Stripping Column. Alcohol would be stripped and returns it to the Rectifying Column via the Stripping Column overhead vapour line.

  Steam to the Stripping Column would be a combination of 6 bar steam and flash vapour from the Residue Water Flash Drum. The steam used as the motive steam for the Stripping Column Thermocompressor which pulls flash vapour from the flash drum. The water from the bottom of the Stripping Column would be discharged on level control to the Residue Flash Water Drum producing the low pressure steam to the Stipping Column Thermocompressor.

- Dehydration using a molecular sieve

  The Molecular Sieve Unit receives the net Rectifying Column overhead at about 93.5 vol% and dries the stream down to less than 0.1weight% water.

  The stream would be dried by passing the vapour through a vessel filled with molecular sieve beads that selectively absorb water vapour. There would be two byproducts from the Moelcular Sieve Unit.

  - Wet alcohol recycle stream
  - Non-condensible vapour stream

  The net Rectification Column Distillate would be first heated to 113 °C in the Superheater to prevent condensation of vapours on the molecular sieve beads to avoid the liquid blinding the bead pores. The superheated vapour would be then passed through one of the molecular sieve beds. About 15 to 20% of the anhydrous alcohol leaving the bed would be used as purge gas to regenerate the other bed. The remainder would be returned to the Distillation Area as product.

Regeneration of the Molecular Sieve Unit would be achieved using pressure swing adsorption. Adsorption occurs at a pressure slightly above atmospheric pressure and desorption takes place under vacuum. Dropping the pressure on the unit after an adsorption cycle, the molecular sieve releases the water it has adsorbed. Using anhydrous alcohol as the carrying vapour serves three purposes:

- It sweeps the water vapor from the sieve material
- The dry alcohol shifts the equilibrium to maximize the dryness of the sieve material.
- It compensates for the energy loss from water desorption. Maintaining temperature enhances the desorption rate.

The purge gas is reheated to 113 °C before it enters the regenerating bed which adds further heat for water desorption.

The wet purge vapour leaving the bed contains around 66 weight% alcohol and 33weight% water vapour. This vapour would be condensed in the Molecular Sieve Unit Purge Condenser. The condensate would be collected and in the Molecular Recycle Drum and pumped back to the Rectification Column via the Recycle Preheater.

- Vacuum system

The Vacuum System provides the source of vacuum for the Molecular Sieve Unit regeneration system and as a means of removal of carbon dioxide from the Rectification Column overhead system and the dehydrated alcohol recovery system.

The vapour from the Dehydrated Alcohol Gas Cooler which is rich in alcohol vapour would normally be routed back to the Molecular Sieve Purge Condenser which condenses most of this vapour and reduces the load on the vacuum system.

The Rectifying Column Gas Cooler outlet gas which contains minimal alcohol is routed back directly to the vacuum pump suction header.

- Dehydrated alcohol recovery

Dehydrated alcohol vapours would be sent to the Distillation Area where the vapours are condensed in the either the Molecular Sieve Unit Product Condenser/Beer Preheater on in the Molecular Sieve Unit Product Condenser.

To avoid carbon dioxide build-up in the condensers and potentially high product acidity,about 3% of the alcohol vapour would be drawn off the outlet of the condensers and router to the Moelcular Sieve Product Gas Cooler. The steam would be partially condensed to recover as much alcohol as possible. The non-condensibles from the Dehydrated Alcohol Gas Cooler are returned back to the vacuum system where it is recompressed and sent with the other Molecular Sieve Unit non-condensibles back to the Beer Column Vent Scrubber.

The condensed alcohol would be collected in the Dehydrated Alcohol Receiver and pumped by the Alcohol Product Pumps to storage by way of the Rectifying Column Feed Preheater where it preheats the Molecular Sieve Unit wet alcohol recycle. The dehydrated alcohol would be then cooled in the Alcohol Product Cooler before being sent to the Alcohol Product Storage Tanks (x3).

A truck load-out facility would be included to fill B-double road tankers for delivery to customer blending facilities in Sydney.

Vinasse handling

The vinasse is the underflow from the Beer Column. This is typically 10 to 16% solids by weight. It would be pumped through the Beer / Thin Vinasse Preheater and into the Thin Vinasse Tank.

The cooled Thin Vinasse would be transferred to a header supplying two GEA or ANDRITZ D7-series decanter centrifuges. Each one would be capable of handling the full Thin Vinasse flow. The liquid phase passes to the biogas plant as Wastewater for reduction of COD/BOD. Some of the liquid phase would be returned to the thin vinasse tank to control solids content to maintain a consistent feed to the centrifuges, The Wet Distiller Grain Solids at 30% to 35% solids content is conveyed to the Feed Mill. A rotary drum dryer would be used to remove moisture. The heat source would be biogas (60% methane) from the Biogas Plant. Heat from the hot exhaust is transferred to a clean air stream using an air to air heat exchanger. The hot air stream removes moisture and volatile organic carbon. The exhaust would be ducted to the gas burner to provide combustion air for the biogas flame. This removes the dilute volatile organic carbon captured in the vapour-rich stream from the dryer.

