Bioenergy study – final report

Australian Sugar Manufacturers

February 2025

DRAFT – FOR DISCUSSION

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Introduction and project context

- In 2021, low sugar prices prompted the Queensland sugar milling industry to conduct a study to explore alternative revenue sources for sugar mills and the industry more broadly. The study identified electricity cogeneration as a viable pathway to generate additional income, but requiring external investment support
- Since then, Queensland's wholesale energy prices have been rising and becoming more volatile, suggesting improved viability of additional cogeneration
- Cogeneration by sugar mills offers a means to address challenges posed by Queensland's energy transition while also potentially providing sugar mills with a sustainable revenue stream
- Queensland sugar mills are not currently set up to maximise their cogeneration capacity. Augmenting or upgrading mills to maximise cogeneration is possible, but requires large capital investments and introduces a set of operational and regulatory challenges that mill operators must overcome
- Australian Sugar Manufacturers (‘ASM’) secured co-funding through the Queensland Energy and Jobs Plan Bioenergy Fund to undertake a bioenergy study considering two topics areas – specifically:
    1. Cogeneration competitiveness: the role and benefits of expanded cogeneration as a reliable renewable energy source in Queensland
    2. Mechanisms to support investment: evaluating how existing frameworks can drive investment in cogeneration expansion
    3. Management of regulatory and other risks: identifying key risks and mitigation strategies to enable further cogeneration investment
    4. Densification of feedstock: the technical and economic feasibility of bagasse pelletisation for transport and storage
- Importantly, this study has not focused on estimating the investment required to increase cogeneration capacity at mills as the market environment – prior to this study – has not been as well understood to meaningfully assess the viability of potential cogeneration investments
- The study was conducted collaboratively by ASM and L.E.K. Consulting, with energy market modelling provided by Endgame Analytics to achieve the study objectives

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Expanding cogeneration has income potential and energy market benefits but requires investment and may justify external support. Densification and expansion are not attractive in combination

Executive summary

Expanding cogeneration merits further study given its income potential for mills and benefits to Queensland's energy market

- Queensland wholesale electricity prices have increased c.11% p.a. since 2014 and have also become more volatile, driven by the intermittency of renewable generation sources (e.g. solar, wind etc.)
- Constraints associated with the energy transition are expected to increase prices further, before somewhat moderating longer-term as renewable generation capacity and storage becomes available to replace existing thermal generation
- Queensland's sugar mills are not currently set up to maximise cogeneration capacity, but with augmentation or upgrades, can deliver up to an additional 2.1 TWh p.a.
- Modelling suggests the increased energy supply from expanding cogeneration, combined with the ability to dispatch generation to meet peaks in demand, will reduce Queensland's wholesale energy prices
- Expanding cogeneration also reduces Queensland's emissions by c.1.5% in 2035, and has benefits for system reliability
- High capital costs for augmentation and network upgrades mean possible mill revenues from cogeneration are less compelling; however, individual mills should conduct detailed technical feasibility and cost studies to improve confidence in the business case for cogeneration expansion
- Mills likely require incentives to undertake augmentation, particularly given the range of operational, regulatory and market challenges associated with increased cogeneration

Expanding cogen carries commercial, operational and regulatory risk that mill operators must overcome

- Before pursuing augmentation to expand cogeneration, mills must address several operational and regulatory challenges. A separate report on managing regulatory and other risks, and mechanisms to support investment, was commissioned in parallel to this report and details the next steps for each challenge.

Densification is an option mills may pursue if cogeneration is not feasible, but is unlikely to be economical for most mills

- Bagasse densification is not a viable pathway to improve mill profitability for most mills; the benefit densification offers in reducing transport and storage cost is outweighed by the cost of the densification process
- *Redacted for public release*
- Where expanding cogeneration is not viable, pelletising bagasse for sale may offer an alternative revenue stream under some specific conditions. This opportunity would need to be assessed on a site-specific basis before proceeding

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Cogeneration can earn significant revenues for sugar mills and reduce Queensland electricity prices and emissions, but work is needed to refine the business case and address regulatory and market risks

Cogeneration competitiveness summary

Power prices are expected to increase and become more volatile

- Electricity prices have been rising by c.11% p.a. since 2014, and are expected to increase in the future (reaching c.$160-$170/MWh around 2030-32 (real 2023 prices)), reflecting tightness in the Queensland energy market while renewable generation capacity (e.g., wind, solar etc.) and storage (i.e., batteries) is built
- The intermittency and limited predictability of renewable energy sources (i.e., wind and solar) poses a further challenge, producing intra-day volatility in electricity prices and reliability risks

Bagasse cogeneration can reduce power prices in Queensland

- Cogeneration is a green, firm power source with some existing generation infrastructure spread across Queensland sugar mills
- The existing generation infrastructure in sugar mills is not set up to maximise generation, however this infrastructure can be augmented to export up to an additional 2.1 TWh of energy each year
- Modelling suggests that wholesale electricity prices may reduce by up to 20% in the late 2020's and early 2030's if the augmented capacity of cogeneration was made available to the Queensland energy market. This would save Queensland electricity consumers c.$9B-$15B over 2029-2050, while reducing emissions by c.1.3m tonnes in 2030

Cogeneration can create significant revenue, but comes with operational challenges that should be considered in the business case

- Augmenting mills and network infrastructure to maximise cogeneration capacity requires significant capital investment (assumed to be c.$150m for a c.30MW mill for the purposes of this report). Modelling suggests that the revenues earned by mills from expanding cogeneration warrant detailed technical feasibility studies to accurately estimate costs and enhance confidence in the business case
- In addition to capital investment, mill operators must address key operational and regulatory challenges associated with expanded cogeneration. These include, but are not limited to:
  - Mills will need to change their resourcing and operations to maintain cogeneration year-round, instead of their current operating window the sugar crushing season. c.50% of cogeneration revenues could be earnt outside the sugar 'crush'
  - Maintenance schedules will need to be compressed to allow mills to access the peak summer prices
  - Mills may need to operate more intensively overnight, requiring changes to labour deployment and other resources
  - Mill operators will need to develop new capabilities, such as energy market trading and energy risk management capabilities

Cogeneration is well positioned to solve key challenges posed by Queensland's energy transition

