AUSTRALIAN SUGAR
MANUFACTURERS

Bioenergy Fund Project – Electricity Cogeneration in the Sugar Industry

Table of Contents

Overview of the Study

Australian Sugar Manufacturers (ASM) initiated this study to explore the opportunity to significantly expand electricity cogeneration capacity (using bagasse as the feedstock) within the sugar manufacturing sector. Co-funded through the Queensland Bioenergy Fund, the study delivers the following insights:

1 Competitiveness and viability of cogeneration in the National Energy Market

Undertaken by LEK Consulting, the study assessed the economic and commercial feasibility and market competitiveness of cogeneration.

2 NEM operational requirements and risks

Conducted by Brolga Energy, the study sets out the current operational requirements for participation in the NEM for scheduled and unscheduled generators. It notes if sugar mills expand cogeneration they may be reclassified as a scheduled generator with higher operational and compliance demands, and evaluates regulatory, policy, and market risks.

3 Policy, market and commercial mechanisms to support investment

Conducted by Brolga Energy, the study identifies mechanisms to generate sufficient revenues, manage market risks, and ensure the viability of expanded cogeneration capacity.

4 Economics of bagasse densification and feedstock supply

Led by LEK Consulting, the study explores pathways to densify bagasse feedstock for storage, transportation and trade, and to extend the utilisation of cogeneration throughout the year.

The following synthesis report was put together by ASM to provide an overview of and context to reports provided by LEK Consulting and Brolga Energy.

Disclaimers

In reading the synthesis report and associated papers, the following should be noted:

- **Study co-funded by industry and the Queensland Bioenergy Fund:** The Queensland Bioenergy Fund and the sugar manufacturing sector jointly funded the completion of this study. The study was completed independently by the sugar manufacturing sector, and insights and views provided for in this study do not reflect or form Queensland Government policy on energy or cogeneration.
- **Preliminary nature of the study:** This study was a preliminary study to identify whether there are net market benefits and opportunities for the expansion of cogeneration capacity at a systems level. While commercial and physical constraints have been identified for mills, and indicative costs for expansion highlighted, these are general costs and constraints, and full feasibility studies need to be commissioned to identify the feasibility at each mill site that has the potential to expand cogeneration.
- **Assumptions underpinning economic modelling for the expansion of cogeneration:** The modelling underpinning this study was finalised in February 2025, using the Australian Energy Market Operator's (AEMO) 2024 Integrated System Plan (ISP) Step Change forecasts for the supply and demand of electricity. Since the modelling was undertaken, the Queensland Government announced the likely extension to the end of life for the Callide B Power Plant and flagged that a five-year energy plan would be developed by the end of 2025 [1]. While the modelling presents scenarios with differing amounts of generation coming into the energy market, the above-mentioned factors may change the quantum of costs and benefits identified in the study.
- **Data aggregated at the industry level:** The study was undertaken with the sugar manufacturing sector on the proviso that commercial-in-confidence information would not be disclosed. Any mill or organisational specific information collected was only used to identify aggregated industry level insights to ensure confidentiality (unless otherwise agreed and communicated by individual sugar manufacturers).

1 The Hon. David Janetzki MP, Queensland Treasurer and Minister for Energy, *Energy Roadmap to deliver affordable, reliable and sustainable electricity*, 8 April 2025, at URL: https://statements.qld.gov.au/statements/102355

Summary of Key Findings

- Preliminary modelling indicates the expansion of cogeneration capacity could provide up to an additional 2.1 terawatt hours of electricity to the NEM (2.6 terawatt hours in total) – based on the study's modelling. Under the AEMO 2024 ISP, this could reduce projected wholesale generation prices in Queensland by between 10-20% in the coming decade ($9b-$15b of benefit created to 2050). Since the study was quantified, there appears to be an emerging divergence between the assumptions in the AEMO ISP and the evolving energy context in Queensland.
- To capture this opportunity, large-scale investment in the sugar manufacturing sector is required to upgrade boilers, turbines, electrify operations, and establish systems required to effectively operate in the NEM.
- Further transformational investment is required to change the operating processes of the sugar manufacturing sector to be able to effectively operate in both the NEM and markets for sugar. This could include operating outside the traditional season, compressed maintenance windows, more intensive overnight operations, energy risk management and energy trading capability. These are significant operational changes requiring new and additional capabilities.
- Sugar manufacturers face significant risks that act as a barrier to investment in cogeneration expansion, including the economic/commercial risk associated with such large-scale investments; regulatory risks associated with meeting market requirements for scheduled generators; market risk because of exposure to highly volatile energy markets, and; operation risks associated with effectively participating in energy and sugar markets.
- Existing market and regulatory incentive mechanisms were not designed with cogeneration in mind and are not fit-for-purpose in terms of promoting greater investment in additional cogeneration capacity.
- The study considers different commercial models such as Power Purchase Agreements (PPAs) between large private and public sector entities or collectives and sugar manufacturers; or sub-contracting market bidding and settlement to a third-party provider.