The wet feed would be reduced to 10% moisture content to become dried distillers grain solids. The dried distillers grain solids would be pelletised and cooled using ambient air. The dried distillers grain solids are packaged into one tonne FIBC's for truck loading into side-curtain, B-double trucks.

Biogas plant

Cooled wastewater (centrate) from the Andritz Centrifuge would be pumped to the Preacidification Tank. The Preacidification Tank will provide an environment to encourage the acidification of the wastewater as well as equalize the reactor influent. The Preacidification Tank reduces the filamentous bacteria population in the anaerobic bacteria consortium. The Preacidification Tank receives recycle from the Bio-reactor to encourage bacterial growth.

The Preacidification Tank contents will flow by gravity to the front-end of the in-ground covered Bio-reactor where a low-rate upflow sludge blanket process is deployed via the use of a distribution header-lateral piping network along the bottom of the Bio-reactor.

The high COD wastewater passes upward through the sludge blanket and microorganisms digest the feed, destroying BOD, COD, and TSS, while generating biogas. The treated anaerobic effluent will exit the reactor through the floating tube settlers and effluent header piping located at the back-end of the Bio-reactor as the biogas generated begins to separate from the treated wastewater and the anaerobic sludge starts to settle.

The final effluent containing around 4.0 mg/L COD will flow by gravity to the irrigation pond where it will be held until used to irrigate surrounding cropland.

The Bio-reactors will be completely sealed with a floating, insulated geomembrane cover, such that the system can operate under a slight vacuum pressure and allow for collection of biogas, temperature control, and positive odour control. Negative odours caused by hydrogen sulfide in the biogas will not be released to the atmosphere, eliminating the discharge of foul odours. The anaerobic digestion process continuously produces biogas, which would be collected underneath the Bio-reactor cover and transmitted, via biogas blowers, to a gas engine or a back-up biogas flare for disposal.

Bio-sludge will be allowed to accumulate and is removed annually during a refinery shutdown. The nutrient-rich biosludge would be used as fertiliser supplement.

Steam and Energy

Steam and energy is required for process purposes.

Biogas containing around 60% of methane would be recovered from the biogas plant. This is collected in a holding tank at 5 barg pressure. The biogas would be supplied to 2 x 2.5 megawatt gas engine which provides electricity. LPG tanks are provided as a backup fuel.

Exhaust heat is recovered from the engine and used to generate process steam at 9 barg (180 deg C). A steam drum accumulator would be used to hold steam to handle process upsets.

Biogas would be also supplied to the rotary dryer for drying of dried distillers grain solids.

Offices and Laboratory

Office and laboratory facilities are integrated with plant operations and maintenance facilities in a single building.

Feed Plant

Pelleting machines are used to produce pellets from:

- Bran
- Germ
- Dried distillers grain solids

The pellets are transferred through an ambient air cooler. The cooled product would be packaged into one tonne FIBCs suitable for loading onto side-curtain, B-double truck for delivery to customers.

On-site covered storage of 42 metres x 24 metres would be provided to hold 500 tonnes of bagged products in a double height configuration.

Cost assumptions[29]

- Utilities and services considered include raw water, process water, demineralised water, steam, electricity, fuel oil, and effluent treatment.
- Cost of utilities and services were based upon benchmarked and quoted data.
- Chemicals and reagents required include water treatment chemicals, sulphuric acid, caustic soda, nitric acid, defoamer, phosphate, urea, and yeast.
- Annual cost of maintenance has been taken as 3% of the total plant installed capital investment. Lubricants, safety equipment, etc is included in the cost of maintenance and repairs.
- Allowance has been made for 3 fulltime laboratory staff. Laboratory establishment cost have been included in Non-process buildings.
- Office operating supplies costs such as stationary and related supplies and cleaning have been included.
- Technology licensing fees are covered in the capital cost estimate.
- Insurance includes Material Damage and Loss of Production, Public Liability cover and Motor Vehicle insurance. An allowance of 0.3 % of the total installed capital cost has been allowed to cover this item.
- An allowance of 20% has been used to cover payroll tax, workers compensation insurance, holiday loadings and shift loadings. All overheads have been included in operating labour and supervision or executive salaries under general expenses.
- Personnel requirements are based on standard process plant operating practices, handling and administration requirements.

