Sugar Industry
Value Add & Diversification

Background Brief
Industry Prioritisation

Final - Released 11 November 2018

An Industry Agreed List of Priorities

Introduction

Establishing a strategic roadmap for product diversification and value addition – SRA Project 20180104

Sugar Research Australia is advancing its efforts to deliver on its 2017/18 – 2021/22 Strategic Plan with a research project on Key Focus Area 6 (KFA6) product diversification and value addition.

The objective of the project is to better understand industry views on value adding and product diversification and develop a list of agreed prioritised diversification opportunities that may require further RD&A activity or market analysis.

The context is that there are hundreds if not thousands of product opportunities for SRA to pursue on behalf of industry, however, there are limited funds available.

The general overview information provided in this background brief should provide sufficient context to enable targeted discussions and introduce the general themes SRA would like to explore.

Eris O'Brien

Chief Investigator &

Managing Director of Lazuli Consulting

Where should SRA focus its efforts?

Issues for consideration include:

1. Preferred products and processes.
2. Short-term versus longer-term goals
3. Front end research through to adoption – what are your preferences?.
4. Role for market monitoring
5. Role for information gathering and dissemination
6. Role for looking at logistics of feedstock and product. Also Queensland Sugar Terminals.
7. Collaboration efforts – are we competing with other sugar producing countries, or are we looking to work with them to compete against corn and other advantaged feedstocks.
8. How do we enable pilot and demonstration plants as an industry?
9. How do we compete with lower capital costs in competing sugar producing countries?
10. What level of technical and market risk do you think the industry is willing to take versus enabling 3rd parties willing to take this risk to co-locate with the industry?

Disclaimer and Contents

Disclaimer

This document does not represent the views of Sugar Research Australia.

The views in this documents are based on the authors' commercial experience and understanding of the topic, and may not accurately reflect the opinion of their organisations.

The information provided is of a general nature and should not be relied on for an investment decision

Contents

More detail is available at SugarValueAdd.Info

What it takes to achieve financial close

Achieving financial close on a project is a complex and time consuming task, involving many counterparties, banks and equity investors.

We think understanding the risks that investors and banks look at when making a decision to invest is a useful framework for viewing what it will take for value add and diversification opportunities succeed commercially

How then, can SRA assist industry in de-risking technologies and processes?

The remainder of this background brief unpacks some these issues further to provide context for discussions on diversification and value addition.

Of key focus are:

1. Resources – what is available to industry
2. Products and processes
3. Markets
4. Policy
5. Scaling up – the key issues, and
6. Case studies

Typical financial close checklist for project finance

- ☑ Feedstock contracted for period of project, with known surplus capacity.
- ☑ Technology licences for process technology negotiated and contract signed.
- ☑ EPC contracts signed. Contract is for fixed price and schedule.
- ☑ Transport infrastructure proven to match needs, and access contracts signed.
- ☑ Signed offtake agreements with creditworthy counterparties for sufficient price and term for products and co-products.
- ☑ Products known to meet relevant standards given the feedstock and processes used.
- ☑ Regulatory and permitting approvals in place
- ☑ Economic viability shown through a professional financial model
- ☑ Social and environmental issues have been resolved.
- ☑ The conversion technology selected is proven at commercial scale

The above was taken from *Specifications for the application of the United Nations Framework Classification for Bioenergy Resources*, Sep 2017. https://www.unece.org/energywelcome/areas-of-work/unfc-and-sustainable-resource-management/applications/energyseunfc-re/unfc-and-bioenergy.html

More detail is available at SugarValueAdd.Info

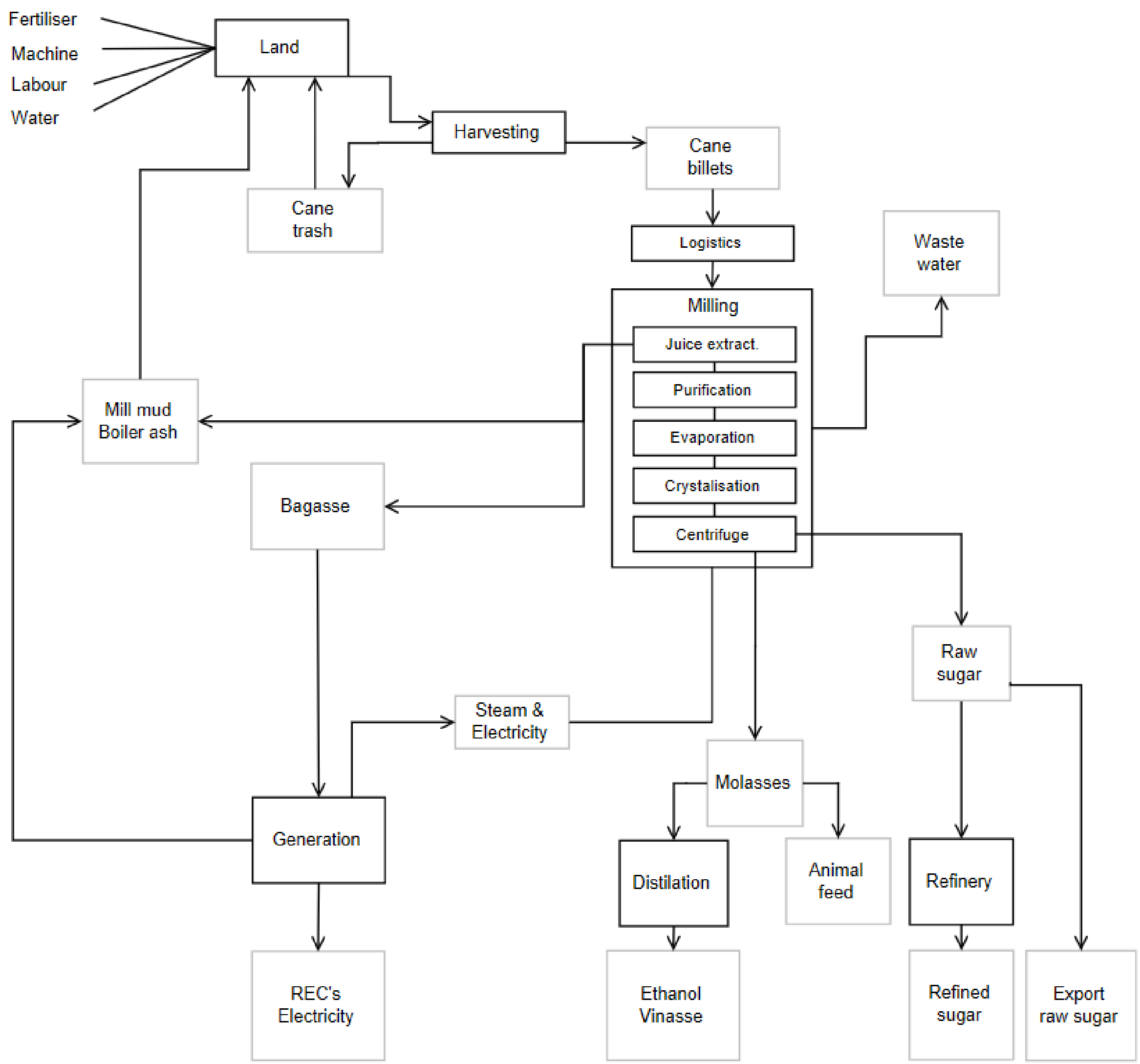
Resources

The industry is both a significant energy producer and consumer taking into the full supply chain, including harvest and other on farm fuel consumption; logistics (rail & road) fuel consumption; in mill electricity and steam consumption

Not all resources are ‘idle’ looking for consumption. For example, almost all bagasse is consumed to generate energy for mill and export; all cane trash is currently returned to paddock as part of harvest.

Industry infrastructure capability and investment is significant, much of which is idle for 7 months of the year.

Resource Overview – Sugar Value Chain



There are known, unused resources in the supply chain.

Existing infrastructure is a key resource.

Product	Yield / ha	Industry / annum	Industry value 2017
Cane trash (dry)	12.5t	4.70 mt	
Cane billets	88.4t	33.34 mt	
Waste water	58.3t	22.0 GL	
Mill mud, boiler ash	5.3t	2.02 mt	
Bagasse (dry)	12.4t	56.7 PJ	
Electricity & REC's	56 kWh	5.9 PJ	A$191m
In mill energy	49.3PJ	50.8 PJ	
Raw sugar	11.9 t	4.48 mt	A$1,816m
Molasses	2.63 t	1.01 mt	A$130m
			A$2,137m

Other
~ land under cane ~ 37,000 ha;
~ 487 MWe generation capacity;
~ 4,000 km rail;
~ 250 * 520 kW diesel-hydraulic locomotives;
~ cane crush capacity 430 t / h;
~ 6 bulk commodity terminals in Queensland.

t = tonne; m = million; PJ = peta joule; GL= giga litres ;
kWh = kilowatt hour; MWe = mega watts (electrical);

Other resources – Existing Industry

As well as sugar cane and its products and by-products, it is useful to consider the other factors of production available to the industry as a whole.

Electricity

For a co-located plant grid supplied electricity is more expensive that co-gen plant supplied electricity. Where tradeable permits are involved, they can be unbundled and on-sold into the electricity market.

Steam

For processes that require steam for heat and/or the actual water contained, co-location at a mill is would be of interest

Land

Underused land, or alternative higher value uses for existing land. For example, could additional biomass be grown and supplied to existing cogeneration plants.

Workforce

Underemployment of skilled and other labour across regional Queensland would make additional jobs of interest. A co-located or nearby plant could use underutilised workforce, during and after the Crush.

Irrigation Infrastructure

Where alternative crops could be grown and water is available existing irrigation infrastructure can be used. E.g. during fallow years, or to supplement feedstock to the mill or cogeneneration plant.

Feedstock Transport

Transport to a central location, whether by train or truck, is of potential value for new plant. Utilisation can be improved during the non-Crush, and incremental capacity can be added during the Crush.

Electrical connection

The substation connecting to the electricity grid is expensive, and underused capacity can be used by a new build plant. In addition, export of electricity through cogeneration, or other renewables such as solar photovoltaics could be possible.