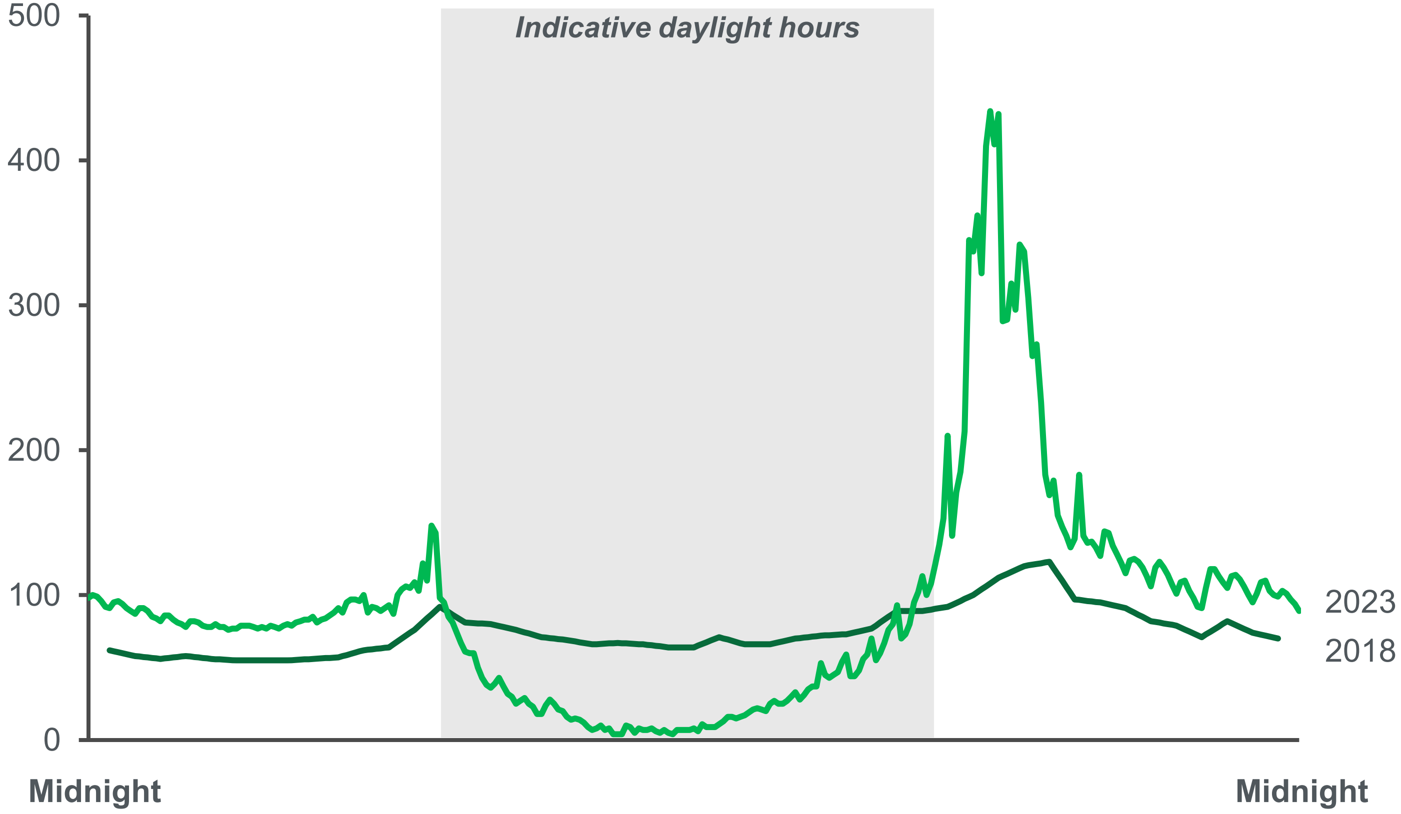
There are key challenges associated with the energy transition…	…and cogeneration is well positioned to meet those challenges
Intermittent generation Renewables such as wind and solar can only produce energy at certain times of day (e.g. solar cannot produce at night) and these times may not align with 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: L.E.K. research and analysis

Over the last five years, the distribution of energy prices throughout the day has changed; average midday prices have dropped close to zero, while morning and evening peaks have risen dramatically

Intermittent generation

Average Queensland wholesale electricity price by time of day* (2018, 2023)
$ / MWh



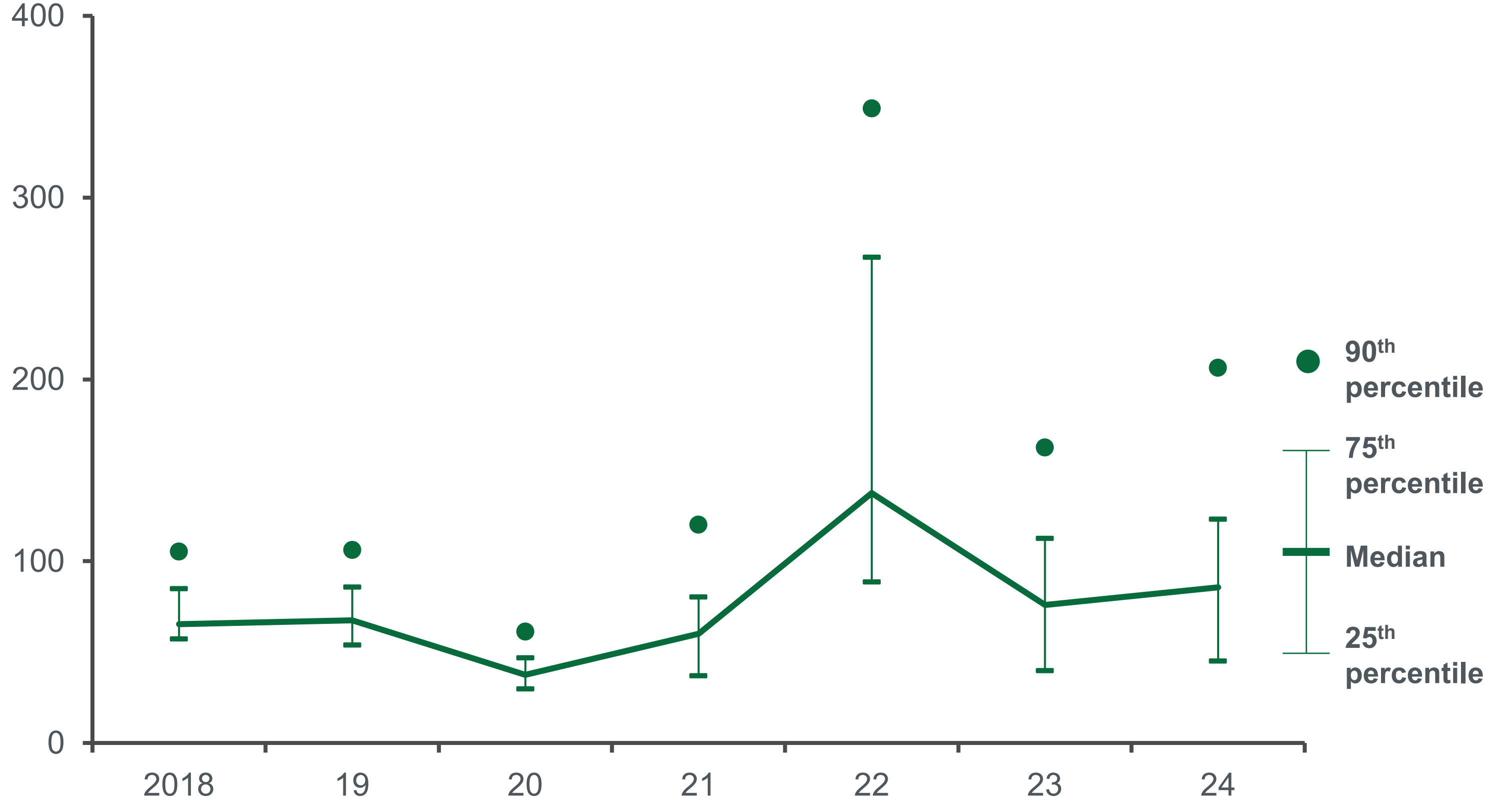
- Over time, the electricity market has become more volatile. Low prices during the middle of the day driven by substantial generation in the middle of the day are accompanied by high prices at peak times when renewables are unable to meet demand
- Inexpensive solar energy becomes available during the the middle of the day. **Solar energy is abundant, and has a marginal cost to produce close to zero, pulling prices down towards zero** in the middle of the day and pushing other generation sources (e.g. coal, gas, etc.) out of the market
- However, **in the evening, household electricity use increases**, while solar generation reduces as the sun begins to set. The resulting '**tightness' in the electricity market** drives electricity prices upwards, incentivizing generators to come online