[29] The process design, equipment specification and costs used for this process have been developed by AECOM from a variety of sources. We have not had access to any production information from an Australian proponent.

C3 Cellulosic Refinery

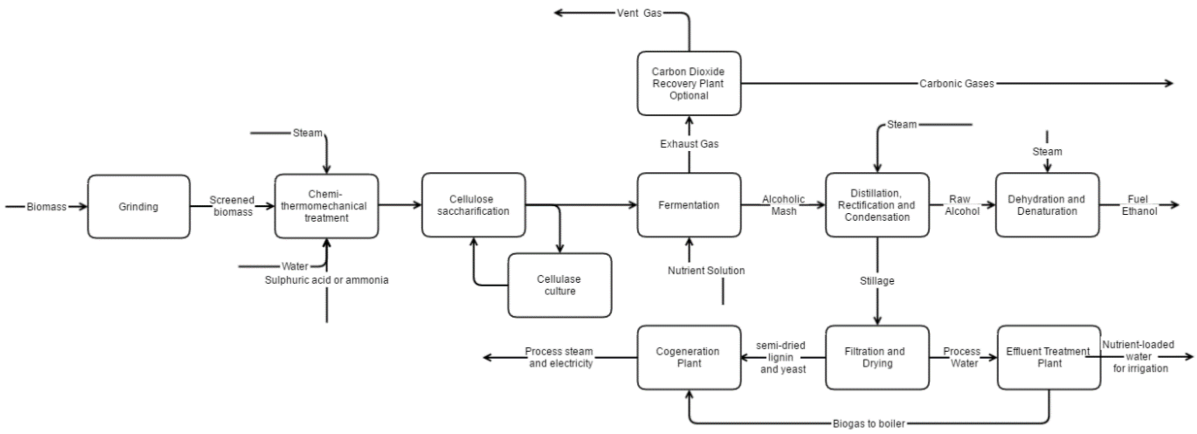
Introduction

Cellulose and hemi-cellulose are the most abundant feedstock in the world and represent the cornerstone for renewable fuels either from trees, grasses, crop by-products, algae or recycled fibrous waste.

The cellulosic process described below is substantially based on the NREL two stage, low acid pre-treatment process followed by enzymatic hydrolysis discussed in the 2012 report titled, "Process Design and Economics for Biochemical Conversion of Lignocellulosic Biomass to Ethanol: Dilute-Acid Pretreatment and Enzymatic Hydrolysis of Corn Stover".

The key requirement to produce high yielding ethanol is to release cellulose and hemi-cellulose from lignin and then using enzymes to convert these streams to sugars and ethanol. It is complicated by the chemical diversity of cellulosic feedstock leading to side reactions and side products that constrain efficient conversion to ethanol.

Cellulosic Ethanol Plant Process Description



Simplified Cellulosic Ethanol Refinery Block Diagram

Biomass Receival

Forest residues and thinnings will chipped in-forest and screened prior to delivery to site in side-tipping B-double trucks. The stockpile at site will be built by trucks discharging onto the stockpile with a dozer and extended pushing blade operating to build the stockpile. Cane trash and mallee eucalypt will be supplied using the same method. A weighbridge will measure each truck's net load.

Recovery from the stock-pile will use a front end loader with a large bucket. The front end loader will tip the biomass into a hopper where it will be conveyed to a screening room. Oversize wood will be re-chipped and re-screened. Cane trash will be shredded prior to screening using a modified cane shredder.

Chemi-thermomechanical treatment

The objective of chemi-thermomechanical treatment is to breakdown the biomass, to convert hemi-cellulose to soluble sugars such as xylose and to soften and solubilise lignin to enhance cellulose availability. Care must be taken to avoid excessive degradation of the hemi-cellulose and cellulose to avoid sugar degradation products which reduce yield and subsequently act against enzyme activity.

To this end, biomass is conveyed to a pre-steaming bin which raises the temperature of the feedstock to around 85 to 95 degrees Celsius. It holds the biomass at temperature for ten minutes prior to feeding to two prex (pressure-expansion) screw feeders. Expansion following compression occurs in the presence of hot dilute sulphuric acid. Additional steam is added to raise the temperature in a horizontal (Pandia) digester for a period of 10 minutes to allow the acid to react with biomass at 160 degrees Celsius.

Acid is applied at a rate of around 15 to 20 kg per tonne of biomass.

Compression of the biomass in the prex screw feeders removes water and extractives which are pumped to the biogas plant. Recycled filtrate is added to reduce solids content to around 30% solids.

Pressure letdown occurs to flash steam at 130 degrees. The recovered flash steam is used in the pre-steaming vessel.