Ethanol/Vinasse

Where ethanol is already produced, it can be used as a feedstock for other processes. The waste product vinasse (aka dunder) can be used as a fertilizer once composted.

Harvest equipment

Harvest equipment and workforce could be used for alternative crops.

Product Transport - Sugar Terminals Limited

Underutilised capacity to transport to the six STL ports, and of the ports themselves could be valuable part of the supply chain for new products.

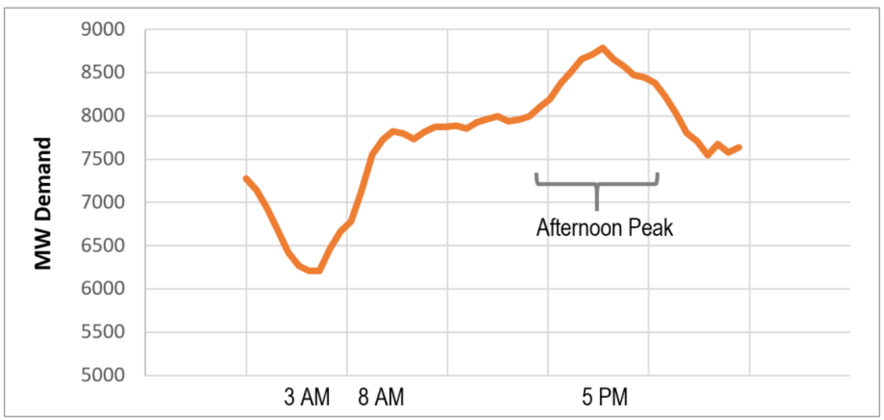
Marketing

Through QSL, and mill owners, there is access to skills and markets for

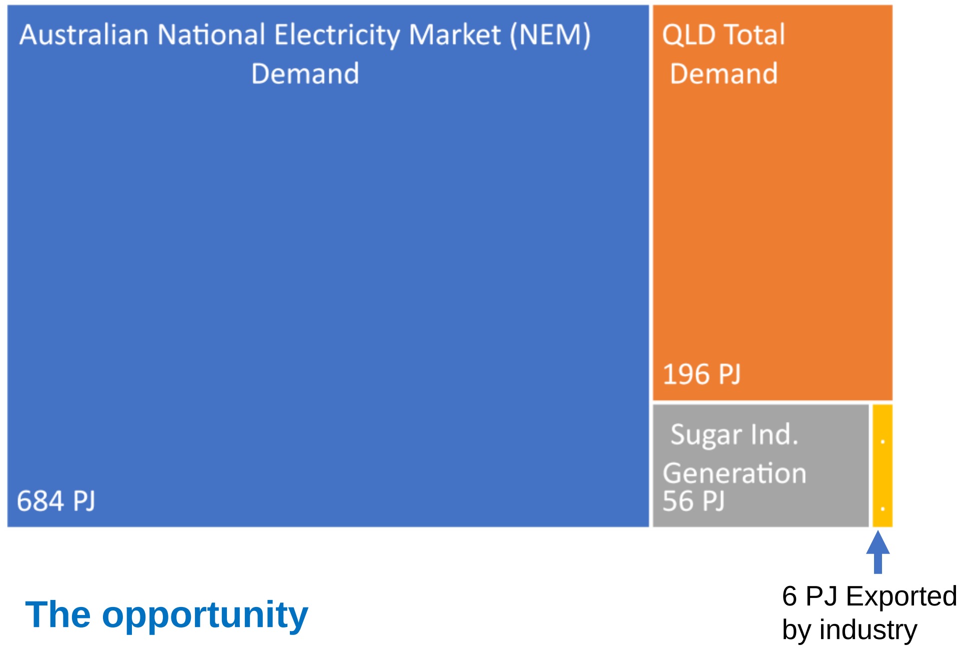
Opportunities in electricity generation

Electricity Overview

- Energy export volumes, since inception of the Mandatory Renewable Energy Target ('MRET'), have grown at a CAGR of 7.7%. In 2017, the approximate value of energy exports was A$191M.
- The industry operates circa 487MWe of generation capacity over 25 sites. A small number of large projects have contributed to this growth including Isis (25MWe), Condong & Broadwater (60MWe) Pioneer (68MWe) and most recently, Racecourse (48MWe).
- The capital cost of both wind and solar generation is now very cost competitive in the market and as they operate 12 months of the year, the resultant project economics are more competitive than bagasse fired generation. Nonetheless, this substantial market opportunity remains available to and accessible by the sugar industry.



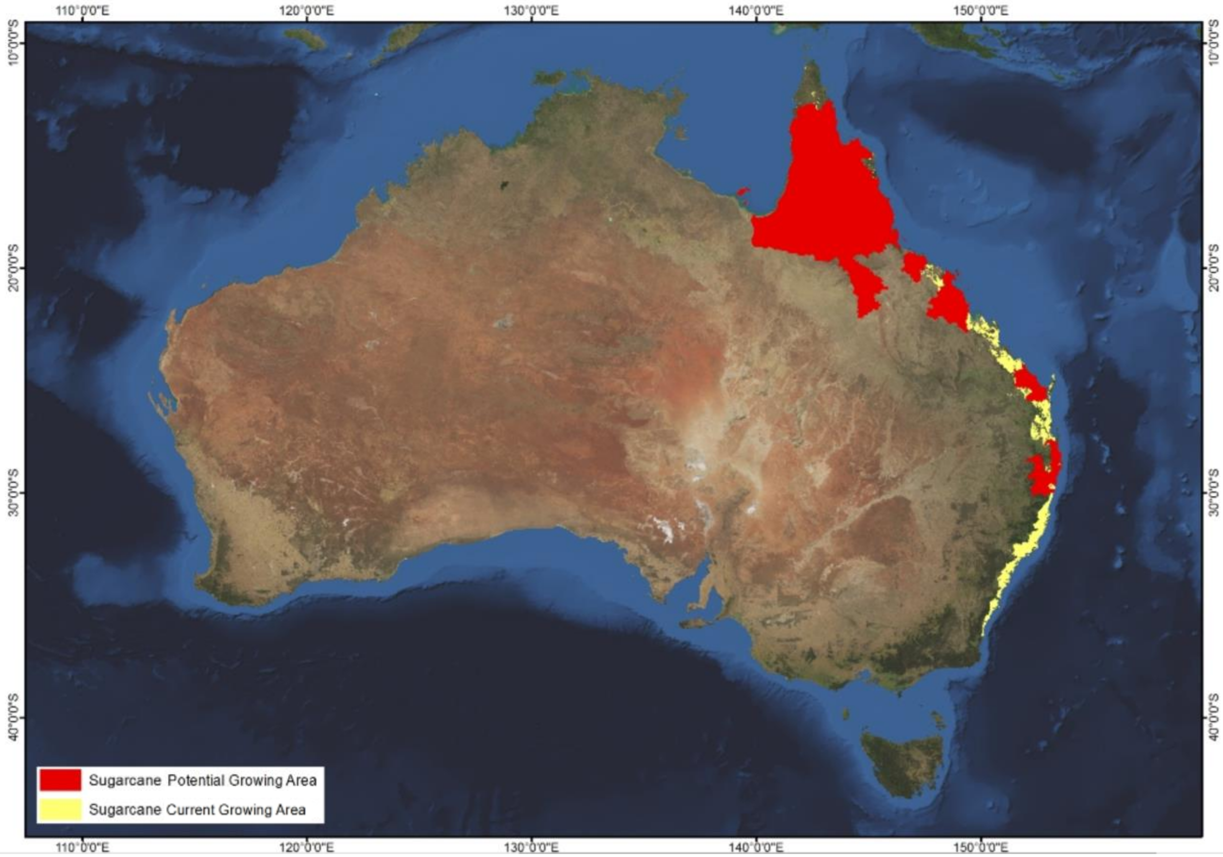
Electricity in 2017



The opportunity

- The sugar industry exports only 6 PJ. The Tablelands Mill cogen facility will add additional capacity, generating for a greater period than the Crush.
- There is potential strong demand for dispatchable renewables, especially in the afternoon peak to firm up the growing supply of wind and solar power.
- Throughout the supply chain solar PV could supplement electricity consumption and enable additional electricity sales.

Geographic Diversification – Future Potential



Source: AgriFutures website – https://www.agrifutures.com.au/farm-diversity/sugarcane/

- AgriFutures Australia suggest significant tracts of land in north Queensland would be suitable for cane growing. Aside from proximity to processing facilities however, water has been presented as limiting factor.
- CSIRO recently completed North Australia Water Resources Assessment was that an additional 140,000 hectares of land would be enabled if all four proposed dams in Queensland were constructed
- Any geographic diversification ambitions with respect to cane land must be tempered by its locality to the Great Barrier Reef.

While industry battles to maintain viability in the current sugar market, could there be opportunities to expand land under cane In the medium to longer term?

