Review of the development of the co-products industry in Australia

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Abstract  Australia has been in the forefront of the production of co-products over the last hundred years. In particular, the industry has led in the production of alcohol, co-generation, waxes, fertilizers, animal feeds and in the research and development of new co-products. However, the growth of the co-product industry in the country has been relatively slow over the past 20 years. This paper reviews value adding to factory operations through co-products. In the past 20 years, the Australian sugar industry has moved toward cogeneration as a value-adding opportunity for bagasse, but there have been relatively few major commercial developments for other co-products. Growth of the industry has been restricted by many factors including limited internal markets, high cost structure, strict environmental practices and competition from fossil-fuel derived products. This paper provides 10 guidelines for the development of successful projects.

Key words  Co-products, cogeneration, ethanol, bagasse, animal feeds

INTRODUCTION

The Australian sugar industry is a successful sugar producer with a long history. The industry was effectively started in the 1860s following the construction of several factories and refineries in the Australian states of New South Wales and Queensland. The first factory in the Mackay district was established in 1869 (Kerr 1980). It is of interest to note that the early pioneers of the industry often produced rum as a co-product (Kerr 1980).

Since those early days, the industry has advanced to the present day where it has 24 mills, 8 milling companies, about 4,200 growers, with 377,000 ha under cultivation producing between 30 and 35 Mt of cane per annum (ASMC 2016). Figure 1 shows a map of the Australian industry. Data from the Australian Sugar Milling Council report for the 2014 season notes a harvest of 32.4 Mt of cane that produced 4.55 Mt of raw sugar with 3.60 Mt destined for export (ASMC 2016). The total revenue generated for the industry including sugar, electricity and molasses amounts to AUD 2,100 million, with AUD 1,500 million accruing from sugar exports [or an estimated total of USD 1,600 million for the industry with an estimated USD 1,160 million accruing from sugar exports, assuming a 2014 exchange rate of USD 0.775 to AUD 1.00] (ASMC 2016). The value add for co-products to the industry reported by ASMC is relatively small. The difference between total revenue and export revenue is about AUD 600 million, which includes refinery sugar consumption of 0.95 Mt of raw sugar.

Value adding for a variety of co-products has been undertaken in the Australian industry, including cogeneration, ethanol production, animal feeds manufacture and other activities. This paper reviews the development of the co-product industry in Australia in recent years.

METHODOLOGY

In this paper, a co-product is defined as anything except sugar. Co-products are categorised on the basis of the feedstock, namely bagasse, molasses, mill mud and ash. The information for the paper is sourced from reports and papers published in the open media. This research methodology includes information published on the World Wide Web.
Fig. 1. Map of the Australian sugar industry (Queensland Sugar Limited).

Bagasse co-products

Cogeneration

Cogeneration based on surplus bagasse production has been the most significant development undertaken by the industry in the last 20 years.

New South Wales (NSW) has three cane sugar factories, of which one has an attached sugar refinery and the other two have established large cogeneration plants. Palmer et al. (2009) described the installation of the cogeneration facilities at the Condong Mill and the Broadwater Mill. Each site has a 152 t/h maximum continuous rating (MCR) boiler operating at
The operation of the NSW cogeneration plants ran into difficulties and both cogeneration facilities were sold by the joint venture partners to Capital Dynamic in November 2013 (Connors 2013). Depressed green-energy prices were cited as a major reason for the plant's failure (http://www.tweeddailynews.com.au/news/25m-loan-paid-back/2085527). The cogeneration plants at the NSW factories have continued to be operated by new owners and supply low-pressure steam and electricity to each factory.

Queensland has the majority of the country’s factories, with 21 mills in operation. Several factories in Queensland have been upgraded in the past 20 years to improve boiler efficiencies and produce surplus bagasse for cogeneration. Surplus bagasse is often transported between factories to ensure economies of scale for the cogeneration facility.

The first major cogeneration plant commissioned is at Wilmars Sugar’s Invicta Mill (Harrison and Lavarack 1997). The new boiler has a MCR rating of about 320 t/h and operating conditions of 4.3 MPa and 450°C. It supplies a 38.9 MWe backpressure STG that provides low-pressure steam to the factory during the crush season.

The second major development in Queensland is the joint venture by Stanwell Corporation and WH Heck & Sons at the Rocky Point Mill. The boiler was designed to produce 118 t/h steam at MCR and operates at 6.8 MPa and 508°C (Lowry et al. 2001). To improve the economics, the plant was designed to burn bagasse in the crush season and both green and wood waste in the non-crush period. The operation of the cogeneration plant suffered from a number of maintenance issues during the 2010 crushing season that slowed the harvest, before substantial damage to the boiler resulted in the cogeneration plant being placed into receivership in January 2012 (Brown 2013). The co-generation plant is under new ownership following its sale in mid-2012.