A further retention period of 30 minutes at 130 degrees is used iwith an additional acid application of 2 to 5 kilograms per tonne of biomass in an upflow vessel

A further flash to atmospheric pressure is used to transfer the slurry to a conditioning tank where it is diluted to 20% solids. Ammonia gas is fed with the dilution water to raise the pH of the slurry to 5. The slurry is cooled to 75 degrees Celsius.

Enzymatic Saccharification and fermentation

The cellulose and xylose from hemi-cellulose is converted to glucose by enzymatic action. The conversion occurs simultaneously with the fermentation of glucose to ethanol. This process occurs in staged tanks over a period of five days.

The initial pre-fermentation tanks are at an elevated temperature of around 47 degrees to increase the rate of enzymatic conversion. As glucose is fermented and removed, the enzymatic conversion of cellulose and xylose to glucose are encouraged. Consequently, the fermenters are cooled to around 31 to 33 degrees to promote the enzymatic conversion of glucose and xylose to ethanol.

High solids at 20% creates problems with pumping and the breakdown of cellulose is required. This is achieved by using high consistency slurry pumps to feed a downflow tower with intensive in-line mixing of the enzyme in the feed pipe to the tower. As the cellulose enzymes convert the cellulose to glucose, the solution viscosity drops leading conventional pumping and tank agitation.

Fermentation occurs over five days in a series of vessel trains. As fermentation to ethanol occurs drawing on glucose and xylose, the driving force for conversion is not constrained by an increasing concentration of product until depletion of the cellulose and xylan (hemicellulose) occurs.

Enzymes are supplied as full stream cream from the co-located enzyme production facility.

Enzyme production

The major cost in lignocellulosic ethanol is the cost of production of sufficient enzyme to convert cellulose to glucose and hemi-cellulose to xylose for subsequent conversion to ethanol.

Enzyme can be purchased or produced in-house. A co-located enzyme production facility is proposed and capital is allowed for the construction of the facility. The facility is expected to be built and owned by a specialist enzyme producer such as Novozymes and Genencor. Enzymes will be purchased across the fence to supply the needs of the ethanol refinery. This approach secures:

- Lowest cost enzyme production
- Skilled process design and management
- State of the art enzymes

The enzyme reactors use glucose to promote enzyme production. It is assumed that a cellulosic ethanol refinery will be co-located with an existing sucrosic or starch-fed refinery to secure its financial sustainability. Glucose syrup can be purchased or, if the refinery has co-located starch production, can be manufactured on-site.

Four reaction trains are needed to produce the bacterial strains and enzyme by-products for transfer to the saccharification and fermentation tanks in the ethanol refinery.

Distillation, Rectification and Condensation

- Beer Preheat Train

  The 5% (by volume) Beer is pumped from the Beer Tank through a series of heat exchangers to raise the temperature. Heat is sourced from the:

  - dehydrated vapour from the Molecular Sieve Unit.
  - Beer column bottoms (thin vinasse)

  Periodic cleaning of the heat exchanger is required and is achieved using clean-in-place systems.

The Beer Preheater / Molecular Sieve Unit Product Condenser is a shell and tube heat exchanger with the beer on the tubeside and dehydrated alcohol vapours on the shell side. The Beer/Thin Vinasse shell and tuber exchangers operate with two on-line units and one unit in standby or undergoing a cleaning cycle. The fouling tendency is high and CIP systems are hard-piped for efficient cleaning.

- Beer Column, degassing column and sludge column

The Beer Column has 22 trays with rising vapor in contact with liquid. It strips alcohol and carbon dioxide gas from the beer.

Beer enters the top of the Degasssing Column which is heated by some of the alcohol/water vapour generated in the beer column. The acid gas containing carbon dioxide is drawn from the top.

The thin vinasse leaving the bottom of the Beer Column at 10% dry solids contains less than 100 ppm by weight of alcohol.

The stripped alcohol is drawn of tray 22 as a vapour and passes to the Rectifying Column.

- Degas Condenser and vent gas scrubbing

These vapours are fed to the Degas Condenser where the gas is cooled and most of the alcohol/water is collected and condensed in the Degas Condensate Drum.

The gas leaving the Degas Condenser is mostly CO_2 with some residual alcohol and water. This stream is sent to the Beer Column Vent Scrubber for recovery of alcohol. This scrubber consists of 6 metres of packing over which the alcohol-laden gas is counter-currently contacted with water. This scrubber removes 98 to 99% of the residual alcohol in the carbon dioxide rich vapour before it is vented.

The scrubbed water leaves the bottom of the scrubber is pumped to the Degas Condensate Drum.

- Beer Column Reboilers

The Beer Column reboilers generate the steam that is used in the Beer Column for stripping the alcohol vapour and dissolved gases from the beer. There are two reboiler circuits – each with 100% capacity.