More detail is available at SugarValueAdd.Info

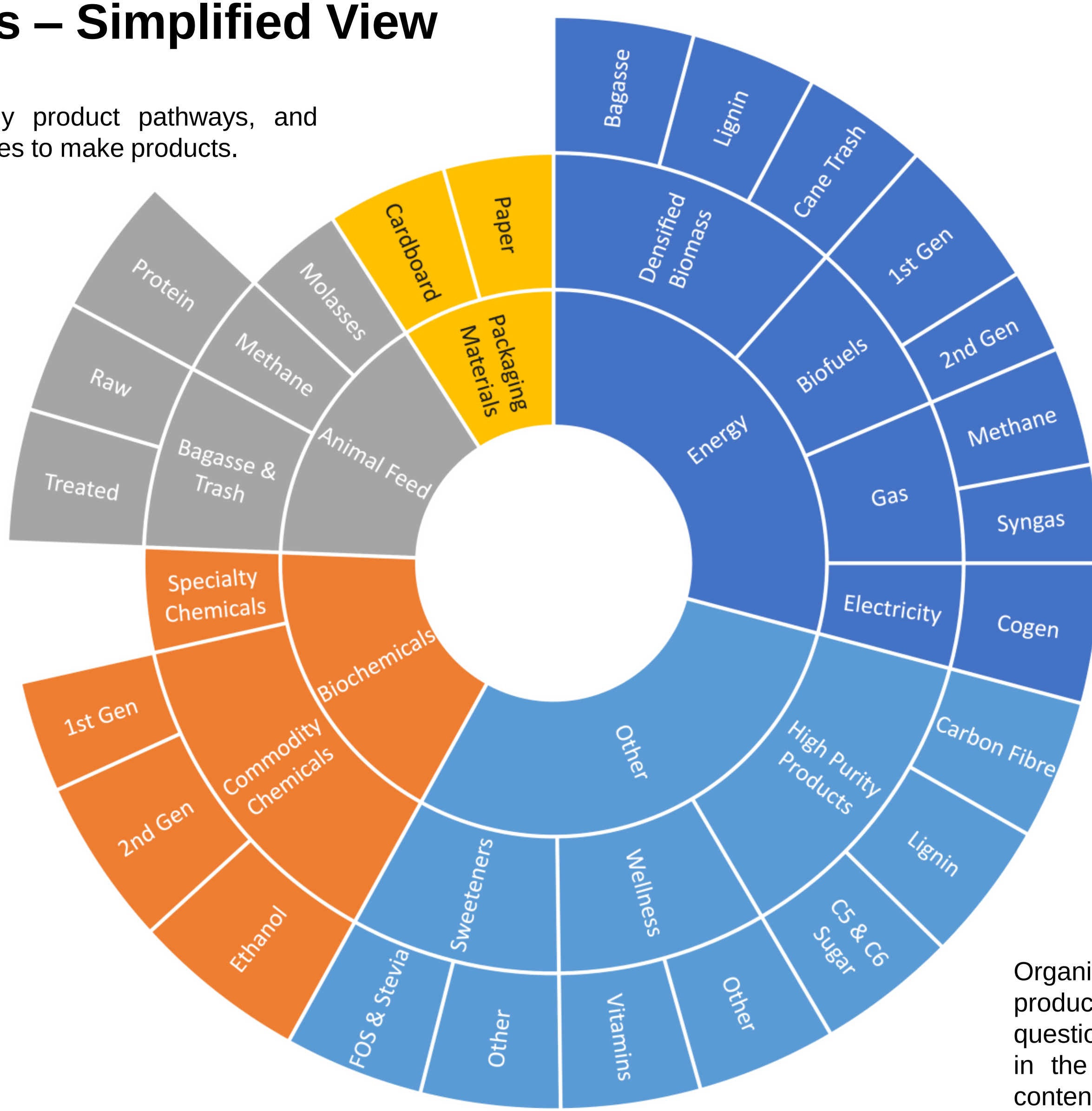
Products & Processes

Dr Mark Harrison QUT Senior Research Fellow | Centre for Tropical Crops and Biocommodities

SRA has funded numerous projects to evaluate product diversification and value-adding technologies on behalf of the sugarcane industry. Further, there are numerous domestic and international studies describing both the potential products that can be made from crop residues and processing by-products (including those from sugarcane) and the relevant technologies. The present chapter is intended to highlight recent advances in product identification and technologies of relevance to the sugarcane industry.

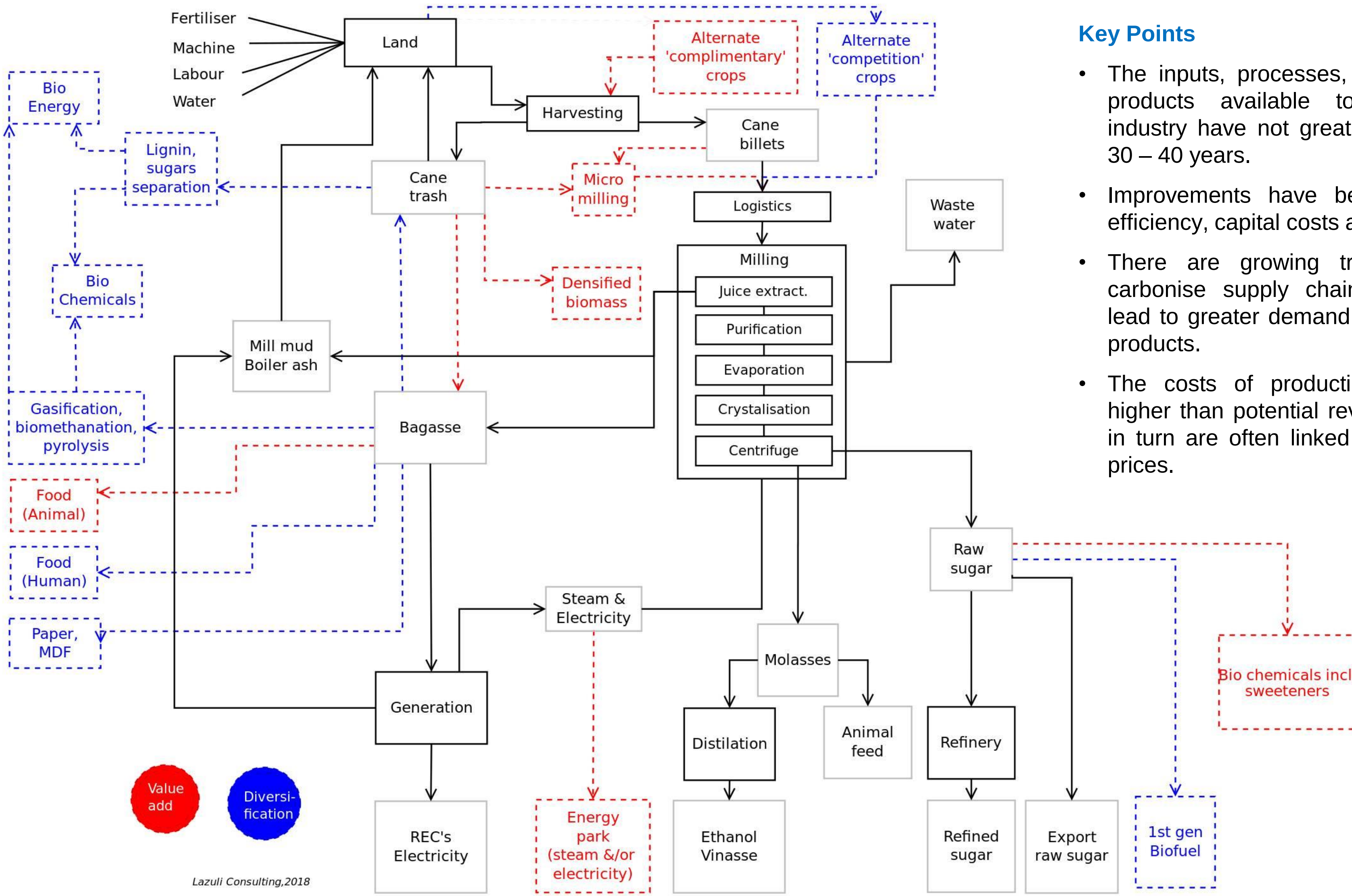
Products – Simplified View

There are many product pathways, and multiple processes to make products.



Organisations will choose preferred products and pathways. However, the question remains which will be 'economic' in the short term, and which are likely contenders for mid to long term investment.

Value-Add & Diversification – Schematic Map



Key Points

- The inputs, processes, and potential products available to the sugar industry have not greatly changed in 30 – 40 years.
- Improvements have been made to efficiency, capital costs and yields.
- There are growing trends to de-carbonise supply chains which will lead to greater demand for bio-based products.
- The costs of production are often higher than potential revenues, which in turn are often linked to volatile oil prices.

Products – Current Trends

A Shift Away From Biofuels

The global bioeconomy shifted away from biofuels towards smaller but higher-value markets in fine chemicals, nutrition, nutraceuticals, pharmaceutical, materials, flavourings, fragrances, and cosmetics in the last five years. This trend was clearly seen in the topics of presenters at BioWorld Congress 2018, held in the USA.

In simple terms, second generation bio processes have yet to achieve costs and commercial scale operations. Low fossil fuel prices, lack of investment, the role of government, and lack of uptake in industry all contribute to this. Consequently, there is a focus on smaller volume, higher margin products.

More details on the barriers within industry are shown on p. 30 – The Chicken or the Egg Problem.

Biofuels

With oil prices tipped to rise, biofuels (1st and 2nd generation, and advanced fuels) are once again attracting significant attention but the current sugar price limits the capacity of the sugar industry to exploit its favourable position. This is no more evident than in Brazil, where corn has replaced sugarcane as the feedstock for newly developed bioethanol plants.

Biofuels for marine diesel engines may be a promising opportunity in the longer term; the marine diesel market is currently in transition, the market is sizeable (330 MT pa) and almost any carbon-based stable liquid that is low in sulphur will work (i.e., biodiesel, ethanol, butanol).

Animal Feed

The Food and Agriculture Organization projects that food production will have to expand by 70% to meet the projected demand for adequate nutrition. An increase of 70% in production of meat, milk, and other animal products represents a significant challenge to feed production capacity.

Protein is a key component of feed and the feed production sector is increasingly looking to the emerging bioeconomy for new, economic sources of protein.

Sugarcane bagasse (raw or pretreated), trash, and molasses are all potential substrates for feed protein production.

Further, energy products from sugarcane (including methane) are also potential substrates for feed protein production (e.g., Protelux has recently completed construction of a 6,000 t pa methane-to-protein plant).

Useful references

Biofuel-driven Biorefineries: A Selection of the Most Promising Biorefinery Concepts

Bio-based Chemicals: Value Added Products from Biorefineries

Proteins for Food, Feed and Biobased Applications: Biorefining of protein containing biomass

These reports can be found at task42.ieabioenergy.com

Overview of Key Processes

Lignocellulosic pretreatment, hydrolysis, and fermentation

Delivery of optimal industrial production requirements using existing pretreatment methods (chemical, physicochemical, and biological) is challenging. Recently, advances in applied chemistry approaches under extreme and non-classical conditions has led to possible commercial solutions in the marketplace (e.g., high hydrostatic pressure, high pressure homogenizer, microwave, ultrasound). These new industrial technologies are promising candidates for sustainable pretreatment of lignocellulose in large-scale biorefineries

Fermentation to generate products (including bioethanol) requires sugars to 'fuel' growth of the fermenting microorganisms. Fermentable sugars can be obtained directly from sugarcane juice or molasses, or from the enzymatic hydrolysis of sugarcane bagasse and trash. In the later instance, enzymes from microorganisms act together to break down and convert the insoluble carbohydrates in sugarcane bagasse or trash into fermentable sugars. The yield of fermentable sugars from sugarcane bagasse or trash is greatly increased after pretreatment. Recent research has focused on the identification of thermotolerant enzymes that can hydrolyse cellulose in lignocellulose without the need for pretreatment.