The study also considers a range of avenues for support including regulatory incentive mechanisms, revenue support (such as 'cap and floor') and direct government capital grants.

Pelletisation of bagasse

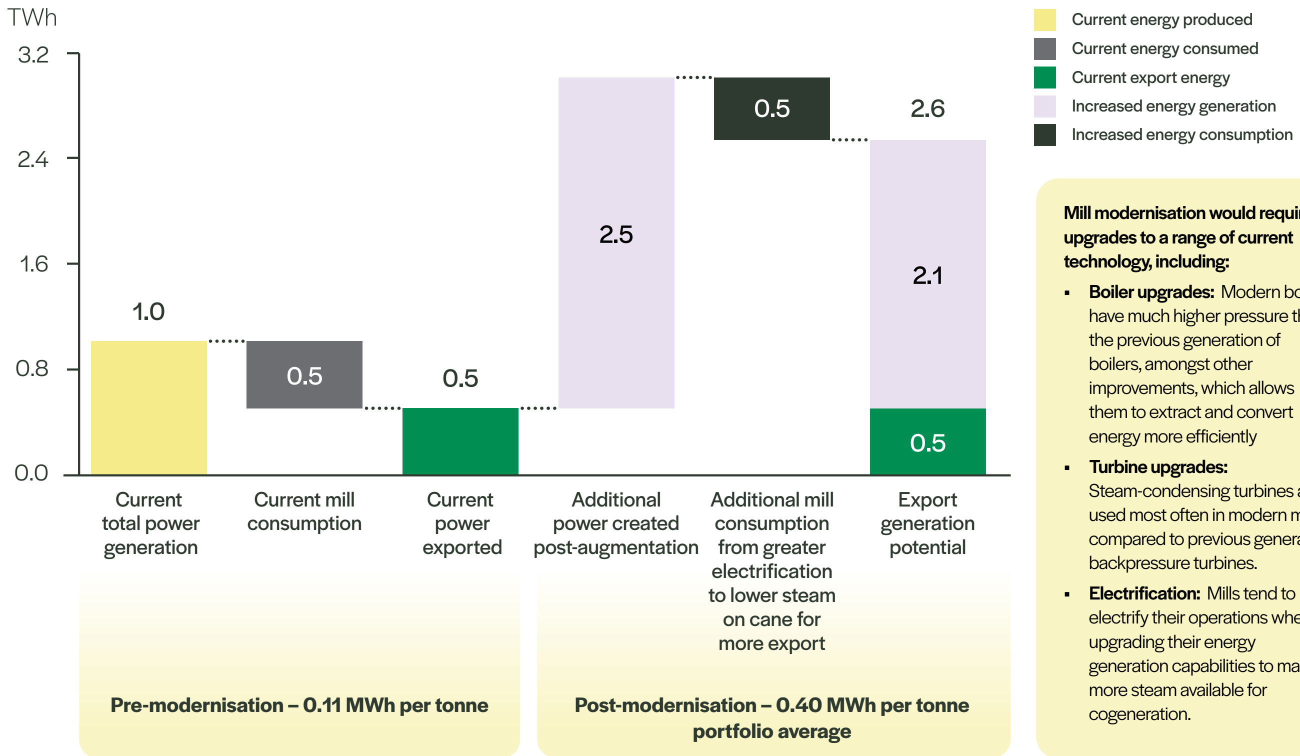
- Densification of bagasse (especially into black pellets) is technically feasible and provides several benefits:
  - Improved energy density, storability, and handling.
  - Reduced ignition risk, better grindability, and combustion efficiency.
- Queensland mills could theoretically produce up to 2.3 million tonnes of pellets annually, depending on investment in mill electrification and efficiency upgrades.
- Densification reduces the volume of bagasse by ~57%, removing 250 daily truck movements from regional roads (for 230,000 tonnes), and reducing transport emissions by ~2,250 tonnes CO_2e annually.
- Densification might be viable for specific mills, particularly those unable to pursue cogeneration expansion.