Note: * Between 2018 and 2023 electricity market pricing switched from 30-minute increments to 5-minute increments, which may exacerbate the volatility shown
Source: AEMO Aggregated Price and Demand Data - Historical; L.E.K. research and analysis

Average electricity prices and intra-year price volatility have been increasing in Queensland, driven by the intermittency of renewable generation

Limited predictability

Regional reference price, Queensland (2018-2024)
$AUD/MWh



- Over time, the price of electricity has **risen and become more variable**, driven by the changing nature of the energy system
- Increasing variability in the electricity price is driven by increases in energy created from intermittent renewable power, which mean that the **price mechanism is constantly adjusting to incentivise different generation sources** to come online
- The dynamics of renewables mean that the electricity **they produce is generally inexpensive** (i.e. there are no ongoing input costs), but given their intermittency, a grid which relies on them **may face shortfalls** at certain times
- As the grid decarbonizes, **storage and flexible generation (such as gas, or biomass) become increasingly important**, as they provide the firm power underpinning renewables and reduce the peak energy prices driving the average higher

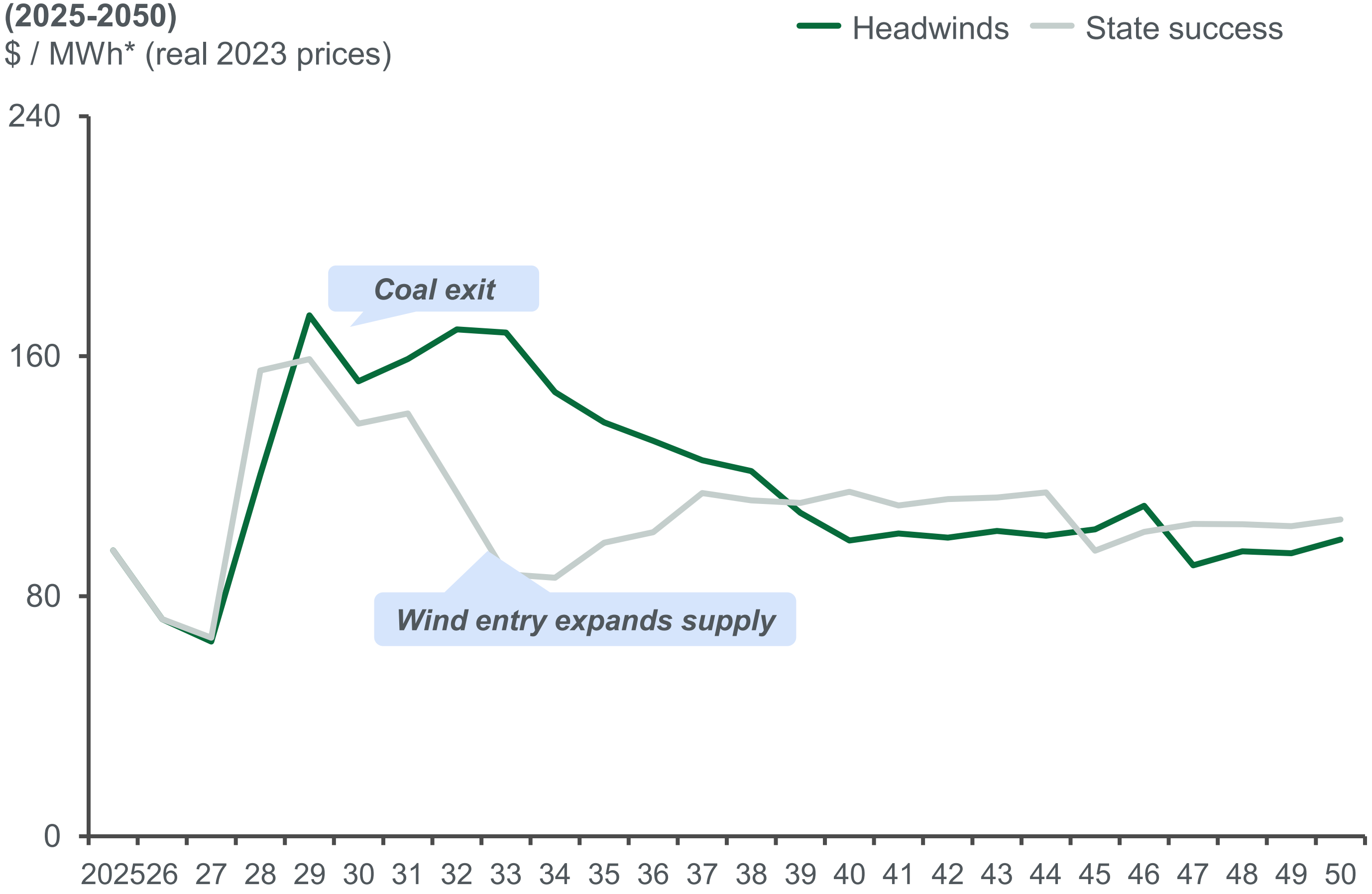
Note: * Between 2018 and 2023 electricity market pricing switched from 30-minute increments to 5-minute increments, which may exacerbate the volatility shown
Source: AEMO Aggregated Price and Demand Data - Historical; L.E.K. research and analysis