Separate hydrolysis and fermentation (SHF) and simultaneous saccharification and fermentation (SSF) are the dominant strategies to produce fermentation products from lignocellulose; however, industrial biotechnology and synthetic biology are enabling consolidated bioprocessing (CBP) and simultaneous saccharification and co-fermentation of hexoses and pentoses (SSCF); both CBP and SSCF enable improvements in productivity, yield, and substrate cost, and thereby reducing the cost of the final fermentation product.

Thermochemical processes

Recent advances in the four fundamental thermochemical processes (combustion, pyrolysis, gasification, and liquefaction) include co-firing/co-combustion of biomass with coal or natural gas, fast pyrolysis, plasma gasification, and supercritical water gasification. The co-firing of biomass and coal is the easiest and most economical approach for the generation of bioenergy on a large-sale. Fast pyrolysis has attracted attention as it is to date the only industrially-available technology for the production of bio-oils. Supercritical water gasification is a promising approach for hydrogen generation from biomass feedstocks, especially those with high moisture contents (such as sugarcane bagasse).

Genetic Modification

Genetic modification of sugarcane with traits that reduce input costs, enhance crop yield, and allow sugarcane to generate new value-added products have been demonstrated. Genetically-modified sugarcane with Bt-mediated resistance sugarcane borer) was approved for commercial production in Brazil in 2017. Sugar produced from this variety has recently been determined to be safe for human consumption by the US Food and Drug Administration, thereby paving the way for the international trade of sugar, and potentially value-added products, from genetically-modified sugarcane.

Additional information

The International Energy Agency Bioenergy Task websites hold a lot of useful information on products and processes.

Task 32: Biomass Combustion and Co-firing - task32.ieabioenergy.com

Task 33:Gasification of Biomass and Waste- task33.ieabioenergy.com

Task 34: Direct Thermal Liquefaction - task34.ieabioenergy.com

Task 36: Integrating Energy Recovery into Solid Waste Management – task36.ieabioenergy.com

Task 37: Energy from Biogas – task37.ieabioenergy.com

Task 38: Climate Change Effects of Biomass and Bioenergy Systems – task38.ieabioenergy.com

Task 39: Commercialising Conventional and Advanced Liquid Biofuels from Biomass - task39.ieabioenergy.com

Task 40: Sustainable Biomass Markets and International Trade to support the biobased economy task40.ieabioenergy.com

Task 42: Biorefining in a Future BioEconomy - task42.ieabioenergy.com

Task 43: Biomass Feedstocks for Energy Markets – task43.ieabioenergy.com

One of the many reports available from IEA

More detail is available at SugarValueAdd.Info

Markets

Dr Dianne Glenn – Corelli Consulting

A current view on the market.

The full article and list of references can be found on SugarValueAdd.info

Sugarcane Hydrolysis Products

The juice and residues from sugarcane processing have the potential to generate products other than sucrose that are inherently valuable: xylose (C5), glucose (C6), and lignin predominately, as well as microcrystalline cellulose and hemicellulose.

Lignin can be burned to meet the energy requirement of the biorefinery and/or valorized to make fuels (ethanol, biodiesel, aviation fuel) and industrial chemicals. The global lignin market is expected to reach US$6.2 billion by 2022, based on the high market potential for lignin as a key intermediate to manufacturing carbon fibres, phenol, BTX and vanillin. Production of lignin exceeded 1.1 million tons in 2013 and was dominated by manufacturing in Europe and North America (over 35% of global demand volume each). Increasing R&D for development of lignin use in untapped applications is anticipated to provide new opportunities in biomaterials and biobased chemicals for market growth, although applications for lignin as a feedstock for the manufacture of other industrial products is determined by the purity and integrity of the lignin.

Lignocellulosic breakdown products: indicative value

Hydrolysis product	**Value US$/tonne**
High purity xylose	$4,500 to $20,000 (1)
Microcrystalline cellulose (MCC)	$3000 to $4,000 (2)
High purity glucose	$400-600 (powder) $450-790 (liquid glucose) (3)
Lignin	$1700-1860 to as high as $6,500 (4)

Price is dependent on the purity or grade of the product.
Sources: online catalogs – listed in SugarValueAdd.info

Biomanufacturing - Overview

The opportunity for biobased manufacture based on renewable feedstocks continues to expand to include a widening array of biomaterials, chemicals, fuels, and solvents, of application within global industries from automotive and aviation through agriculture and pharmaceuticals to food, beverages and cosmetics.

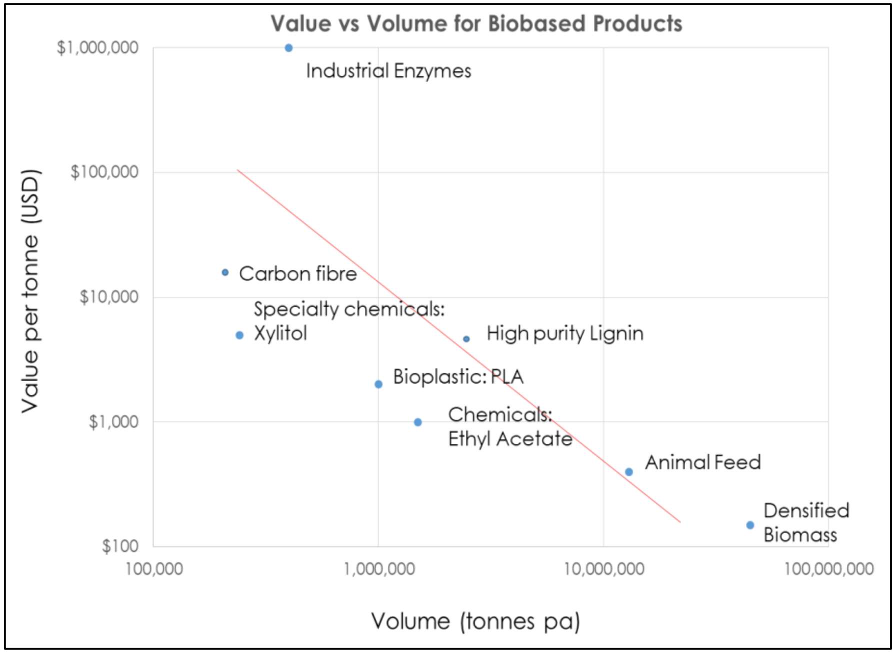
Many industrial groups, corporations and governments, including the US, the EU and Brazil, have conducted detailed scoping studies to identify sets of bioproduct targets for future manufacture in a new prospective industry sector. Those targets have been prioritised as consistent with patterns of consumption in domestic industries, as an import replacement, and to build or reinforce export from high value specialty molecules, platform chemicals, and aviation fuels. Local consumption of by-products are also factored into the economics, especially transport fuels and enriched animal feeds.

This target-setting often considers the volume and nature of feedstock available (sugar, starch, cellulose) and the resultant product value. Indeed, within the array of bioproducts there is a relationship between the volume of global demand and product value, such that value is often inversely proportionate to volume (Figure). In this way, those agricultural industries looking to value-add crops or crop residues and diversify revenues may consider which of those biobased options have the potential to deliver the highest value rather than the highest volume (commodity products).

Biomaterials derived from agricultural feedstocks include phenolic formaldehyde resins, the second largest resin class in global use, as well as carbon fiber, polymer modifiers, adhesives and resins, derived from lignin or cellulosic residues such as bagasse and wood residues.

The global volume for the phenol-formaldehyde resins market is expected to reach 16 million tonnes by 2016 valued at US$10.8 billion, with a compound annual growth rate of 12% and is expected to reach US$16 billion by 2022. For other biomaterials, lignin represents a potential low-cost carbon source suitable for displacing synthetic polymers such as polyacrylonitrile (PAN) in the production of carbon fibre.

Biomanufacturing: indicative relationship between product value and volume of production



Biomanufacturing - Overview (continued)

The **carbon fibre** market is expected to grow strongly at ~10% pa until 2020, with 89,000 tonnes pa generating revenues over US$3.3 billion. The market for carbon fibre is driven largely by the aerospace and defence, construction, wind turbine, and sports and leisure industries. A major producer of lignin-based biomaterials is Norway's Borregaard LignoTech (1 million tpa of lignosulphonates). Borregaard manufactures lignin-based products for battery applications and as agrochemicals (sales of A$360 million in 2016) and specialty cellulose products including cellulose ethers, cellulose acetate (revenues of A$264.7 million in 2016).

Biobased chemicals include bulk commodity (~100,000 tpa), platform, and small volume specialty molecules (1000 tpa or kg quantities). Platform chemicals are often smaller chemical structures that serve as intermediates for the manufacture of many chemical families.

Platform molecules within the value chain from an agricultural feedstock include **ethanol**, **succinate** and ethyl acetate. US-based Greenyug and its subsidiary Prairie Catalytic are establishing a facility to manufacture high-grade ethyl acetate from ethanol at 50,000 tonnes per year. The facility is co-located adjacent to the Archer-Daniels-Midland Company ethanol production facility, which in turn is co-located with a corn mill in Nebraska.

Ethyl acetate is a specialty solvent used in a variety of industrial and consumer product applications in paint, coating, printing ink and other industries, including coating formulations such as epoxies, urethanes, cellulosics, acrylics and vinyls and increasing used in packaging, food and beverage and fragrance and flavour industries., or as the intermediate in the manufacture of polymers, resins, food and pharmaceuticals, among other products.

Biobased ethyl acetate is a drop-in replacement, i.e. chemically identical to the conventional product. The global ethyl acetate market is ~1-1.5 million tonne pa valued at US$1-2 billion. The strongest growth market for ethyl acetate is in Asia Pacific.