The Cogeneration Opportunity

Sugar manufacturers in Australia currently have a nameplate capacity of approximately 400 MW, this could be expanded to over 835 MW, providing the National Energy Market (NEM) with up to an additional 2.1-terawatt hours of electricity per annum, while meeting the sector's own energy needs. This is equivalent to powering approximately half a million Queensland homes.

Cogeneration is a potentially cost competitive synchronous dispatchable source of renewable electricity. This could help stabilise the grid, especially during peak demand periods or when intermittent renewable sources like solar and wind are not generating electricity.

Breakdown of the increase in export power generation vs 2024 generation baseline (2024)



Mill modernisation would require upgrades to a range of current technology, including:

- **Boiler upgrades:** Modern boilers have much higher pressure than the previous generation of boilers, amongst other improvements, which allows them to extract and convert energy more efficiently
- **Turbine upgrades:** Steam-condensing turbines are used most often in modern mills, compared to previous generation backpressure turbines.
- **Electrification:** Mills tend to electrify their operations when upgrading their energy generation capabilities to make more steam available for cogeneration.

Source: LEK Consulting Bioenergy Study – Final Report (2025)

Downward pressure on Queensland and east coast electricity prices

Electricity prices have been rising, and are expected to increase in the future, reflecting tightness in the Queensland energy market while renewable generation capacity and storage is being built.

The intermittency and limited predictability of renewable energy sources poses a further challenge, producing intra-day volatility in electricity prices and reliability risks.

Preliminary modelling, undertaken by Endgame Economics and LEK Consulting, suggests that wholesale electricity prices in Queensland may be reduced by 10–20% over the coming decade compared to forecast prices if the augmented capacity of cogeneration was made available to the Queensland energy market. This could represent between $9b - $15b over 2029-2050, while reducing emissions by 1.3m tonnes in 2030. As previously stated, since the study was quantified, there appears to be an emerging divergence between the assumptions in the AEMO 2024 ISP and the evolving energy context in Queensland.

How could cogeneration put downward pressure on electricity prices?

Cogeneration is a renewable source of baseload and predictable electricity that, with investment, could quickly provide 'fill-in' capacity to the market, and can be online in the next 3-5 years.

There are key challenges associated with the energy transition ...	... and cogeneration is well positioned to meet those challenges
Intermittent generation Renewables such as wind and solar can only produce energy at certain times of day (e.g. solar cannot produce at night) and these times may not align with peak energy usage	**Green firming capacity** Cogeneration is dispatchable, meaning its output can be controlled and aligned to peak energy usage
Limited predictability Renewables such as wind and solar are more volatile, because they are affected by natural processes (e.g. cloud cover, wind speed) which can cause variation in energy production	**Predictable** Cogeneration is controllable with respect to its output and timing (subject to milling operational requirements), reducing energy market price volatility
Higher electricity prices Wholesale electricity prices are expected to increase through the energy transition to support new generators to cover the costs of investment, and reflecting constraints on the deployment rate of new generation	**Lower electricity prices** Cogeneration can provide 'fill-in' capacity quickly. Most required infrastructure is available via sugar milling processes, with significant capacity able to be deployed in c.3-5 years
Concentrated energy generation In a system where renewable energy dominates, the energy system is exposed to 'energy droughts' where both wind and solar may become unable to produce sufficient energy for consumers	**Diversified energy generation** Cogeneration is highly dispatchable. It is preferable to storage because it can generate electricity during energy droughts, whereas storage is vulnerable to the droughts due to the need to re-charge
New infrastructure required Renewables require large amounts of additional infrastructure. For example, wind or solar requires large amounts of land, on top of additional transmission required. This makes it vulnerable to eroding social licence considerations	**Leverages existing built infrastructure** Much of the infrastructure and land required for cogeneration already exists, and cogeneration supports sugar milling viability, improving social licence in the communities which would house the projects

Source: LEK Consulting Bioenergy Study – Final Report (2025)