System modelling shows prices are expected to increase further, driven by constraints associated with the energy transition, before moderating longer-term as more renewable capacity enters the market

Higher electricity prices

Queensland wholesale electricity price forecast, by scenario – no cogen investment (2025-2050)

$ / MWh* (real 2023 prices)



Note: * Volume-weighted RRP prices in Endgame 'Headwinds' and "State Success" central scenario.
Source: Endgame Analytics; L.E.K. research and analysis

- Energy prices have been forecast to 2050 using specialist energy market modelling that accounts for system constraints, most notably constraints on the rate of wind development
- Two scenarios have been modelled, referred to as the 'Headwinds' and 'State Success' scenarios. The Headwinds scenario is the 'best guess' of what will happen in the energy system, and the State Success scenario simulates the outcome if all States meet their renewable energy targets
- The initial rise in prices in c.2028 is **driven by the exit of coal from the system**. These coal exits are modelled based on commercial viability for generators and to solve for capacity in the energy market. Given the reduction in baseload power, and insufficient replacement capacity, prices increase in the short-term which incentivises other forms of generation to come online
- Although wind is being built, the rapid exit of coal in c.2028 **outweighs the addition of wind capacity**, resulting in increasing prices. However, **over time wind build is assumed to catch up**, and drive prices down by c.2040 (this happens earliest in State Success, and explains the early reduction in prices there)
- Post-2030, **as storage via batteries and pumped hydro enters the system, prices are expected to moderate further**. Storage is able to take advantage of the low-cost power in the middle of the day, and deploy it during the evening high-price evening peak

The addition of expanded cogeneration capacity to the Queensland electricity market was modelled to determine the impact on prices under two future market scenarios

Modelling approach

Define future market scenarios	**Use two scenarios to determine future of electricity prices in Queensland** • Two future market scenarios have been considered: ***'Headwinds'*** is a central scenario that provides a 'best guess' of the future, and ***'State Success'*** models the future energy market assuming all States achieve their renewable energy targets • Modelling estimates future market prices by analysing the economic operation of different technologies and providers, and assuming they will operate unless it's uneconomic to do so. This is a widely accepted modelling approach, similar to AEMO's ISP modelling workflow. This approach allows the lowest price required to incentivise generation to be determined
Define augmentation contribution	**Understand the additional generation augmentation will create** • The augmented generation capacity of sugar mills is calculated by applying the efficiency and utilization of the Queensland portfolio's best-in-class mill to the characteristics of un-augmented mills. This calculation also considers the increase in electricity required to operate the mill following its augmentation to make more steam available for cogeneration • As a byproduct of processing sugar cane, the amount of bagasse available to mills is held constant, and it is assumed that mills must process all of their bagasse on a yearly basis. A consequence of this is that mills with constraints such as storage capacity or grid transmission constraints are modelled with lower efficiencies to dispose of all bagasse
Model impact of increased cogeneration	**Model additional generation's impact on the market** • Given the characteristics of cogeneration (determined above), the augmented cogeneration capacity is added into the Headwinds and State Success scenarios to determine how cogeneration capacity would be dispatched • Cogen is dispatched in preference to more expensive generation methods: While there is significant upfront investment required, there is little marginal cost associated with cogeneration at any given time (similar to technologies like pumped hydro) • Cogen's ability to ramp up and down quickly compared to other renewable sources means its generation is focused on the peak electricity prices – instances where the electricity system most needs additional supply

Source: Endgame Analytics; L.E.K. research and analysis

Cogeneration could deliver significantly greater amounts of electricity to the grid if Queensland sugar mills are upgraded and augmented

Queensland cogeneration characteristics – pre and post augmentation

Parameter	Units	Pre-augmentation	Post-augmentation
Nameplate capacity	MW	433	835
Total annual energy availability (*both for export and mill consumption)*	MWh	1,000,000	3,550,000
Total annual fuel availability	Tonnes	8,900,000	8,900,000
Efficiency	MWh generated per tonne of bagasse	0.11	0.40
Total energy available to be stored	MWh	50,000	1,300,000
Total fuel available to be stored	Tonnes	450,000	3,300,000

- An additional c.400 MW of capacity could be created if the portfolio of Queensland sugar mills analyzed are augmented to increase cogeneration
- The mills analysed vary in size, efficiency and capacity. The analysis assumes all 19 mills can be upgraded to match the efficiency of the best-in-class mill in the portfolio (0.65 MWh generated per tonne of bagasse)
- Constraints prevent eight mills from reaching the best-in-class efficiency of 0.65 MWh/t-bagasse. These mills are considered constrained either by fuel storage, grid connection capacity or both. For these mills, the efficiency is reduced to 0.22 MWh/t-bagasse, to account for these constraints
- There are five mills for which constraints cannot be determined, so they are assumed unconstrained*

Note: Marginal cost to produce is modelled at zero, ramp rates assume 0-100% in 30 minutes, and $10k start-up cost & 150 tonnes of start-up fuel, 6-hour cold start rate; * For these mills with unidentified constraints the average efficiency is limited to 0.53 MWh/t-bagasse rather than 0.65 MWh/t-bagasse to account for any constraints which have not been accounted for