Enzymes and specialty sugars are examples of high value, specialist products that are exclusively manufactured by bio-based processes from renewable feedstocks. The global enzyme market is a substantial industry generating sales of over US$5 billion in 2016, and anticipated to exceed 400,000 tons pa by 2024. Enzymes have found uses across the commercial spectrum, with major industrial applications in the food and beverage, personal care and cosmetics, nutraceuticals, detergents, textiles and fabrics, animal feeds, biofuels, pulp and paper, and wastewater industries. The sugar alcohol, xylitol, is the first rare sugar to have established a global market, with applications in the food industry as a sugar substitute and as an inexpensive starting material for the production of other rare sugars. **Xylitol** was one of the promising biobased specialty chemical targets identified by the US DoE in 2004 and 2010 and is manufactured from cellulosic sugars. The global market for xylitol is expected to reach 242,000 tonnes, valued at just above US$1 billion, by 2020, with the value of xylitol estimated at ~US$4,100/tonne.

Biomanufacturing - Bioplastics

Global bioplastics production capacity is set to increase from ~1.7 million tonnes in 2014 to ~7.8 million tonnes by 2019, with biobased polyethylene (PE) and biobased polyethylene terephthalate (PET) as the main drivers of this growth. The global bioplastic market is projected to grow from US$17 billion this year to almost US$44 billion pa by 2022. Biobased plastics from renewable feedstocks may either be drop-in replacements for petrochemical-based plastics such as PE or PET, or new molecules such as polylactic acid PLA or polyhydroxyalkanoates PHA.

In 2009, the Coca-Cola Company launched its PlantBottle™ technology and subsequently licensed the technology to other major companies such as food manufacturer H.J. Heinz as well as the Ford Motor Company. Green PET bottles were initially made up of 30% plant-based material, but Coca-Cola's goal is to produce a PlantBottle™ that is completely bio-based to replace around 60% of all of Coca-Cola's packaging. The action by Coca-Cola sends a strong signal to the market, raising the bar for other manufacturers and providing a substantial opportunity to the bio-manufacturing sector: Coca-Cola alone retails more than 690 billion drinks per year globally.

Biodegradable plastics include PHAs and PLA, both made from sugars or starch. PHAs are produced in Italy as biodegradable microbeads for cosmetics and personal care markets to stem the tide of petrochemical microplastic entering the food chain. PLA is the highest yielding bioplastic from sugar: 1 kg PLA can be manufactured per 1.6 kg sugar compared with PET (1kg per 5kg sugar).

The global PLA market was valued at ~US$700 million in 2017, and it is anticipated to reach US$2 billion by 2023 and growing rapidly (20%). In terms of volume, the market is expanding from 286 kilo tonnes in 2017 to 830 kilo tonnes by 2023. The largest and first manufacturer of PLA was Cargill Dow (NatureWorks®) at a 140,000-ton per year manufacturing facility, co-located with field corn mills, in Nebraska, US. Other major players in PLA are BASF, Corbion, Mitsubishi Chemical, DowDuPont, Eastman Chemicals, and Bayer.

Image Source: european-bioplastics.org/market/applications-sectors/

Biomanfacturing – Energy and Fuel

Energy and fuels are often fundamental to the economic viability of many value-adding scenarios in the sugarcane industry. Cogenerated electricity is already well established within many operations, and the efficiency of cogen production and export depends on boiler efficiency. São Martinho is a major sugarcane participant in Brazil producing 327,000 MWh of cogen contributing R$75.7 million (A$26 million) or 10% of total revenues in the first quarter of this year16. The fuel ethanol industry build by the Brazilian government since 1975 now underpins the next stage of bioproducts value-adding, in which ethanol derived from sugar is a platform molecule for the manufacture of ethylene- and urethane-based products (PE, PEG; polyurethane foams and resins respectively) as well as solvents.

Global consumption of jet fuel is around 933 million litres per day, with the US responsible for the largest share (37%) of that volume. Bio-based aviation fuel from renewable feedstocks has already enabled more than 130,000 commercial flights by Qantas, Virgin, British Airways, United, Cathay and others. The US Department of Defense (DOD) is the single largest consumer of petroleum in that country, spending almost US$17 billion on fuel in 2011. The US Air Force and Navy account for most (85%) of the DOD's fuel consumption and both forces are collaborating in developing advanced alternative fuel. The US Navy's marine diesel fuel is blended with 10% advanced alternative fuels made from beef tallow: first bulk purchases cost US$0.54 per litre (US2.05/gallon) for the blended product, very competitive with US petroleum-based fuels. Provision of biojet fuel in the Pacific is a strategic concern for the US Navy's Green Fleet19 and a potential opportunity for Australia.

Image Source: neste.com/blog/who-will-be-leader-reducing-air-traffic-emissions

Densified Biomass

Another value-adding opportunity for the agricultural sector is the production of densified pellets as renewable energy feedstocks derived from compressed biomass such as bagasse, sawdust or other ground woody or cellulosic biomass. Densified pellets have two major applications: energy generation in coal power plants and residential heating in stoves and boilers.

Over the past 10 years, the production of wood pellets alone has increased in response to rising global demand for renewable energy. Global production is expected to grow to 45 million tons/year by 2020, while the global demand is expected to increase to 59 million tons/year, indicating an addressable gap in market supply. The European Union has become the principal market for biomass pellets with 94% growth in the last decade, and prices up to €250/t.

Japan and South Korea are the main pellet consumers in Asia based on the growing development of large-scale power markets in East Asia, and both nations have introduced sustainability certification schemes for wood pellets. China has reported a consumption target of 30 million tonnes of biomass pellets by 2020 to replace 15 million tonnes of coal, as part of its five-year plan for biomass development. It is uncertain how much of China's demand could be sourced domestically, suggesting a regional export opportunity for Australia.

Currently, Australia has only two domestic companies with a business in the production of wood pellets for the export market: Altus Renewables Limited (capacity of 100,000 tonnes pa) and Western Australia's Plantation Energy (250,000 tonnes pa capacity).

Location of major Queensland coal-fired generators and estimated biomass required for 3% co-firing

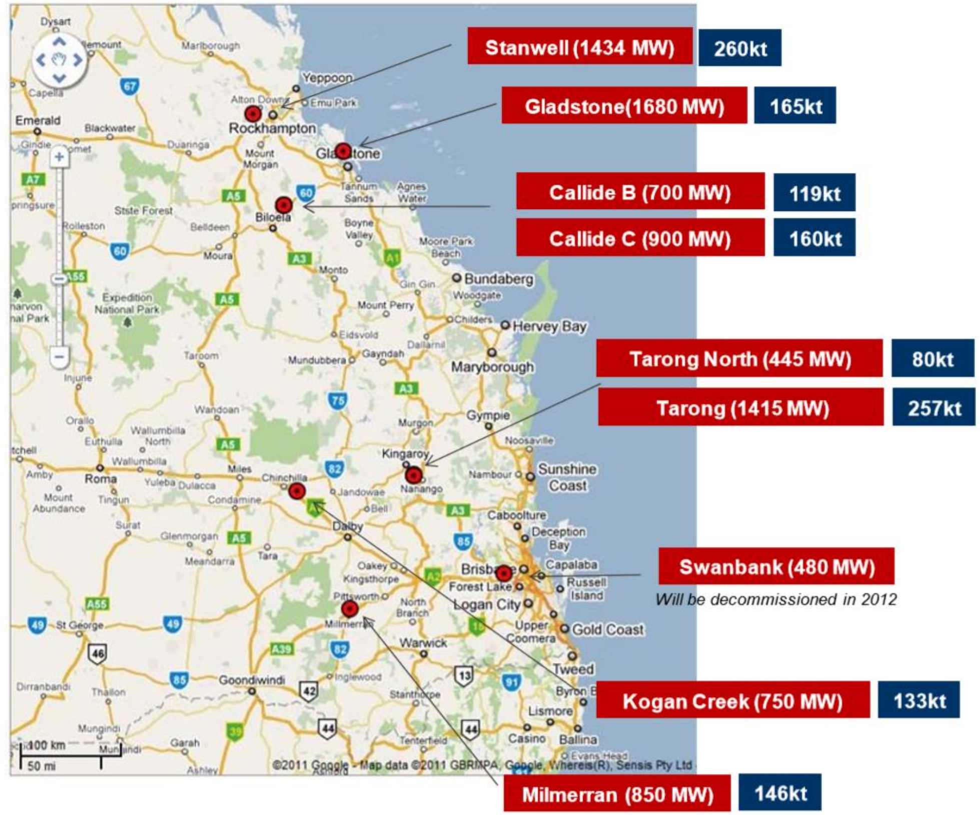


Image Source: Facilitating the Adoption of Biomass Co-firing for Power Generation ; Rural Industries Research and Development Corporation; Australian Government; August 2011. RIRDC Publication No. 11/068

MARKET PULL FOR BIOBASED CHEMICALS AND PLASTICS

Forces are already in place within the consumer market that are driving the uptake of biobased and sustainable products as preferred replacements to manufactured goods, previously sourced from petrochemical feedstocks. The nature of the consumer goods is significantly broad, encompassing the food and beverage packaging industry (Nestlé Waters, Carlsberg, Tetrapak) through to furniture and car manufacture.

This corporate landscape is largely shaped by the demands of a consumer market increasingly alert to issues of renewable materials and global warming, although to some measure there is a growing corporate awareness, particularly among chemical manufacturers, that sustainable feedstocks are essential to their future commercial viability.