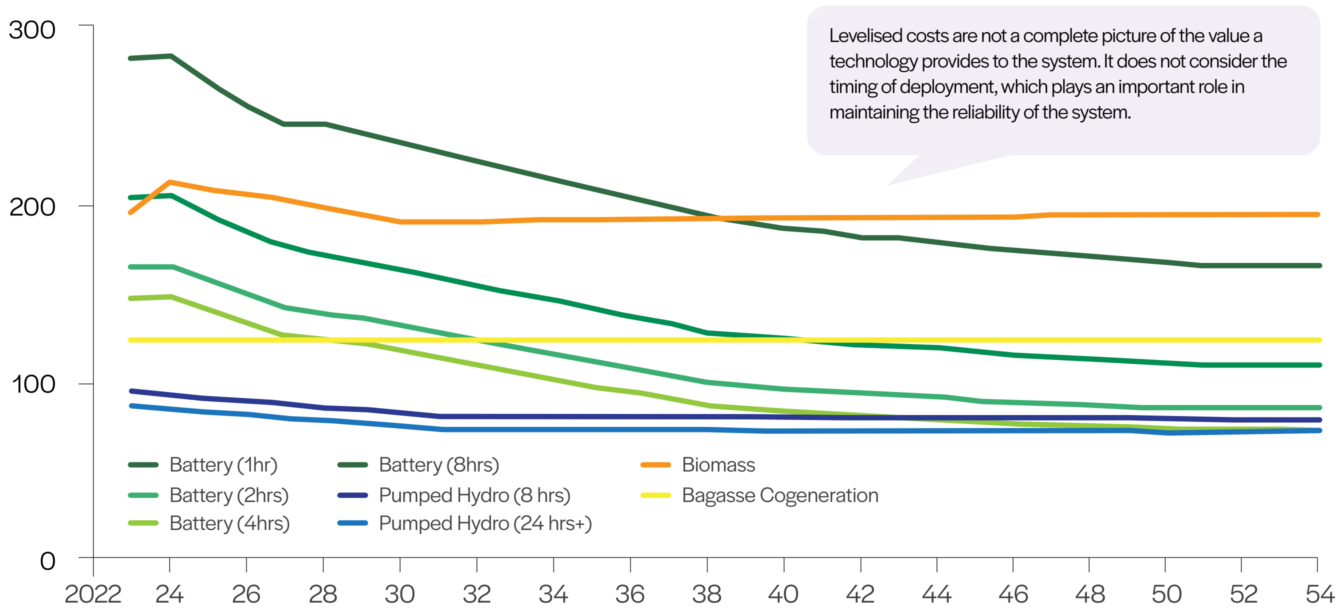
How cost effective is cogeneration?

Cogeneration may offer a regionally appropriate and potentially cost-effective contribution to firming capacity, particularly when compared with other dispatchable energy solutions such as gas peaking plants or certain battery storage configurations.

While indicative modelling suggests that cogeneration can be competitive on a levelised cost basis with these technologies (see graph below), the relative cost-effectiveness will ultimately depend on site-specific technical feasibility, regulatory frameworks, and operational integration. Importantly, cogeneration provides firming capacity that is not dependent on intermittent weather patterns, offering a complementary role alongside storage technologies that may be affected by extended periods of low wind and solar generation.

Levelised cost of energy/storage* (FY2024–FY55)

$AUD/MWh (real 2023 prices)

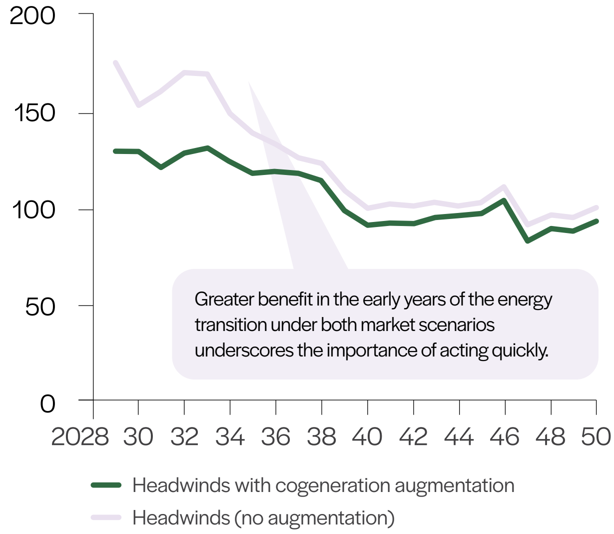


Source: LEK Consulting Bioenergy Study – Final Report (2025)

"Cogeneration is a renewable source of baseload and predictable electricity that could provide 'fill-in' capacity to the market"