Source: ASM member data; L.E.K. research and analysis

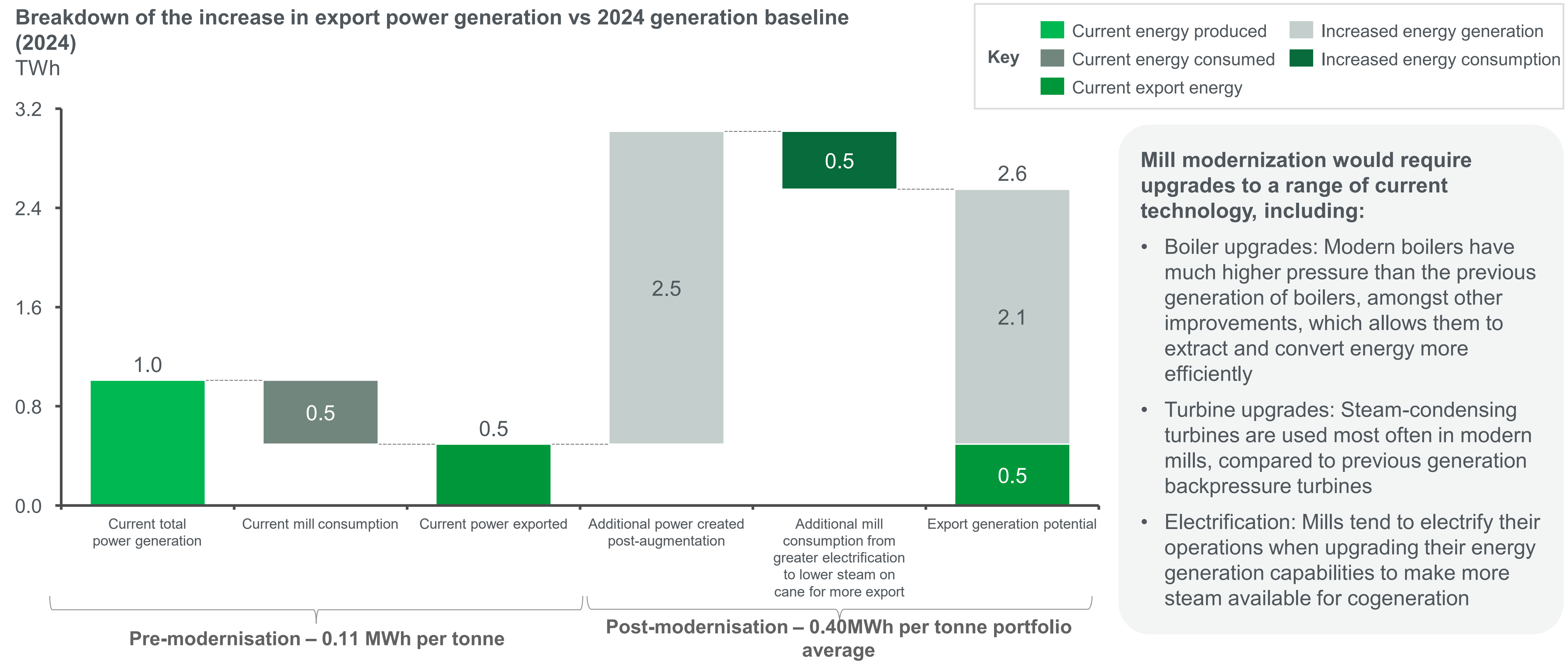
The generation capacity of mills in the cogeneration portfolio is limited by constraints that are likely costly to resolve. These constraints are incorporated into the model using mill ‘archetypes’

Operating archetype	Defining site operational characteristics	Transmission constraint	Storage constraint
Unconstrained	• Mill can export its maximum generation capacity with no grid constraint, and can store sufficient bagasse to generate over the non-crush season	x	x
Grid constraint	• A current, known and sized grid constraint exists, which prevents the mill from exporting its full generation potential; the reason for the constraint and cost to resolve it may or may not be known	✓	x
Seasonal	• No ability to store bagasse during the off-season, meaning all generation and feedstock must be used during the ‘crush’ season	x	✓
Double constraint	• Mills are subject to both a grid constraint and a storage constraint (although storage is only limited, rather than the zero-storage assumption in the seasonal archetype)	✓	✓

Source: ASM member data; L.E.K. research and analysis

Mill augmentation could produce an additional c.2.1 TWh of energy per year

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



Mill modernization 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: ASM member data; L.E.K. research and analysis

Cost estimates suggest cogeneration could be competitive with other forms of dispatchable generation

Redacted for public release

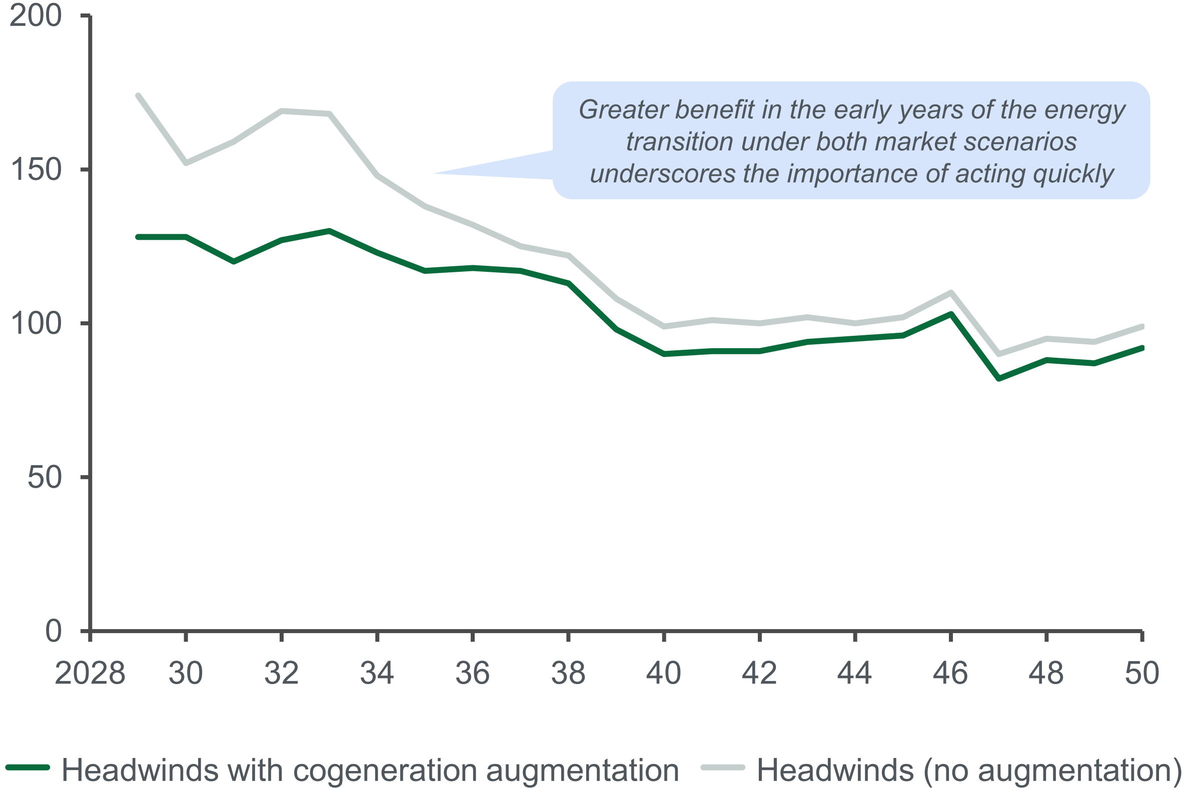
- Although some technologies have higher costs, **each has a different role to play in the grid**. For example, while pumped hydro may be cost effective compared to some battery storage, its capacity may be limited by the number of suitable sites and by other social / environmental concerns. **For bagasse cogeneration, a key benefit in addition to firming capability is that it is not susceptible to 'energy droughts' (extended periods with low wind and solar output) that could concurrently impact storage technologies**
- **The levelised cost of energy is not the sole determinant of whether it should be used**. Other factors such as ability to provide firm power, contribution to decarbonisation, stability and inertia could play a role. On the chart to the left, **bagasse and biomass are energy generators, so cannot be compared directly to energy storage technologies** – the energy storage technologies could leverage the energy that bagasse cogeneration produces
- Cogeneration has **not had detailed cost estimates produced**, however, if capex were c.$150m with 5% of that as opex each year, the levelised cost is lower than other biomass technologies. The low cost is because **there are no direct fuel costs** (bagasse is a byproduct of sugar production and thus only has opportunity cost), and **operational costs are shared with the sugar production processes**