The thin dunder side of the boiler (tube side) must be cleaned every one or two days.

- Dunder cooling and handling

The thin vinasse from the bottom of the Beer Column is pumped through the Beer Vinasse heat exchanger to cool the thin vinasse stream. The cooled thin vinasse is pumped to the Thin Vinasse Tank at about 10% dry solids.

- Rectifying column

The Rectifying column is a 33 tray column that receives alcohol/water streams from:

- The Beer Column stripping section which enters below tray 1 with around 43% alcohol content
- The wet alcohol recycle stream from the Molecular Sieve Unit. This liquid stream contains around 66 weight% alcohol.

The Rectifying Colum produces alcohol at 93.5% by volume. Vapour distillate is drawn off tray 30 and is fed to the Molecular Sieve Unit.

The water separated from the alcohol is recovered at the bottom of the column and contains around 6.5 weight% alcohol which is processed in the Stripping Column.

Vapour above tray 30 is collected, condensed in the Rectifying Column Condenser and returned to tray 33 as reflux. Pressure controllers maintain the operating pressure on the top of the Rectifying Column.

Non-condensible, carbon-dioxide-rich gases with residual alcohol vapours are carried through the Rectifying Column Condenser to the Rectifying Column Gas Cooler where the gas is further cooled and condensed to recover alcohol. Remaining non-condensible gas is routed to the vacuum pump.

Two other vapour side-draws:

- Fusel oil vapour is removed from tray 2 or 4
- Technical vapor stream is drawn from tray 6 or 7.

These heavy alcohols and organics are removed to avoid build-up. They are passed forward to the Molecular Sieve Unit.

- Stripping Column

The 6.5 weight% bottoms stream is pumped to the top of the Stripping Column. Alcohol is stripped and returns it to the Rectifying Column via the Stripping Column overhead vapour line.

Steam to the Stripping Column is a combination of 6 bar steam and flash vapour from the Residue Water Flash Drum. The steam is used as the motive steam for the Stripping Column Thermocompressor which pulls flash vapour from the flash drum. The water from the bottom of the Stripping Column is discharged on level control to the Residue Flash Water Drum producing the low pressure steam to the Stipping Column Thermocompressor

- Dehydration using a molecular sieve

The Molecular Sieve Unit receives the net Rectifying Column overhead at about 93.5 vol% and dries the stream down to less than 0.1weight% water.

The stream is dried by passing the vapour through a vessel filled with molecular sieve beads that selectively absorb water vapour. There are two byproducts from the Moelcular Sieve Unit.

- Wet alcohol recycle stream
- Non-condensible vapour stream

The net Rectification Column Distillate is first heated to 113 °C in the Superheater to prevent condensation of vapours on the molecular sieve beads to avoid the liquid blinding the bead pores. The superheated vapour is then passed through one of the molecular sieve beds. About 15 to 20% of the anhydrous alcohol leaving the bed is used as purge gas to regenerate the other bed. The remainder is returned to the Distillation Area as product.

Regeneration of the Molecular Sieve Unit is achieved using pressure swing adsorption. Adsorption occurs at a pressure slightly above atmospheric pressure and desorption takes place under vacuum. Dropping the pressure on the unit after an adsorption cycle, the molecular sieve releases the water it has adsorbed. Using anhydrous alcohol as the carrying vapour serves three purposes:

- It sweeps the water vapor from the sieve material
- The dry alcohol shifts the equilibrium to maximize the dryness of the sieve material.
- It compensates for the energy loss from water desorption. Maintaining temperature enhances the desorption rate.

The purge gas is reheated to 113 °C before it enters the regenerating bed which adds further heat for water desorption.

The wet purge vapour leaving the bed contains around 66 weight% alcohol and 33weight% water vapour. This vapour is condensed in the Molecular Sieve Unit Purge Condenser. The condensate is collected and in the Molecular Recycle Drum and pumped back to the Rectification Column via the Recycle Preheater.

- Vacuum system

The Vacuum System provides the source of vacuum for the Molecular Sieve Unit regeneration system and as a means of removal of carbon dioxide from the Rectification Column overhead system and the dehydrated alcohol recovery system.

The vapour from the Dehydrated Alcohol Gas Cooler which is rich in alcohol vapour is normally routed back to the Molecular Sieve Purge Condenser which condenses most of this vapour and reduces the load on the vacuum system.

The Rectifying Column Gas Cooler outlet gas which contains minimal alcohol is routed back directly to the vacuum pump suction header.

- Dehydrated alcohol recovery

Dehydrated alcohol vapours are sent to the Distillation Area where the vapours are condensed in the either the Molecular Sieve Unit Product Condenser/Beer Preheater on in the Molecular Sieve Unit Product Condenser.