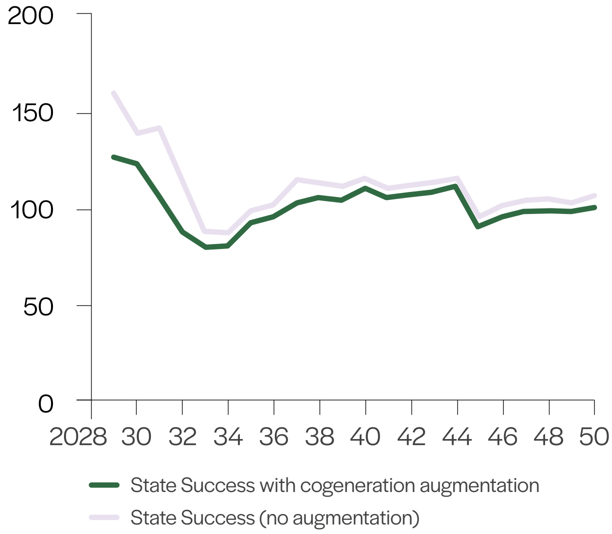
Headwinds – Regional wholesale pricing by augmentation scenario (2029F–2050F)

$AUD/MWh (volume-weighted average)



State Success – Regional wholesale pricing by augmentation scenario (2029F–2050F)

$AUD/MWh (volume-weighted average)



Source: LEK Consulting Bioenergy Study – Final Report (2025)

What is Required to Expand Cogeneration Capacity?

The mills analysed vary in size, efficiency and capacity. Targeted feasibility studies will outline the exact requirements and costs of cogeneration on a factory-by-factory basis.

Key upgrades include:

- **Boiler upgrades:** Modern boilers have much higher pressures than the previous generation of boilers, amongst other improvements, which allows them to extract and convert energy more efficiently.
- **Turbine upgrades:** Steam-condensing turbines are used most often in modern mills, compared to previous generation backpressure turbines.
- **Electrification:** Electrification of factory operations is a significant enabler to make more steam available for cogeneration.

The opportunity is modular, noting that cogeneration can be expanded at multiple sites across the sugar industry in Queensland. Based on discussions with ASM members, there some economies of scale when site capacity is above 20-30MW of capacity. However, the benefits of scale are limited by the amount of bagasse available at each site.

The study provides indicative costs for cogeneration expansion (see LEK report at p24), however, these are not site specific and require full feasibility and site assessments.

Most mills analysed do not have any physical constraints in terms of housing expanded cogeneration facilities, and based on previous experience, planning approvals have not been a barrier to the installation of new cogeneration capacity.

Above and beyond investments in cogeneration, sugar manufacturers will need to invest in sophisticated systems to interact with the NEM and maintain compliance with AEMO's operational standards.

What Are The Risks & Challenges of Expansion?

If sugar manufacturers invest in expanded cogeneration capacity and adopt the practices required to unlock expansion benefits, there will need to be a step-change in the operations and functions of the sugar manufacturing sector.

Such monumental change poses significant risks and challenges to the sector. Brolga Energy's report *Regulatory and Commercial Considerations for Expanded Cogeneration* provides an overview of some of these risks, while LEK Consulting highlight the economic/commercial risks.

Economic/commercial risks

The LEK Consulting report *Bioenergy Study Final Report* provides the main economic risks facing sugar manufacturers in investing in cogeneration expansion. Expanding cogeneration capacity in sugar mills requires significant capital investment, potentially over a billion dollars across the sector. This high upfront cost is a major barrier, especially given the current financial constraints within the sector. Additionally, the potential revenues from cogeneration are less compelling without external incentives or support.

Regulatory risks

A key consideration for the viability of expanded cogeneration investment is the potential to transition from non-market, non-scheduled generators, to become scheduled generators. This involves stricter compliance obligations. Scheduled generators must adhere to real-time reporting, dispatch instructions, and participation in ancillary services markets.

Operational Risks

Operating as a scheduled generator requires sophisticated systems for real-time market participation, accurate forecasting, and compliance with dispatch instructions. This complexity can divert focus from core milling operations and necessitate specialized expertise.

Market Participation Risks

Scheduled generators are exposed to market price volatility and must manage real-time bidding and dispatch. This can lead to significant revenue fluctuations and financial risks during low-price or negative pricing events. Non-scheduled generators, while less exposed to short-term price volatility, face challenges in securing favourable Power Purchase Agreements (PPAs) and optimizing revenue from market price fluctuations.

Connection and Registration Process

Navigating the NEM connection and registration process can be complex and time-consuming. Securing a new connection agreement, negotiating generator performance standards, and completing registration requirements with AEMO and the Network Service Provider (NSP) involve multiple steps and potential delays. The process requires thorough understanding and compliance with regulatory documentation, which can be resource-intensive and costly.