Source: Endgame Analytics; L.E.K. research and analysis

Because of its dispatchability, adding cogeneration to the Queensland energy market would reduce wholesale power prices significantly by generating during high demand periods

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

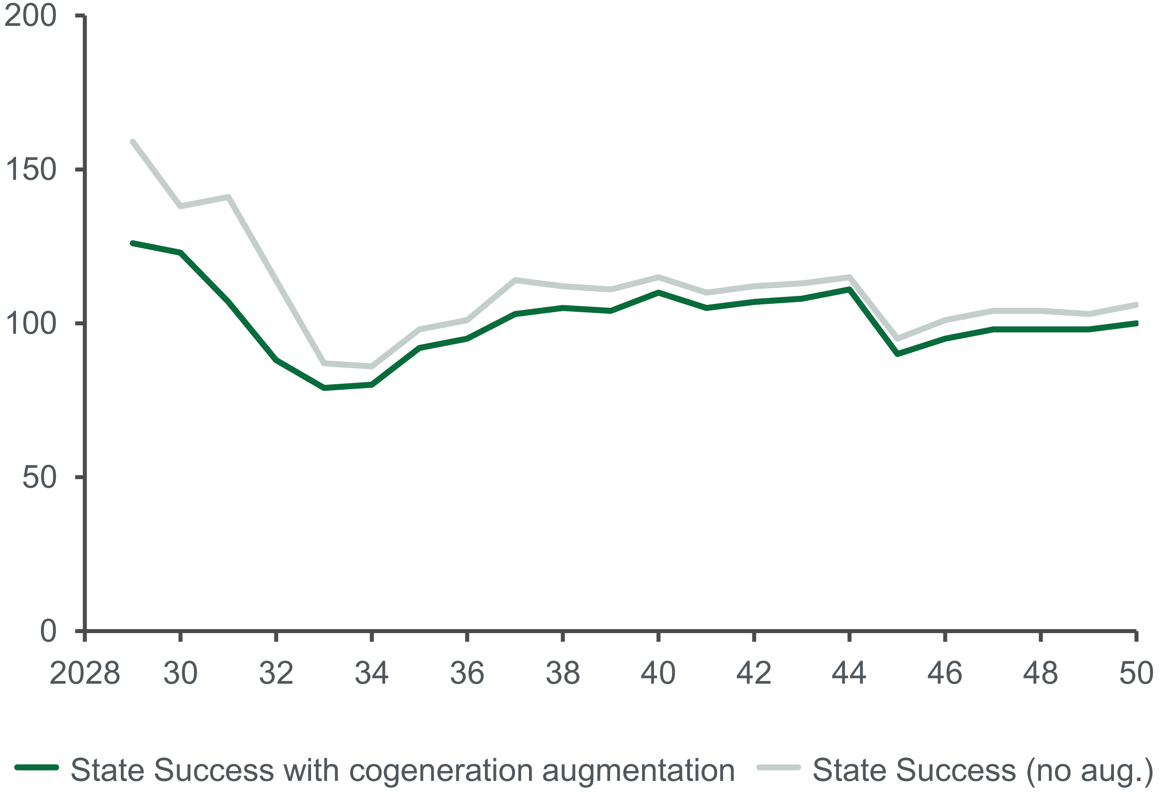
$AUD/MWh (volume-weighted average) (real 2023 prices)



Greater benefit in the early years of the energy transition under both market scenarios underscores the importance of acting quickly