The third major development in Queensland is the cogeneration project at Pioneer Mill. Both Trayner (2008) and Stirling et al. (2008) describe the development of cogeneration at the Pioneer Mill. The existing number 2 boiler was uprated to 241 t/h MCR at 3.1 MPag and 383°C to supply a 30.8 MWe backpressure turbine. A new number 3 boiler rated at 130 t/h MCR and 6.5 MPa and 483°C with a dedicated condensing STG of 37 MWe was commissioned. This allows for a maximum export of 50 MWe from the factory. Pioneer Mill is supplied with surplus bagasse from other nearby Burdekin mills to allow power export during the non-crush period. Improvements for increased cogeneration have been undertaken at Wilmars Sugar factories in Australia, including Invicta Mill, Victoria Mill, Pioneer Mill and five other factories to have a total generation capacity of about 197 MWe of which about 123 MWe is available for export (https://www.wilmarsugarmills.com/about-us/cogeneration).

The fourth major development in Queensland is Mackay Sugar’s Racecourse Mill cogeneration project. Hodgson et al. (2013) reported the new number 4 boiler at Racecourse is rated at 150 t/h MCR on bagasse. The boiler supplies 8.0 MPa and 525°C steam to a condensing turbine with pass-out. The STG is rated at 38 MWe. Like the Pioneer Mill project, surplus bagasse from surrounding factories is supplied to Racecourse Mill. The Racecourse project has been augmented by efficiency upgrades to boilers at both Farleigh Mill and Marian Mill to increase the supply of bagasse to Racecourse Mill (Lloyd and Hodgson 2014). The economics of the Racecourse project are enhanced because the cogeneration facility operates in the non-crush period to supply the co-located sugar refinery at Racecourse Mill.

Although there are only about six or seven major cogeneration plants in the Australian sugar industry, the factories in the vicinity of the cogeneration facility are often configured to produce surplus bagasse to maximise cogeneration operations. It is apparent that the Australian sugar industry has moved decidedly toward cogeneration as a value-adding opportunity for bagasse, despite the lack of financial success of the early production units. The Australian Government’s 2009 mandated Renewable Energy Target of 33,000 GWh/year has improved the economics for sugar-mill cogeneration. The revenue from the renewable energy component of electricity generation (certificate system) now exceeds the energy value received from exporting to the grid.
Other bagasse co-products

There have been numerous attempts to add value to bagasse and trash at the commercial scale in Australia. There have been some successes at small scale, including:

- the use of cane trash as garden mulch and soil conditioner (e.g. Rocky Point Mill mulch, Giru Organics and direct farm-gate sales) (http://www.rpmulching.com.au);
- production of biochar as a soil conditioner and for other uses (http://www.biochar-international.org/projects/BiGchar);
- manufacture of dietary fibre (http://www.kfsu.net/au/).

There have been some disappointments including the development of a pulp and paper production facility at Marian Mill (Hodgson personal communication 2006), the production of furfural at Proserpine Mill (Watson and Connors 2008; Raiteri 2011) and the Cow Candy animal feeds plant based on adding syrup to bagasse and drying the product for export (http://www.sunshinecoastdaily.com.au/news/three-hurt-cow-candy-explosion/416723/). Aspects of these projects are discussed below.

Major research efforts have been undertaken into the development of bagasse co-products in Australia including gasification, cellulosic ethanol and other products (Hobson et al. 2006; Wong et al. 2011; Deloitte 2014; Lavarak 1999). These research initiatives have not resulted in the establishment of Australian plants at full commercial scale, because of process economics.

### Molasses co-products

#### Bioethanol

The Australian sugar industry has one major bioethanol plant located at Sarina in Queensland. The plant can supply both fuel-grade and industrial-grade alcohol. The plant has a nominal capacity of 60 ML/y and was upgraded in both about 2006 and 2008 to produce fuel-grade ethanol with molecular-sieve dehydration technology ethanol (http://wilmarbioethanol.com/about-csr and http://www.theaustralian.com.au/business/biofuel-demand-fuels-csrsethanol/story-e6frg82x-1111117084732). The Sarina bioethanol plant has been in production since the 1920s, with a major technology upgrade undertaken in the late 1980s (Chapman et al. 1995). In the upgrade, an innovative approach to vinasse distribution has been adopted by Wilmar Bioethanol (formerly called CSR Bioethanol). The approach involves the production of concentrated vinasse to which supplementary nutrients can be added to produce a liquid fertilizer product to match the specific farm requirements (Chapman et al. 1995).