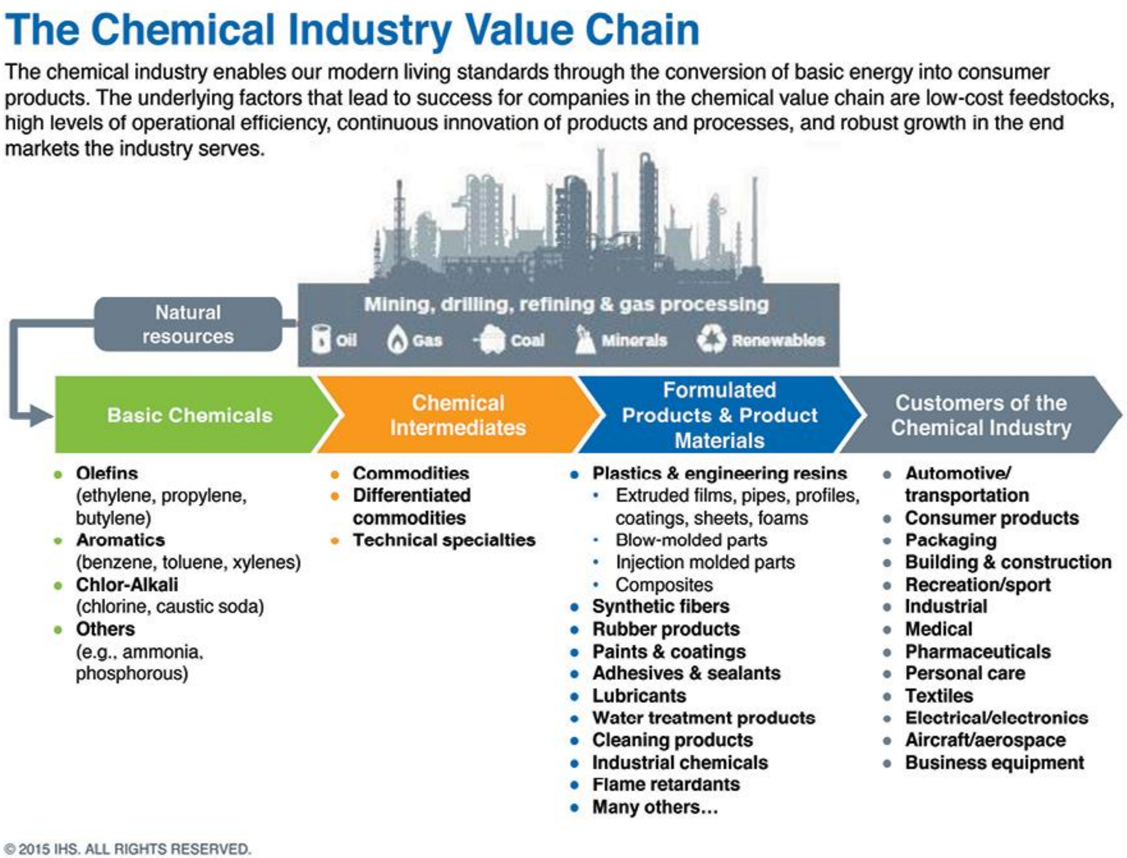
This changing landscape for both bio-based and recycled materials for new manufacture is illustrated by such international corporations as Target, Unilever, Lego, Ikea, Coca-Cola, Danone and Suntory. Furthermore, industry associations such as the Sustainable Packaging Initiative and the Natur'ALL Bottle Alliance have attracted major international manufacturers such as Coca Cola, Danone, and Nestlé Waters, corporations that are aligning their in-house strategy into an industry initiative.

Evidence of the changing consumer landscape and the rise of bio-manufacturing among major consumer brands is represented in the following table.

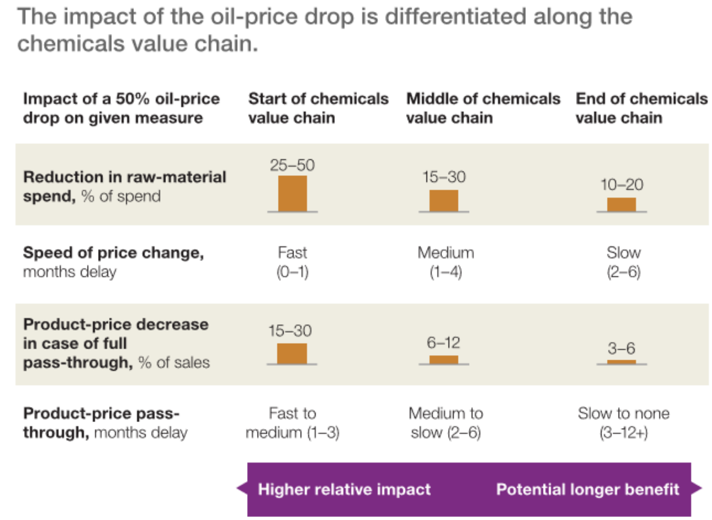
Bio-manufacturing within consumer brands: Indicative announcements for 2018

Company	Biobased product	Feedstock
Total and Corbion	Poly-lactic acid (PLA) for motor vehicle construction	Sugarcane (Thailand)
LEGO	LEGO pieces made from plant-based polyethylene	Sugarcane (Brazil)
Danone, Nestlé Waters	Bio-based PET bottles	Lignocellulose
Allbirds and Braskem	Resin for shoe construction	Sugarcane (Brazil)
Carlsberg and EcoXpac	Fibre containers	Wood fibres
Reebok, DuPont Tate & Lyle	Susterra propanediol for shoe construction	Corn
Suntory and Annellotech	Polyester, polyethylene terephthalate (PET), polystyrenes, polycarbonates, nylons and polyurethanes	Non-food biomass
IKEA and Neste	Polypropylene (PP) and polyethylene (PE) plastics	Waste & residue raw materials, eg used cooking & vegetable oils

Biochemicals Value Chain



Taken from: Plastics Engineering Magazine, Jan 2016 – Resin Market Focus – by IHS Chemical
http://read.nxtbook.com/wiley/plasticsengineering/january2016/resinmarketfocus.html



Taken from: Oil-price shocks and the chemical industry: Preparing for a volatile environment
https://www.mckinsey.com/industries/chemicals/our-insights/oil-price-shocks-and-the-chemical-industry-preparing-for-a-volatile-environment

Key Points

1. The chemical industry is well established.
2. Oil price changes have an almost immediate effect on chemical prices. This is hard to compete with, and on the market side, there is a need to find buyers willing to pay the premium for biochemicals.
3. Researchers are looking for ways to move up the value chain from basic chemicals to chemical intermediaries.

Policy

Dr Stephen Cox of the QUT Business School

The Role of Policy in Innovation

Dr Stephen Cox of the QUT Business School has been looking at the topic of '*Biorefining and the Australian Sugar Industry*' as part of SRA Project 2015/902 'A *profitable future for Australian agriculture: biorefineries for higher-value animal feeds, chemicals and fuels.*'

The following is a high level summary of as yet unpublished findings of this study.

1) In countries and regions where substantial biofuels industries have developed, policy has been a key enabler of industry growth.

2) Australia has experienced inconsistency and instability in biofuels policy; and policies have often been poorly designed.

3) The introduction and expansion of a biofuels market in Australia has suffered from insufficient coordination between the biofuels industry and other industry sectors critical to the introduction and expansion of biofuels (including the blending, distribution and retail segments of the oil industry, and the auto manufacturing industry).

4) R&D policy has assumed a linear development to technological development, which has, until the last decade, likely hindered important knowledge development outcomes.

5) Market formation and development for many years was largely left to the nascent biofuels industry in competition with the dominant and incumbent petroleum industry, resulting in subsidies that were highly unlike to result in the development of an economically sustainable industry.

6) Unlike international regions where biofuel markets and consumption has expanded (US, Brazil, EU), the public legitimacy of biofuels in Australia has never been strong. This has been in part due to narrow advocacy on the part of biofuel producers, de-legitimisation from other industry sectors, and, in the main, a lack of a clear policy rationale on the part of Federal and until recently, State governments for supporting biofuels.

7) There appears to be a current limit to consumer acceptance of ethanol blends, as shown in the experience of NSW in which many consumers chose more expensive premium blends than ethanol blends when forced to a choice.

8) The more recent focus on biorefining (and Biofutures) usefully broadens the focus from domestic biofuels. Challenges exist for the identification and access of markets.

9) There have been some attempts to develop markets for biorefinery products, but these still appear to be largely aspirational. It is possible, however, that non-public actions have been undertaken.

On the basis of this analysis, it would seem that there have been very limited commercial opportunities for investment in further ethanol production capacity: there has been insufficient market development, and ethanol producers alone have been, and remain unable, to expand that market significantly without government action.

Recommendations on Policy and Innovation

Points for the sugar industry

The identification and coordination of biorefining markets is essential if Queensland is to develop an economically sustainable biorefining industry. While there have been some market formation actions undertaken as described above, the overall appearance is that market linkages have, in the main, been left to individual companies to develop.

If there is a desire for the sugar industry to diversify, then work needs to be undertaken to identify products and markets and assist with the development of the necessary value chains. Identification of products and potential markets is insufficient: market linkages need to be made.

This diversification may also require direct market formation in the form of niche protected spaces, depending upon the products identified. The evidence from technology transitions is that such protected markets are essential for entrepreneurial experiments to be encouraged .

Diversification into biorefining requires inter-sectoral coordination. The coordination required for the diversification into biofuels requires inter-industry coordination that has been limited, and has required government to take a larger coordination role for promote biofuel industry development. The sugar industry, nor the nascent biofuels industry itself can undertake that coordination.

If the sugar industry itself could enact the necessary coordination both within the sugar industry and with other industry sectors as required, then government does not have to undertake that role. However, if coordination cannot be successfully undertaken by the sugar industry alone, as has been the case for biofuels, it would be valuable for the sugar industry to work with the government to increase coordination and develop a shared agenda, increasing the likelihood of generating genuine commercial opportunities.

The four key structural elements of technological innovation systems

The main 'actors'	• Commercially oriented businesses • university or research organisations • public organisations, such as government departments, and • advocacy groups.
Institutional elements	'Hard' institutional elements are policies of government and other bodies of relevance, such as industry bodies, that impinge on the system. 'Soft' institutional elements are shared belief sand norms held by a range of system participants about current and future industry expectations, and about 'how things should be done'.
Networks	Connections that allow knowledge exchange among the various classes of actors within the innovation system.
Infrastructure	The provision of resources that are available to many or all innovation system members required for functioning of the system.

Scaling up

An overview of the lessons learned in industry to date

Why financing is so hard.

Oil price volatility affects the economic viability of second generation technologies.

The global supply chain largely chases lowest price inputs.

The 4 Steps to Commercialisation

1 Laboratory

From idea to proving parts of the process, optimizing and developing initial plant design. Process run in batches.

Cost: $100,000 - $1 M

Funding from gov't, universities and corporate R&D.