To avoid carbon dioxide build-up in the condensers and potentially high product acidity, about 3% of the alcohol vapour is drawn off the outlet of the condensers and router to the Molecular Sieve Product Gas Cooler. The steam is partially condensed to recover as much alcohol as possible. The non-condensibles from the Dehydrated Alcohol Gas Cooler are returned back to the vacuum system where it is recompressed and sent with the other Molecular Sieve Unit non-condensibles back to the Beer Column Vent Scrubber.

The condensed alcohol is collected in the Dehydrated Alcohol Receiver and pumped by the Alcohol Product Pumps to storage by way of the Rectifying Column Feed Preheater where it preheats the Molecular Sieve Unit wet alcohol recycle. The dehydrated alcohol is then cooled in the Alcohol Product Cooler before being sent to the Alcohol Product Storage Tanks (x3).

A truck load-out facility is included to fill B-double road tankers for delivery to customer blending facilities in Sydney.

VInasse handling

The vinasse is the underflow from the Beer Column. This is typically 10 to 16% solids by weight. It is pumped through the Beer / Thin Vinasse Preheater and into the Thin Vinasse Tank.

The cooled Thin Vinasse at 47 degrees is transferred to a header supplying two pressure filters. Each one is capable of handling the full Thin Vinasse flow. The liquid phase passes to the biogas plant as Wastewater for reduction of COD/BOD and recovery of biogas. Some of the liquid phase is returned to the thin vinasse tank to control solids content to maintain a consistent feed to the pressure filter.

The lignin-loaded Vinasse at 30 to 35% solids is conveyed to the Drying Mill. A rotary drum dryer is used to remove moisture. The heat source is biogas (60% methane) from the Biogas Plant. Heat from the hot exhaust is transferred to a clean air stream using an air to air heat exchanger. The hot air stream removes moisture and volatile organic carbon. The exhaust is ducted to the gas burner to provide combustion air for the biogas flame. This removes the dilute volatile organic carbon captured in the vapour-rich stream from the dryer.

The wet feed solids is increased to 65% solids and conveyed to an undercover storage or by-passes the storage to feed the boiler. The operation of the boiler is maintained during ethanol plant downtime by supplying the semi-dried lignaceous feed to the boiler from the covered storage stockpile.

Biogas plant

Cooled wastewater (filtrate) from the Pressure Filter is pumped to the Preacidification Tank. The Preacidification Tank will provide an environment to encourage the acidification of the wastewater as well as equalize the reactor influent. The Preacidification Tank reduces the filamentous bacteria population in the anaerobic bacteria consortium. The Preacidification Tank receives recycle from the Bio-reactor to encourage bacterial growth.

The Preacidification Tank contents will flow by gravity to the front-end of the in-ground covered Bio-reactor where a low-rate upflow sludge blanket process is deployed via the use of a distribution header-lateral piping network along the bottom of the Bio-reactor.

The high COD wastewater passes upward through the sludge blanket and microorganisms digest the feed, destroying BOD, COD, and TSS, while generating biogas. The treated anaerobic effluent will exit the reactor through the floating tube settlers and effluent header piping located at the back-end of the Bio-reactor as the biogas generated begins to separate from the treated wastewater and the anaerobic sludge starts to settle.

The final effluent containing around 4,000 mg/L COD will flow by gravity to the irrigation pond where it will be held until used to irrigate surrounding cropland.

The Bio-reactors will be completely sealed with a floating, insulated geomembrane cover, such that the system can operate under a slight vacuum pressure and allow for collection of biogas, temperature control, and positive odour control. Negative odours caused by hydrogen sulfide in the biogas will not be released to the atmosphere, eliminating the discharge of foul odours. The anaerobic digestion process continuously produces biogas, which is collected underneath the Bio-reactor cover and transmitted, via biogas blowers, to a gas engine or a back-up biogas flare for disposal.

Bio-sludge is allowed to accumulate and is removed annually during a refinery shutdown. The nutrient-rich biosludge is used as fertiliser supplement.

Steam and Energy

Steam and energy is required for process purposes. The bolier firing semi-ried lignaceous vinasse produces steam for process needs and 145 MW of electricity generation – an excess of around 10 MW over internal requirements.

Biogas containing around 60% of methane is recovered from the biogas plant and transferred to the Vinasse Drying Plant to provide heat to dry the lignaceous vinasse.

Offices and Laboratory

Office and laboratory facilities are integrated with plant operations and maintenance facilities in a single building.