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

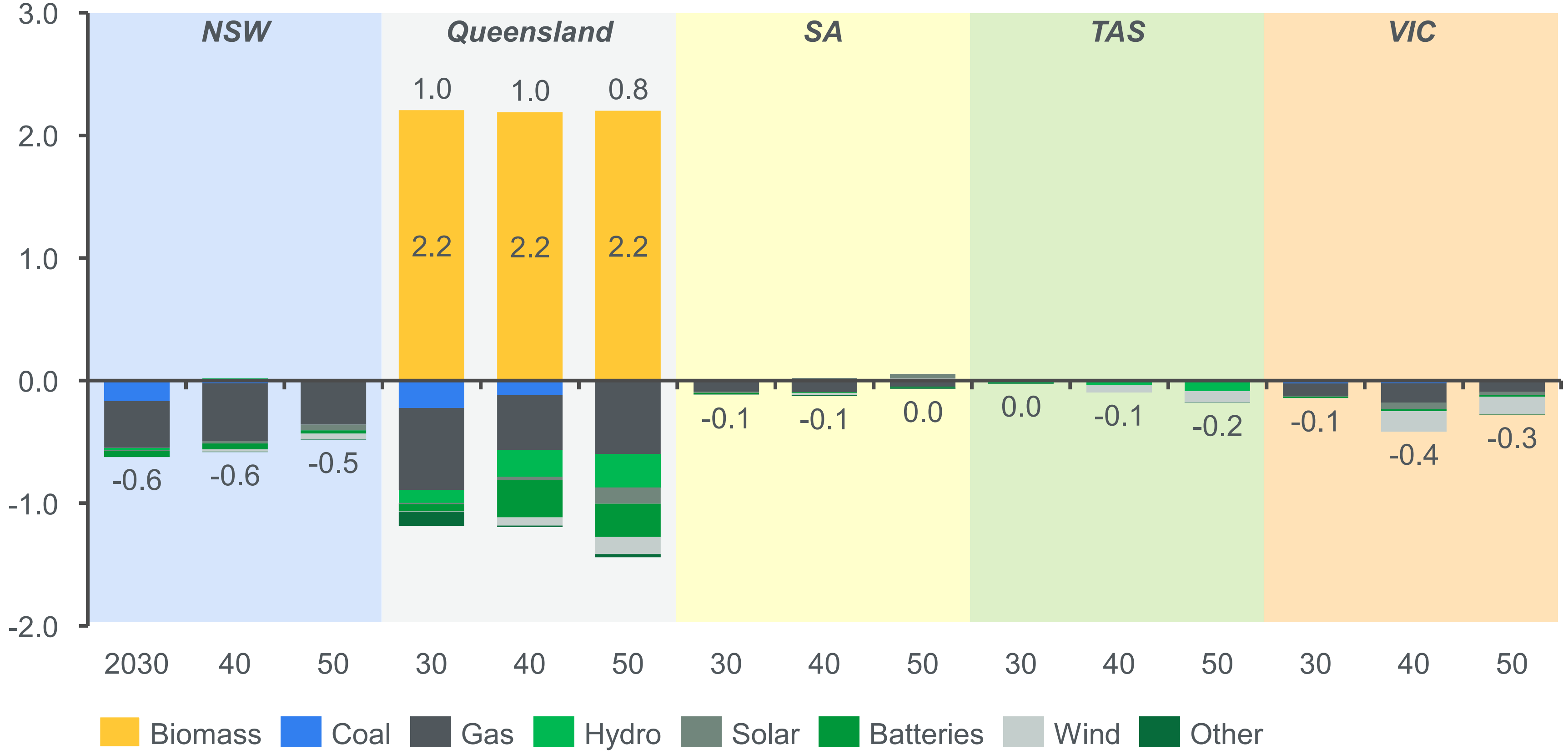
$AUD/MWh (volume-weighted average) (real 2023 prices)



Source: Endgame Analytics; L.E.K. research and analysis

When considering the constraints of different generation sources, augmented cogeneration is dispatched in preference to other forms of generation, in particular gas

Difference in NEM generation dispatched by source, post-augmentation (2030, 2040, 2050)
TWh



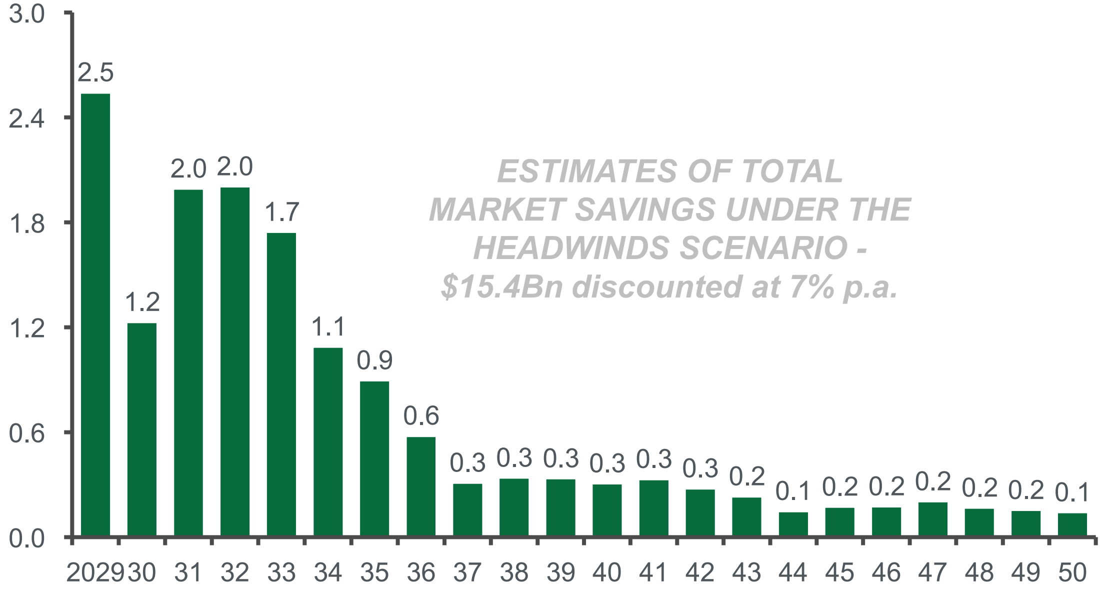
- The energy market provides energy at the least cost at each 5-minute increment in time. This accounts for availability and constraints of generators, and cost to produce
- Cogen's advantages in timing and cost over other forms of generation mean it displaces other generation when it can provide providing lower-cost energy
- Cogeneration mainly displaces gas generation, resulting in a reduction in emissions of 1.3m tonnes in 2030 across Australia (c.1% of Queensland's 2030 emissions target), when compared a scenario without upgraded and augmented cogeneration

Source: Endgame Analytics; L.E.K. research and analysis

Modelling suggests that mill augmentation delivers a significant impact on wholesale prices and can save Queensland energy consumers between $9.3B and $15.4B over the modelled time horizon

Headwinds - Annual savings from augmentation for Queensland electricity users (2029F-2050F)