Australia has two other major bioethanol plants that take the nominal capacity of the three combined plants to about 440 ML/y. The two other bioethanol plants are based on wheat starch and grain sorghum feedstocks, respectively (http://biomassproducer.com.au/markets/bioenergy-markets-in-australia/ethanol/#.V0wxAkJf3IU).

It is of interest to note that the Sarina plant supplied ethanol to a facility in Sydney (CSR Chemicals) that produced ethylene for the manufacture of polyethylene (van Santen 1995). Ethylene production based on ethanol ceased in the 1960s as it could not compete with the fossil-fuel based product. Other chemicals were also manufactured at the Sydney facility, which ceased production in the late 1980s (van Santen 1995).

A major rum distillery is located at Bundaberg and is based on a molasses supply from the local factories operated by Bundaberg Sugar. A small rum distillery has recently re-commenced operation at Beenleigh. The small bioethanol plant at Rocky Point Mill has closed recently (Brown 2013).

There is significant potential to develop the bioethanol industry in Australia. The Queensland State Parliament has legislated for an initial 3% ethanol mandate for gasoline that is due to start on 1 January 2017. In practical terms, the mandate will require E10 to make up 30% of regular gasoline sales in Queensland in 2017 (http://statements.qld.gov.au/Statement/2015/12/1/biofuels-mandate-powers-sustainable-future). Given that the total gasoline sales for Queensland in 2014 were 3,270 ML/y (ABS 2015), the potential market for bioethanol fuel in Queensland is about 98 ML/y. The potential market for bioethanol is large, since total gasoline sales for Australia in 2014 were 17.5 GL/y (ABS 2015). There are three new sugar business proposals in Queensland that have been under development in recent years. These are based on predominantly ethanol and cogeneration outputs, but none has commenced.
Other molasses co-products

The main use of molasses in Australia is for export and for the production of animal feeds (ASMC 2016). There is strong demand for molasses from the animal feed sector, particularly from cattle feedlots. An animal feed production unit was recently completed at Mackay Sugar's Marian Mill. There are some yeast manufacturers in Australia that consume small quantities of fermentation feedstock.

Paturau (1989) describes a compendium of potential co-products that can be produced from molasses. Other than the plants mentioned above, there are few or no major commercial units owned or operated by sugar interests for the production of bio-products based on molasses.

Mud and ash co-products

Mill mud and ash produced in Australian factories are both regarded as regulated wastes, with special dispensation given to allow each to be applied in the cane fields as a soil conditioner and/or fertilizer (Markley et al. 2010).

Mill mud contains lipids and waxes that have value. A production plant to extract and refine waxes was operated up to the early 1960s at the Moreton Mill in Nambour. It closed because it could not compete with waxes produced from crude oil (Paturau 1989). A major research project was undertaken in the late 1990s to develop a wax-manufacturing plant in the Herbert region of Australia, but the project did not proceed. Some research outputs (Askew et al. 1999; Valix 2004) result from this project.

DISCUSSION

Development models

At the 2015 ISSCT Co-products Workshop held in Mauritius, presentations by Davis, Foxon and Booysen of SMRI and by Punter of AB Sugar outlined two methodologies for the development of co-products. Each methodology has its merits. SMRI’s new-product greenhouse follows a rigorous five-stage approach. In contrast, the AB Sugar model welcomes ideas that promote energy efficiency, operational excellence and co-products. AB Sugar’s Wissington factory is an embodiment of the latter model as the sugar factory produces a wide variety of co-products. Standard texts such as Peters and Timmerhaus (1991) provide checklists, step sequences and other information required for developing large projects.

Australian aspects for development of co-products

Hobson et al. (2006) and Deloitte (2014) have outlined the large potential to produce bio-based products in Australia. Massive research and developments efforts have been and continue to be undertaken to develop bio-based industries in the country. In this respect the establishment in 2011 of the Australian Renewable Energy Agency (ARENA) is a major boost that can support co-product development for the Australian sugar industry within the sphere of renewable energy. ARENA’s timeframe for delivering its objectives is 2022, with an intent to provide competitive energy solutions up to 2030-2040 (http://arena.gov.au/about-arena/). There are several other Australian Government agencies that foster research.

Given this potential and government input, why has progress in Australia been limited to cogeneration and to some relatively small scale value adding activities?