Cost assumptions[31]

- Utilities and services considered include raw water, process water, demineralised water, steam, electricity, fuel oil, and effluent treatment.
- Cost of utilities and services were based upon benchmarked and quoted data.
- Chemicals and reagents required include water treatment chemicals, sulphuric acid, caustic soda, nitric acid, defoamer, phosphate, urea, and yeast.
- Annual cost of maintenance has been taken as 3% of the total plant installed capital investment. Lubricants, safety equipment, etc is included in the cost of maintenance and repairs.
- Allowance has been made for 3 fulltime laboratory staff. Laboratory establishment cost have been included in Non-process buildings.
- Office operating supplies costs such as stationary and related supplies and cleaning have been included.
- Technology licensing fees are covered in the capital cost estimate.
- Insurance includes Material Damage and Loss of Production, Public Liability cover and Motor Vehicle insurance. An allowance of 0.3 % of the total installed capital cost has been allowed to cover this item.
- An allowance of 20% has been used to cover payroll tax, workers compensation insurance, holiday loadings and shift loadings. All overheads have been included in operating labour and supervision or executive salaries under general expenses.
- Personnel requirements are based on standard process plant operating practices, handling and administration requirements.

[31] The process design, equipment specification and costs used for this process have been developed by AECOM from a variety of sources. We have not had access to any production information from an Australian proponent.

Appendix D

Sources of Cost Estimates

Appendix D Sources of Cost Estimates

Capital Costs ($2017FY)

Item	Cost Estimate	Unit	Basis for Cost Estimate
C-Syrup (Sucrosic); C-Syrup & B-Syrup (Sucrosic)			
Molasses Receival	10	$M	Recent Mackay Sugar project at the Port of Mackay
Fermentation Plant	18	$M	Items based on prior Vogelbusch quote / AECOM estimate.
Distillation, Rectification and Dehydration	23	$M	as per above
Alcohol Storage	5	$M	as per above
Dunder and Fertiliser Plant	17	$M	Recent Dalby Bioethanol drying facility
Biogas Plant	11	$M	ADI indicative quote
Cogeneration Plant	7.5	$M	Goldman Energy (+/- 25% indicative quote)
Non-Process Buildings	5	$M	Estimate factored from other process plant projects
Wheat Integrated (Starch)			
Stockpile	10	$M	As above
Dry Mill	20	$M	Estimate based on recent Lauke Flour mills project
Wet Mill and gluten handling	35	$M	Estimate based on GEA indicative quote
Liquefaction and saccharification	8	$M	Factored from Aecom estimate/prior Vogelbusch quote
Fermentation Plant	18	$M	As above
Distillation, Rectification and Dehydration	23	$M	As above
Alcohol Storage	5	$M	As above
WDGS drying plant	14	$M	Recent Dalby Bioethanol drying facility
Stockfeed plant - bran, germ, DDGS	6	$M	Factored from general non-pricess building estimates
Biogas Plant	13	$M	As above
Cogeneration Plant	10	$M	As above
Non-process buildings	5	$M	As above
Sorghum (Starch)			
Stockpile	10	$M	As above
Dry Mill	10	$M	As above
Liquefaction and saccharification	8	$M	As above
Fermentation Plant	18	$M	As above
Distillation, Rectification and Dehydration	23	$M	As above
Alcohol Storage	5	$M	As above
WDGS drying plant	14	$M	As above
Stockfeed plant - bran, germ, DDGS	4	$M	As above
Biogas Plant	13	$M	As above
Cogeneration Plant	10	$M	As above
Non-process buildings	5	$M	As above
Forest Residues (Cellulosic)			
Stockpile and wood handling	15	$M	NREL and internal estimates
Pretreatment	25	$M	NREL and internal estimates
Enzyme production	25	$M	NREL and internal estimates
Enzymtic hydrolysis and Fermentation Plant	40	$M	NREL and internal estimates
Distillation, Rectification and Dehydration	23	$M	As above
Alcohol Storage	5	$M	As above
Biogas Plant	13	$M	As above
Cogeneration Plant	40	$M	Factored from Aecom US ethanol plant estimate
Non-process buildings	5	$M	As above
Starch			
Liquefaction and saccharification	8	$M	Refer to Wheat Integrated (Starch)
Fermentation Plant	18	$M	Refer to Wheat Integrated (Starch)
Distillation, Rectification and Dehydration	23	$M	Refer to Wheat Integrated (Starch)
Alcohol Storage	5	$M	Refer to Wheat Integrated (Starch)
WDGS drying plant	14	$M	Refer to Wheat Integrated (Starch)
Biogas Plant	13	$M	Refer to Wheat Integrated (Starch)
Cogeneration Plant	10	$M	Refer to Wheat Integrated (Starch)
Non-process buildings	5	$M	Refer to Wheat Integrated (Starch)
Allowances			
Project Management Services	12.5%	%	AECOM quote / generally accepted process industry factor
Project Fee	10%	%	AECOM quote / generally accepted process industry factor
Owners development cost	5	$M	Allowance. $7.5M adopted for Forest Residues Cellulosic
Owners costs during construction	10	$M	Allowance. $17M adopted for Forest Residues Cellulosic
Contingency	10%	%	Generally accepted process industry factor (note that the estimate is accurate to +/- 50%)