2 Pilot

Technical proof of concept. Run on a continuous basis to test, optimize and prove up the process. Product tested against relevant standards.

Cost: $1 M to $5 M

Difficult to fund. Some Gov't support.

Funding Gap

3 Demonstration

Commercial proof of concept. Full plant, but at sufficient scale to lower financial risk and prove ability to scale up volumes while maintaining process efficiency and costs.

Cost: $5 M to $30 M

Funding from private equity and government. On balance sheet funding for larger corporations

4 Commercial Scale

Commercially viable plant, operating life of 20 years. One plant operating successfully at commercial scale is the requirement for adoption across industry.

Cost: >$50 M

Funding from owner equity, institutional equity, banks and government agencies.

As a rule of thumb, each step should be 10 times larger than the last

New process – 8 to 15 years

Incremental improvements to existing processes – 2 to 5 years

Limited capacity to drive adoption of bioproducts

Biofuels capacity not growing fast enough

Source: The Future of Second Generation Biomass https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/the-future-of-second-generation-biomass?cid=eml-web

Key trends

- Current growth is stop and start, depending on oil prices. This is evident in the boom bust cycle of the US ethanol market as shown on the left. Investors are wary.
- There is a strong dependency on government regulations for price support.
- For commodity products that compete with fossil fuel derived products, price volatility due to changing oil prices deters investors unless they can see long dated offtake contracts with firm pricing.
- For new products there is interest from industry consortia. For example there is a consortia looking at bio-derived PEF as a potential replacement for PET in making plastic bottles.
- Technology development is hampered by lack of capital to demonstrate and scale up.
- While there is a trend to ‘green-up’ value chains, this depends on the actions of companies, rather than regulations. A good case in point being the Corporate Power Purchase Agreements (PPAs) being struck with renewable generators, outside the Commonwealth Government Renewable Energy Target (RET) scheme.
- It will be hard for the sugar industry itself to drive the adoption of biofuels and biochemicals.
- The sugar industry can enable demonstration of cutting edge technologies which could reduce costs of production.

What's holding the industry back – and potential solutions

The Chicken or the Egg Problem

- Investors want to see a pilot plant operating in a continuous manner and making consistent product before they'll invest equity into the company.
- Bankers want to see the technology proven at commercial scale, with the same feedstock, somewhere else first.
- Institutional equity investors don't want to build the first of a kind plant (FOAK). They want reference sites.
- Regulators want to see a reference plant, at suitable scale, somewhere else, so they can understand environmental matters.
- We know proven technologies are not yet cost effective enough to compete with fossil fuel based products. Incremental improvements are possible, but not significant gains.
- Cutting edge technologies which promise lower costs and higher efficiencies are difficult to finance. Many are stuck in the laboratory, or waiting to build a pilot plant.
- Feedstock partners are often reluctant to commit to a new technology as it can take up precious land and provide complications if it doesn't work out.
- Buyers won't convert their supply chain to 100% sustainable feedstock until their competitors do too.

Everyone wants someone else to take the risk

Potential Solutions

- Make small bets - experiment at a smaller scale to prove up a process to your own satisfaction, allowing you to scale up later once you understand the processes. This has a lower financial risk.
- Partner up with product offtakers to prove up quality of product and pricing.
- Reduce financial risk through business models such as having a third party take the technology and market risk.
- Reduce risk through a consortium – a classic model in the resources industry. Combine forces on research, pilots and extension activities.
- Showcase the attractiveness of the local sugar industry through enabling pilot/demonstration scale projects.
- An industry requires an ecosystem of suppliers, consultants, logistics firms, regulations, etc. The more projects that get built, the more robust this ecosystem will become.
- Work with governments to enable a new industry and look at broader issues such as water, infrastructure and regulations.

Construction and Operations

Construction

- Existing technologies can be bought under licence, with the appropriate EPC wrap to provide fixed price and schedule.
- New technologies and processes that are being constructed for the first time are riskier. Construction companies often charge a premium to provide a fixed price, where required.
- Faster process times means shorter vessel residence times for the same volume of product. This means smaller vessels and lower capital costs.
- Construction costs are higher in Australia than many competing sugar producing countries.
- Many EPC firms have outsourced design to international branches, meaning that local expertise is harder to find.
- Anecdotally, local construction companies have little experience with these kinds of plants.
- The history of the industry is littered with cost blow outs when building demonstration and commercial scale plants.

Operations

- Economies of scale are important to reducing costs. However, there needs to be sufficient feedstock available at a reasonable cost to achieve economies of scale.
- Variability in the price of feedstock is what makes or breaks many products competing with fossil fuels. Given the disconnect between agricultural commodities and oil prices, this is difficult.
- Revenues from the sale of by-products and co-products are often necessary to be commercially viable. E.g. Ethanol plants sell dried distillers grain (DDG) as animal feed to reduce the cost of ethanol production.
- Location is critical. There is a tradeoff between transporting feedstock, and the costs of other inputs to the process.
    - For example, there have been proposals to have treatment of biomass in multiple locations, transporting an intermediate product to a centrally located plant to produce the final product.
- Achieving a sufficient price for offtake for 10 years is difficult. Many buyers/traders have incurred losses in past endeavours and can be reluctant to back new processes.

More detail is available at
SugarValueAdd.Info

Case Studies

Dr Dianne Glenn – Corelli Consulting

Case Studies

Corn

The US corn industry generates revenues as a food (sweet corn) and as an animal feed (field corn). Industry grower associations have actively assisted the diversification of applications for field corn: to generate revenue streams as a feedstock for fuel ethanol production as well as for biobased plastic PLA.

NatureWorks is the first and still one of the largest lactic-acid plants in the world, used to manufacture the biodegradable industrial bioplastic polylactic acid (PLA). This bioplastic can be made from a number of sugar or starch-based agricultural crops. NatureWorks was initially formed as the joint venture of Cargill and Dow Chemical Co (1997) and now is a JV between Cargill and Japan's Teijin Ltd (2007). The NatureWorks PLA plant in Nebraska produces 140,000 tonnes per year.

The PLA production plants are located next to a corn wet mill where the starch in corn kernels is converted into glucose used as the raw material for the lactic acid fermentation process. Co-location of PLA manufacture with the production of the corn feedstock within one of the largest corn producing states sets up an efficient integrated production operation.

The global PLA market is anticipated to reach 830 kilo tonnes valued at US$2.1 billion by 2023. Key factors driving the rapid market growth include favourable government policies promoting bio-plastics and increasing consumer demand for bio-plastic packaging.

Sugar in Brazil

The Brazilian sugar industry is an example of a diversification and value adding in agriculture. Both specialty and bulk commodity products are produced from either sugarcane or ethanol made from sugarcane; these have contributed to Brazil becoming a leading global producer of biobased chemicals. A national survey in 2014 identified a target group of biobased specialty compounds for industrial development leveraging sugarcane feedstocks: for use as cosmetics, agrochemicals, feed additives, aromas, flavours and fragrances, solvents and carbon fibre.

The São Martinho Group is one of Brazil's largest producers of sugar and ethanol. The company purchases, cultivates, harvests and crushes sugarcane as the feedstock for both sugar and ethanol operations. Sao Martinho has a well-diversified agri-business, producing annually, in addition to crystal sugar and ethanol26:

- Electricity: exported from its co-generation plant; RNA:
- a specialty nucleic acid for the pharmaceutical and food industries;
- Yeast: a protein and vitamin source used in animal feed;
- Fusel oil and amyl alcohol: used in heavy industry manufacture; and
- Fertilisers.

Sugar in Brazil - continued

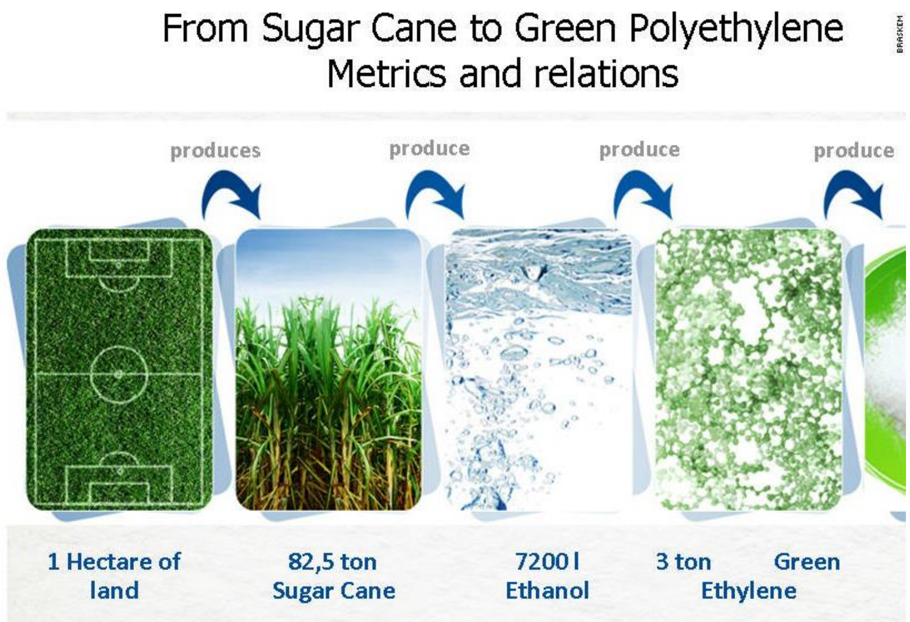
The company understands the value of sugar as a feedstock to make high value chemicals. In April 2010, São Martinho partnered with US-based Amyris Biotechnologies for the construction of a chemical plant to produce the speciality chemical farnesene, a platform molecule used to make families of other chemicals including flavour and fragrance compounds, vitamins and lubricants.

Amyris recently sold its Brazilian factory and IP for speciality products to DSM for US$58 million: vitamin E is one of DSM's biggest revenue earners, and producing farnesene from sugarcane allows DSM to be the lowest-cost global vitamin E producer.

Ethylene is a basic organic chemical serving as an ingredient for a basket of other commodity chemical products. With global production exceeding 140 million tonnes per year and growing actively, ethylene is by far the largest bulk chemical used for the production of around half of all plastics.