Risks associated with network connections and any potential network constraints can only be identified during full feasibility and in conjunction with the network service provider to assess the interaction between the proposed cogeneration and broader system performance requirements.

Business Risks

The requirement to invest in sophisticated systems and maintain compliance with AEMO's operational standards adds significant capital and operational expenses. Sugar mills could face financial and operational strain if market participation diverts resources from their primary milling operations.

Available Market & Regulatory Incentives

The study conducted by Brolga Energy was required to focus on existing market and regulatory incentives that would enable the expansion of cogeneration capacity.

Commercial opportunities to progress cogeneration expansion

Power Purchase Agreements (PPAs)

Renewable PPAs are viewed as a long-term hedge, offering partially fixed prices over a typical 10-year horizon. PPAs provide a more stable and predictable energy cost structure.

There is a myriad of potential PPA customers, most notably energy retailers, industrial and commercial businesses, regional industries, grower communities and government entities.

Virtual Power Plants

Virtual Power Plants (VPPs) aggregate decentralised energy resources, including cogeneration units to operate as a single entity in the energy market. VPPs optimize electricity generation, storage, and dispatch, providing reliable, flexible, and cost-effective power to the grid. By pooling resources, VPPs enable distributed energy systems to compete effectively in energy markets and offer a range of services such as frequency regulation and demand response.

Third-Party Service Providers (TPSPs)

Sugar manufacturers have the option of outsourcing NEM operations, such as plant bidding and settlement services to TPSP's to minimise NEM participation costs and the additional regulatory risks associated with NEM operations. While this addresses some of the regulatory and operational risks associated with cogeneration expansion, it does not address the fundamental economic/commercial risks associated with investment in expansion.

Market and regulatory incentives

There are a host of regulatory inventive mechanisms that sugar manufacturers could utilize to underpin the expansion of cogeneration:

The **Capacity Investment Scheme (CIS)** is an Australian Government initiative designed to incentivise investment in renewable energy and storage projects to meet jurisdictional reliability needs between 2026 and 2030. The scheme's focus on grid reliability and revenue certainty makes it a potential mechanism for cogeneration projects, though operational complexities and contractual requirements may pose challenges for sugar manufacturers. There is currently no specific CIS tender allocation for Queensland, however eligible Queensland projects can bid for unallocated capacity in CIS NEM wide tenders.

As Australia phases out the Renewable Energy Target (RET) by 2031, the emerging **Guarantee of Origin (GO)** scheme will play a critical role in certifying renewable electricity and low-emission products. This framework offers sugar manufacturers opportunities to leverage renewable electricity generation for brand value, ESG commitments, and market differentiation, though may be of limited value in terms of generating the revenues that the RET provided.

Other mechanisms for consideration, such as the **Australian Carbon Credit Units (ACCUs)** and the **Safeguard Mechanism**, are likely to provide only incremental benefit in terms of building the business case for investment in cogeneration expansion.

The Viability of Bagasse Pelletisation

The opportunity

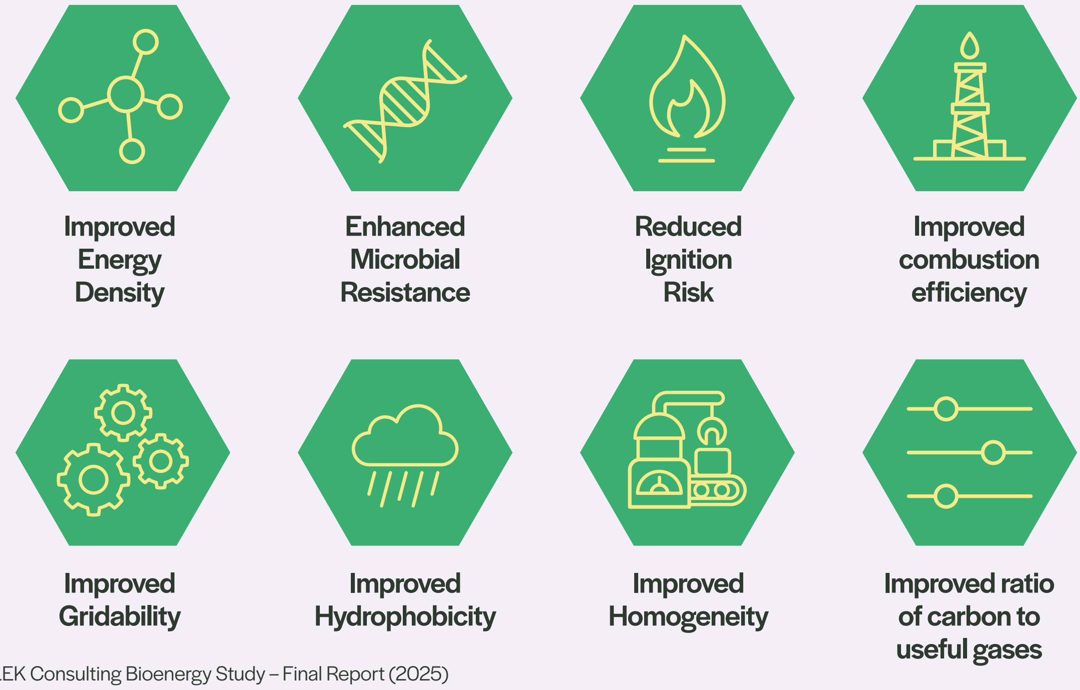
Sugar manufacturers have been exploring opportunities to pelletise bagasse to increase it usability, transportability and tradability.