Some pointers given by Raiteri (2011), Palmer et al. (2008) and van Santen (1995) have been interpreted together with outputs from other projects reported here. I have formulated these into 10 guidelines for the development of successful projects, which are given below in point form:

1) Complete a comprehensive feasibility study and risk assessment prior to project commitment. Include the social and environmental impacts of the project and legislative requirements in the assessment.
2) Recognise that the co-product should be profitable and be cost competitive with existing products derived from fossil-fuel sources.
3) Obtain comprehensive knowledge of the co-product market; including competitors, market size and product pricing. Secure long-term product off-take agreements in advance.
4) Practice good project management; use a consultant if required.
5) Undertake good communication with all levels of government (federal, state and local).
6) Work with all stakeholders to minimise delays and to obtain project acceptance.
7) Understand all aspects of the process technology, particularly if the plant is a first-off.
8) Budget for unforeseen project delays or problems.
9) Realise and make allowance for the project life; normal projects should last at least 15 years, if not longer.
10) Have an ability to walk away from a project or have an alternative strategy if any of the above points are not being met.

There are several cost considerations that apply to Australia.

- In general, Australian sugar factories are distant from the main markets and major population centres. The costs for the transport of co-products to major population centres in Australia and Asia are significant and are often more than the production costs.
- The market size in Australia for some co-products is considerably smaller than for Asian countries. This means the co-product requires marketing expertise for sales into Asia.
- Australian projects tend to be one-off and are required to meet strict practices with respect to (i) engineering standards, (ii) occupational health and safety practices, and (iii) environmental standards.
- The relatively low cost of fossil fuels in Australia caps energy pricing. In particular, bagasse compared to low-cost coal, and bioethanol versus petrol.
- The unit cost of labour in Australia compared to other cane sugar-producing nations tends to be significantly higher. Hence, all Australian factories require high levels of automation to remain competitive.

The implication of all the above factors means that Australia often has a higher cost structure than its competitors, which may make investment in co-product projects less attractive.

CONCLUSIONS

This paper reviews the development of co-products in Australia. In the past 20 years, the industry has moved toward cogeneration as a value adding opportunity for bagasse. However, there have been relatively few other major commercial developments in the field of co-products.

Growth of the co-product industry has been restricted by many factors, including limited internal markets, high cost structure, strict environmental practices and competition from fossil-fuel derived products. Ten guidelines for the development of successful projects are given.

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L’évolution de l’industrie de coproduits en Australie

**Résumé.** L’Australie a été à l’avant-garde de la production de coproduits au cours des cent dernières années. L’industrie a joué un rôle principal dans la production d’alcool, la cogénération, les cires, engrais, aliments pour animaux et dans la recherche et le développement de nouveaux produits. Cependant, la croissance de l’industrie des coproduits du pays a été relativement lente au cours des 20 dernières années. Cet article examine la valeur ajoutée aux opérations de l’usine par les coproduits. Au cours des 20 dernières années, l’industrie sucrière a progressé vers la cogénération comme une opportunité de valeur ajoutée pour la bagasse, mais il y a eu relativement peu de développements commerciaux pour d’autres coproduits. La croissance de l’industrie a été restreinte par de nombreux facteurs, y compris les marchés internes limités, des coûts élevés, des pratiques environnementales strictes et la concurrence des produits dérivés de combustibles fossiles. Ce document présente 10 recommandations pour l’élaboration de projets couronnés de succès.

**Mots-clés:** Coproduits, cogénération, éthanol, bagasse, aliments

Reseña del desarrollo de la industria de los coproductos en Australia

**Resumen.** Resumen Australia ha estado en la vanguardia de la producción de coproductos en los últimos 100 años, en particular la industria ha liderado en la producción de alcohol, en cogeneración, ceras, fertilizantes, alimento animal y en la investigación y el desarrollo de nuevos coproductos. Sin embargo, el crecimiento de la industria de los coproductos en el país en el siglo, ha sido relativamente lento.
en los últimos 20 años. Este trabajo reseña el valor agregado a la operación de las fábricas a través de los coproductos, en los últimos 20 años, la industria azucarera australiana se ha movido a la cogeneración como una oportunidad de agregar valor al bagazo, pero han existido relativamente pocos desarrollos comerciales en otros coproductos. El desarrollo de la industria se ha visto restringido por muchos factores, incluyendo un mercado interno restringido, una alta estructura de costos, prácticas medioambientales estrictas y una competencia de los productos derivados de los combustibles fósiles. Este trabajo provee 10 líneas-guías para el desarrollo de proyectos exitosos.

**Palabras clave:** Coproductos, cogeneración, etanol, bagazo, alimento animal