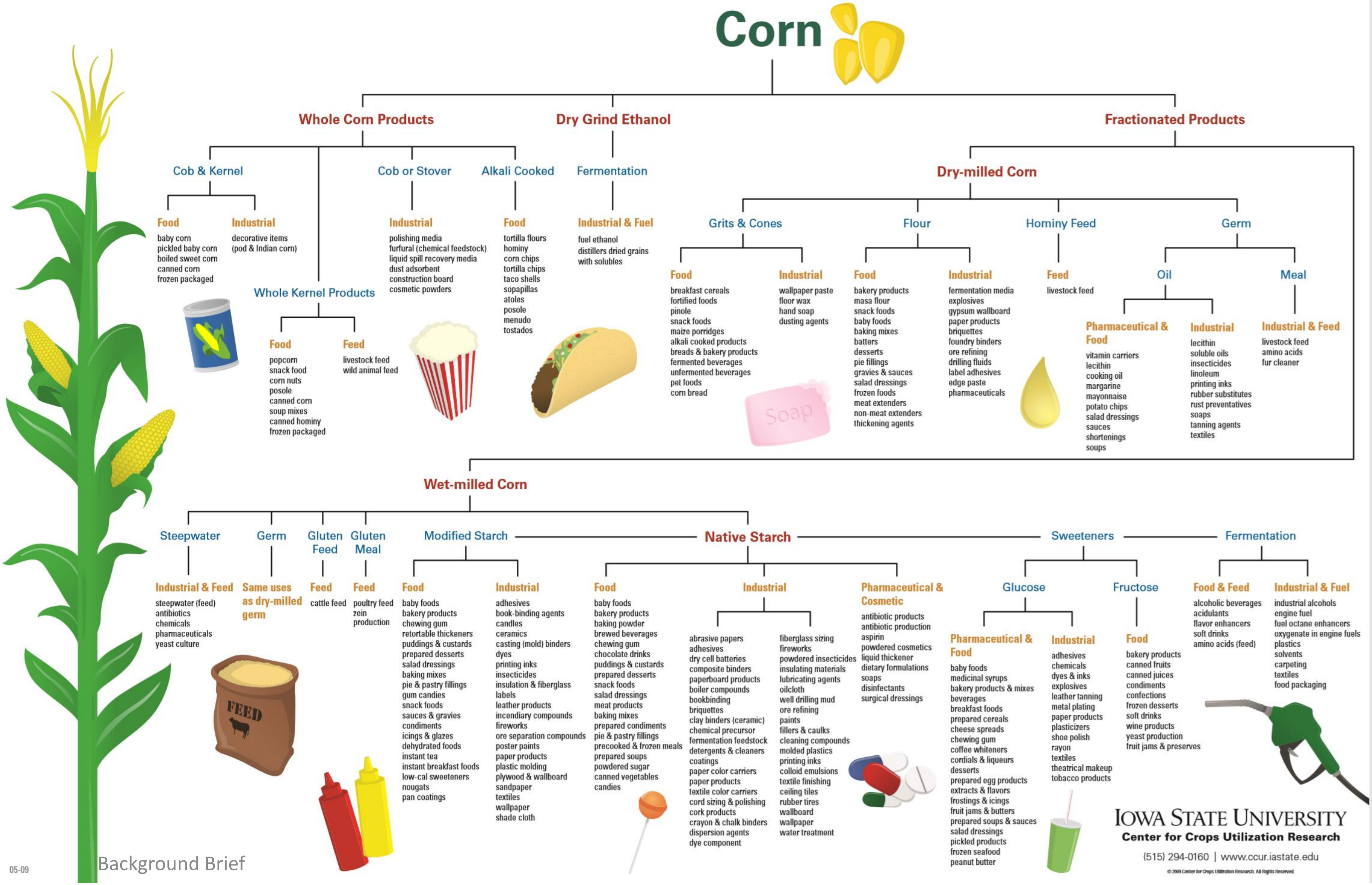
Bio-ethylene is produced from ethanol, and Brazil provides a favourable environment for the production of bio-ethylene from sugarcane. Bio-ethanol has been economically produced in Brazil as a transportation fuel since 1975: inexpensive sugarcane and large scale bio-ethanol production and experience as the world's second largest producer has made Brazilian bio-ethylene cost competitive.

Brazil's national chemical company Braskem has manufactured green ethylene since 2010 as "I'm Green™" polyethylene at 200,000 tonnes pa, making the company a global leader in drop-in bioplastics.



I'm green ™

Image Source: https://edition.cnn.com/2012/02/09/sport/football/football-sugar-seats-brazil-amsterdam/



Background Brief

The Team

Eris O'Brien
Chief Investigator
Managing Director | Lazuli Consulting

Eris O'Brien is an experienced management consultant specialising in commercialisation and business development, primarily in the energy sector. He will lead the study. Eris has a strong background working in projects and commercialisation, including working with sugar mills on biomass co-generation. He is currently helping deliver the Queensland Government's bio-futures roadmap. He has a strong background in technology commercialisation and has worked at the forefront of de-carbonising the economy for the last two decades

Tony Campbell
Co-Investigator
Principal Consultant | Lazuli Consulting

Tony Campbell is an accomplished consultant specialising in energy and has a long history working on biomass related projects. He will deliver commercial market insight analysis to the study and will work with researchers to develop appropriate metrics to allow logical and transparent commercial assessment of strategies developed. Tony has completed major analytical projects and valuations in most of Australia's energy sectors including renewable (sugar, macadamia waste, banana waste, landfill, wind, and solar) , fossil fuel (coal and gas), and utilities (electricity generation, distribution, and retail).

Dr Dianne Glenn
Co-Investigator
Principal | Corelli Consulting

Corelli Consulting has provided technical, commercial and strategic advisory services to the life sciences and industrial biotechnology industry for the past 14 years. Dr Dianne Glenn, the principal of Corelli Consulting, will assist to delineate relevant technologies, advances, opportunities and industry trends which will be cornerstone to the results of this study. She will be instrumental in bridging current state technology into forward looking commercial pathways.

Dr Mark Harrison
Co-Investigator
Senior Research Fellow | Centre for Tropical Crops and Biocommodities | QUT

Mark Harrison is a Senior Research Fellow within the Centre for Tropical Crops and Biocommodities at QUT. He will play a key role in the primary research phase of the project, particularly the review of current technology pathways. Mark is a research scientist with over 15 years' experience in basic, applied, and commercial research. Further, he has over 5 years' experience in industrial biotechnology research as Team Leader - Biochemistry and Enzymology in the Syngenta Centre for Sugarcane Biofuels Development at QUT. Mark is experienced in a diverse range of research areas including industrial chemistry, plant biology and biotechnology, protein science, animal feed, and biofuels.

Dr Stephen Cox
Director | Higher Degree Research Studies
QUT Business School | QUT

Stephen Cox has provided methodological advice to staff and research students within the Business School for 10 years. He has expertise in many statistical and methodological approaches. Stephen Cox's research focuses on the way global value chains operate, and the opportunities and constraints GVCs afford firms to improve their value capture.

A second research focus has been on the psychology of health and wellbeing.

Advice on the background brief was kindly provided by:

Professor Ian O'Hara
Acting Executive Director | Science and Engineering Faculty, Chemistry, Physics, Mechanical Engineering, Energy and Process Engineering | QUT

Mark Moriarty
Manager Business Development | Wilmar Sugar Australia Limited

Burn Ashburner
Senior Manager – Industry | Canegrowers

Hywel Cook
General Manager Business Development | MSF Sugar

Contact Details

SRA Details

SRA Project *2018014*

Establishing a strategic roadmap for product diversification and value addition

Any questions or concerns, please contact:

Dr Michael O'Shea
General Manager Research Funding Unit
(07) 3331 3362
moshea@sugarresearch.com.au

Contact Us

Eris O'Brien
Managing Director
0404 473 896
eris@lazuli.com.au

Tony Campbell
Principal Consultant
0417 761 458
tony@lazuli.com.au

Address
L8, 46 Edward St, Brisbane QLD 4000

www.lazuli.com.au

Appendix 1 : resource table : regional summary

Region	Area harvested	Cane harvested	Cane trash (t)	Waste water (t)	Mill mud & boiler ash (t)	Bagasse (dry t)	Sugar (t)	Molasses (t)	Gross energy (GJ)	2017 Eligible generation (GJ)	Net mill consumption (GJ)	Generation capacity (MWe)
Northern QLD	84,420	6,903,000	976,103	4,384,030	417,616	968,294	879,864	210,838	11,745,447	915,530	10,829,916	67
Herbert – Burdekin, QLD	125,876	13,154,000	1,860,011	8,353,980	795,787	1,845,131	1,819,398	401,762	22,381,516	2,292,289	20,089,227	172
Mackay Proserpine, QLD	105,147	7,579,000	1,071,691	4,813,351	458,512	1,063,118	1,021,016	231,485	12,895,660	1,053,482	11,842,178	110
Southern QLD	46,094	3,835,000	542,279	2,435,572	232,009	537,941	533,908	117,132	6,525,248	345,420	6,179,828	73
NSW	15,558	1,878,000	265,554	1,192,700	113,615	263,430	276,316	57,360	3,195,415	1,319,249	1,876,166	65
Industry total	**377,094**	**33,349,000**	**4,715,639**	**21,179,633**	**2,017,539**	**4,677,914**	**4,530,502**	**1,018,578**	**56,743,286**	**5,925,971**	**50,817,315**	**487**

Other useful metrics are:

- There is 25 operating mills with a collective crush capacity of 38 million tonnes per annum operating 20 to 25 weeks per annum. As currently configured and operating, the average industry milling rate is 430 tonnes per hour.
- The industry owns and operates circa 4,000 kms of cane railway, used to gather 90% of cane harvested. The balance of cane (mostly in NSW), relies on road transport. Per ASMC, the furthest run to a mill is 119km whereas the average distance hauled is between 13 and 35kms. There is about 250 diesel hydraulic locomotives, consuming up to 520 kW power to shuffle around 52,000 cane bins.
- Sugar Terminal Limited ('STL') owns and operates 6 bulk commodity terminals in Queensland and handles over 90% of the raw sugar produced in Australia. STL also handles other commodities including molasses, wood pellets, gypsum and silica sands via it's a$350m investment in Queensland ports.