The LEK study presents three illustrative pathways to assess whether densification would be a commercially viable option for manufacturers:

1. cost minimisation through reduced transport and storage expenses;
2. cogeneration extension - storing energy-dense pellets for electricity generation during high-price periods; and
3. 'make to sell' strategies, whereby pellets are sold on commodity markets.

The densification of bagasse in the sugar manufacturing sector can potentially reduce transport cost, and associated truck movements, and carbon emissions. Densification also presents the opportunity to diversify operations and unlock additional value from a widely available resource in the sugar manufacturing sector. Raw bagasse is a low weight, high volume substance, so the reduction in mass, and increase in energy density, is the key to realising the benefits of pelletised bagasse. This transformation from raw to pelletised bagasse potentially aligns bagasse as a tradable energy source, much like wood pellets in global biomass markets.

Densification of biomass is technically feasible for bagasse. It is likely to improve storability and energy density, amongst other benefits -



Source: LEK Consulting Bioenergy Study – Final Report (2025)

- Densification encompassing torrefaction (heating in a low-oxygen environment) and compaction is most often used with wood chips, but is technically feasible with bagasse as well as other organic products.
- Studies have shown improvements in heating value, energy and mass yield specifically with bagasse because of the torrefaction process.
- The resultant increase in energy density not only enhances transport and handling efficiencies but also makes the product more suitable for energy generation applications or export.
- Several plants have been constructed to produce densified bagasse across major sugar producing regions. These include plants for fuel production in Louisiana, Brazil, and Portugal.

Queensland mills could theoretically, with investment, meet their internal energy needs more efficiently, and make up to 5.3m tonnes of bagasse available for pelletisation for export or domestic usage.

	Current	Post-augmentation
Bagasse created	8.9m tonnes	8.9m tonnes
−		
Bagasse required for internal use	5.5m tonnes	3.6m tonnes
=		
Excess bagasse currently used for electricity export	3.4m tonnes	5.3m tonnes
÷		
t-bagasse / t-pellet	2.3	2.3
=		
t-pellet production	1.5m tonnes	2.3m tonnes

Source: LEK Consulting Bioenergy Study – Final Report (2025)

The conversion ratio is approximately 2.3 tonnes of raw bagasse per tonne of pellet. Mass is lost throughout the torrefaction and compaction process from evaporation of water, loss of volatiles and some reduction in combustible solids. In this process, energy density increases while mass reduces.

Queensland sugar factories could create up to 1.5m-2.3m tonnes of densified bagasse if various investments are made. This is significantly larger than typical plants observed globally which are closer to 400kt.

Benefits and Costs of Pelletisation

To reach the higher 2.3m tonnes of pellet annually, significant investment would be required to electrify the mills, upgrade boilers and turbines and conduct further enabling works, even before investing in pelletisation equipment. If these works were not undertaken, then large amounts of fuel would still be required to power the mills internal operations.

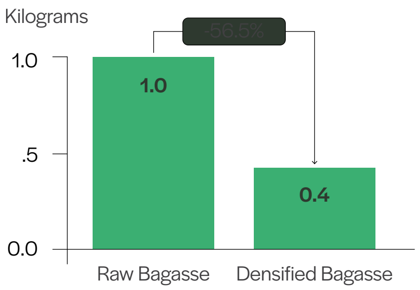
These investments are required due to the interdependence between internal energy use and the amount of bagasse available for pelletisation. Pelletising bagasse is only possible if mills can free up large volumes of bagasse that would otherwise be consumed internally for steam and power generation. As a result, the upgrading and electrification of milling operations is required to ensure there is enough surplus bagasse to pelletise at scale.