Feedstock Costs ($2017FY)

Item	Cost Estimate	Unit	Basis for Cost Estimate
C-Syrup	$120	$/tonne	Typical market price - from $100 to 130 per tonne FIS
B-Syrup	$206	$/tonne	Current sugar price of $0.20 US / lb with an exchange rate of 0.75 AUD and allowance for molasses component
General purpose wheat	$180	$/tonne	AWB/Graincorp web pages for prices by location
Hard wheat	$200	$/tonne	AWB/Graincorp web pages for prices by location
Sorgum	$180	$/tonne	AWB/Graincorp web pages for prices by location
HW forest residues	$51	$/tonne	$15/t for harvest; $10/t for field processing; $15/t for transport; $5/t for stumpage; $6/t for capital recovery
Cassava chip	$280	$/tonne	Current Tahi FOB price + freight + port handling
C Grade Starch	$200	$/tonne	Based on co-located dilute syrup supplied through the fence with non-starch solids and solubles included.

Chemical Costs ($FY17)

Item	Cost Estimate	Unit	Basis for Cost Estimate
Refinery Chemicals			
Defoaming agent	2	$/kg	Supplier quotes
DAP - nutrient solution	0.45	$/kg	Supplier quotes
Urea - nutrient solution	0.235	$/kg	Supplier quotes
Defoaming agent	2	$/kg	Estimated
Disinfectant - 40% formalin	1	$/kg	Estimated
NaOH	0.65	$/kg	Estimated
NitricAcid	0.65	$/kg	Estimated
Yeast cream	100	$/g	Estimated
Denaturant (gasoline)	1	$/litre	Retail price
Biogas Plant Chemicals			
Phosphoric acid at 75 wt%	1	$/kg	Estimated
NaOH	0.65	$/kg	Estimated
Ammonium sulphate	0.45	$/kg	Estimated
Alum for sludge dewatering	1	$/kg	Estimated
Polymer flocculant for sludge dewatering	2.5	$/kg	Estimated
Defoamer	2	$/kg	Estimated
Fertiliser Plant Chemicals			
Urea	0.235	$/kg	As above
Ammonia Sulphate	0.45	$/kg	As above
DAP	0.45	$/kg	As above
Milling chemicals			
Chlorine	*1000*	$/kg	Estimated
Hydrogen peroxide	*1000*	$/kg	Estimated
Liquefaction/Saccharification chemicals			
Alpha-amylase	10	$/g	Estimated
Gluco-amylase	10	$/g	Estimated
Endo-ß-glucanase	0.2	$/mg	Estimated
Exo-ß-glucanase	0.2	$/mg	Estimated
ß-glucosidase	0.2	$/mg	Estimated

Operational Costs ($FY17)

Item	Cost Estimate	Unit	Basis for Cost Estimate
Utilities			
Steam	5	$/t	1.9 t per KL for distillation; 0.63 t per KL for dehyration
Vapour condensate	3	$/t	4.1 t per KL
Process water	1	$1/m3	10% of cooling water demand
Electricity	0.04	KW/h	Non fuel, cost estimate
Personnel			
Refinery manager	$185,000	FTE	Allowance
Finance Manager	$145,000	FTE	Allowance
Sales Manager	$155,000	FTE	Allowance
Administration	$75,000	FTE	Allowance
Operations Manager	$145,000	FTE	Allowance
Engineering	$145,000	FTE	Allowance
Maintenance - electrician, instrument fitter, mechanic	$75,000	FTE	Allowance
Laboratory	$55,000	FTE	Allowance
OHS and Enviro	$65,000	FTE	Allowance
Feed handling	$50,000	FTE	Allowance
Shift Operations	$65,000	FTE/shift	Allowance
Admin and Overheads			
Land Lease	$2,000	$/ ha per year	Allowance
Information Services	$150,000	$/year	Allowance
Certifications and training	$1,000,000	$/year	Allowance
Insurances	$30	% of capital	Allowance
Travel	$1,000	$/trip	Allowance of 75 trips per annum.
Office costs	$200	$/day	Allowance
Freight			
Tanker delivery to fuel blending plant	$0.069	$ per tonne.km	Based on trucking model for long haul B-Double fuel tanker
Maintenance			
Maintenance	3%	%	Allowance
Sustaining capital	1%	%	Allowance