While the total energy consumed internally is higher post-augmentation (driven by electrification of different processes), the amount of fuel required for internal use is reduced compared to pre-augmentation because the energy extracted from each unit of fuel increases.

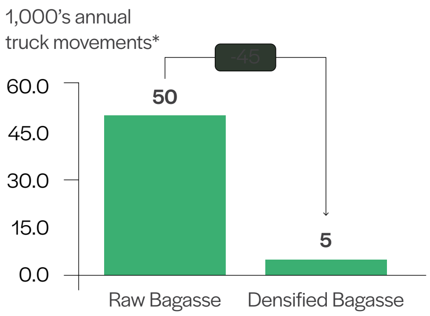
Densification could reduce transport emissions by around 2250 tonnes per annum and approximately 250 daily truck movements on 230,000 tonnes of bagasse.

Densification reduces bagasse's volume → **Which reduces the truck movements required to transport material** → **Reducing truck movements has various efficiency benefits**

Volume of 1kg of raw bagasse, in raw vs densified form (2024)



Truck movements required to transport 230kt of bagasse (2024)



	Required to transport 230kt of material 20km	
	Raw Bagasse	Densified Bagasse
Carbon emissions	c. 2,500 tonnes	c. 255 tonnes
Cost	c. $5.7m	c. $0.5m
Daily truck movements	c. 275	c. 25

Members do not report the current number of truck movements undertaken, but densification would reduce truck movements and associated carbon emissions by c. 57%

If all bagasse produced (c. 8.9m tonnes) was transported 20km, emissions would reduce from c. 22kt to c. 10kt and daily truck movements would be reduced by c. 700

Note: * Calculated with a truck of 46 m^3 capacity and 22 tonne weight limit. Raw bagasse has a density of c. 100 kg / m^3, and densified bagasse has a density of c. 700 kg / m^3, equating to a truck carrying 4.6 tonnes of raw bagasse, or 22 tonnes (its weight limit) of densified bagasse. The reduction in truck movements required is therefore (230kt-bagasse / 4.6) –)100kt-pellet / 22) = c. 45,000

Source: LEK Consulting Bioenergy Study – Final Report (2025)

Despite the emissions reduction and transport cost-savings advantages, the overall economic case for densification remains weaker than that of renewable electricity cogeneration in most scenarios. The cost of producing black pellets is estimated at approximately $190 per tonne, not including the additional capital costs required to free up bagasse for pelletisation.

Pelletisation to minimise costs

This pathway assumes that densification would reduce handling costs and the number of truck movements by significantly decreasing the volume of biomass. Densified bagasse occupies 57% less volume than raw bagasse, which would reduce transport emissions by approximately 2,250 tonnes of CO_2 equivalent annually and cut daily truck movements from around 275 to 25 for a 230,000-tonne volume. While these efficiency gains are notable, the cost of densification remains a challenge, with break-even typically reached only for transport distances beyond 200 kilometres - distances that are less common in the current transport profile.

Extending the availability of cogeneration past the sugar production season

This pathway explores whether mills could use densified bagasse to generate electricity outside the traditional 'crushing' season, thereby capitalising on higher off-peak electricity prices. While this approach could enhance revenue by enabling generation during peak demand periods, the benefits are currently limited.

The densification process reduces energy yield per tonne of bagasse by around 10%, and while energy arbitrage offers some potential, it may not fully offset the associated capital and operating costs under present conditions.

Selling bagasse pellets for other uses

The third and final pathway examines the potential for mills to sell densified bagasse as a commodity fuel on domestic or international markets. For this to be economically viable, mills would need to realise a price of at least $340 per tonne of pellet at the mill gate, accounting for both the cost of production and the opportunity cost of not using the bagasse for cogeneration.

Currently, international biomass markets are thin and highly dependent on government subsidies, which limits their reliability as a revenue source for Australian producers. Furthermore, entering such markets would expose mills to new market risks and contractual obligations.

Conclusions on Pelletisation

Bagasse densification is technically feasible and offers ancillary benefits, but is less economically attractive for most Queensland sugar mills where there are viable cogeneration opportunities.

Densification may be an option, particularly as biomass markets develop. Under such circumstances, pelletisation will likely need favourable commercial conditions. Mills considering this option should undertake detailed site-specific feasibility assessments and market analysis on demand that may provide a way forward on pelletisation.

AUSTRALIAN SUGAR
MANUFACTURERS