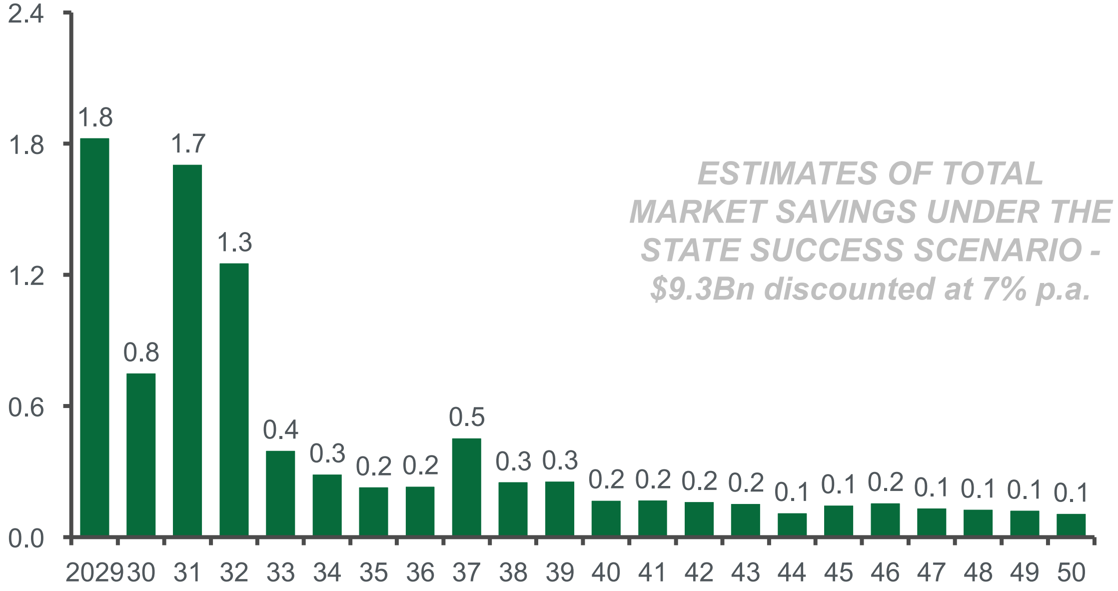
Billions of AUD, real 2023 prices (discounted at 7% p.a.)



ESTIMATES OF TOTAL MARKET SAVINGS UNDER THE HEADWINDS SCENARIO - $15.4Bn discounted at 7% p.a.

State Success - Annual savings from augmentation for Queensland electricity users (2029F-2050F)

Billions of AUD, real 2023 prices (discounted at 7% p.a.)



ESTIMATES OF TOTAL MARKET SAVINGS UNDER THE STATE SUCCESS SCENARIO - $9.3Bn discounted at 7% p.a.

Estimates of savings for Queensland electricity users are calculated as the difference between volume weighted prices with and without augmented cogeneration capacity, multiplied by the total volume in the market each year, discounted at 7% per annum. This number represents the total savings for purchasers of wholesale electricity, over the period 2029-2050

Source: Endgame Analytics; L.E.K. research and analysis

Each MWh of energy exported by the mills provides up to c.$1,000 of benefit across wholesale electricity prices in Queensland

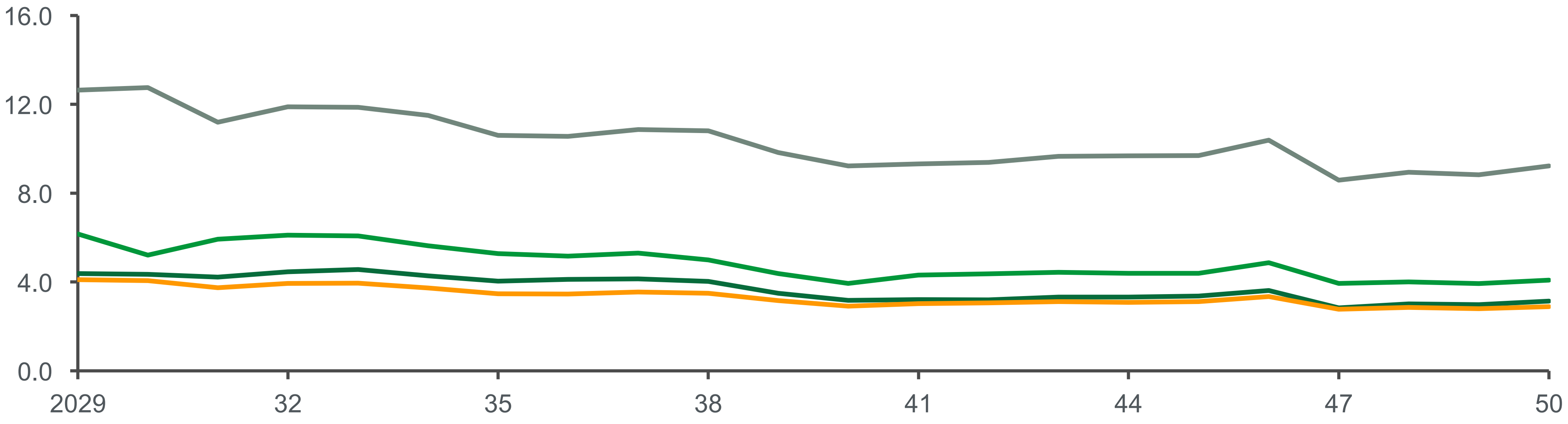
	5-year average	10-year average	15-year average
Price reduction due to augmentation *(Volume-weighted average)*	$38 / MWh	$27 / MWh	$21 / MWh
X			
QLD consumption p.a. *(Volume-weighted average)*	58,000,000 MWh	62,000,000 MWh	66,000,000 MWh
=			
Value provided by mills to consumers p.a.	$2.2B	$1.6B	$1.3B
÷			
Additional MWh produced	2,100,000 MWh		
=			
Value provided by mills to consumers	$1,036 / MWh	$778 / MWh	$648 / MWh

- Sugar mills can significantly influence electricity prices by leveraging their dispatchable generation to supply power during peak price events at a lower cost than other sources
- Mill dispatchability means that augmentation can provide significant value to Queensland's consumers. This is reflected in an average c.$38/MWh reduction in electricity prices post-augmentation over the five-year average (peak prices would likely reduce by much more than that)
- As a whole, this reduction in prices means that consumers are paying $2.2B less for their electricity in the five- year average
- Mills generate an additional 2.1 TWh of electricity in order to provide the $2.2B consumer benefit, indicating that each MWh produced by the mills provides $1,036 of benefit to consumers (on the five-year average)

Note: Undiscounted values presented
Source: ASM member data; L.E.K. research and analysis, Endgame

Augmentation enables mills to maximise generation during periods of high prices. Unconstrained mills earn c.2-3x the revenue of constrained mills, underscoring the importance of eliminating constraints

Headwinds - Annual revenue by archetype (FY29F-50F)
Millions of AUD (real 2023)



	Revenue per MWh exported							
Current grid constraint	115	117	106	106	84	74	83	115
Double	165	158	139	140	122	111	116	165
Seasonal	157	156	134	127	110	100	104	157
Unconstrained	178	167	149	152	131	121	130	178

Source: Endgame; L.E.K. research and analysis

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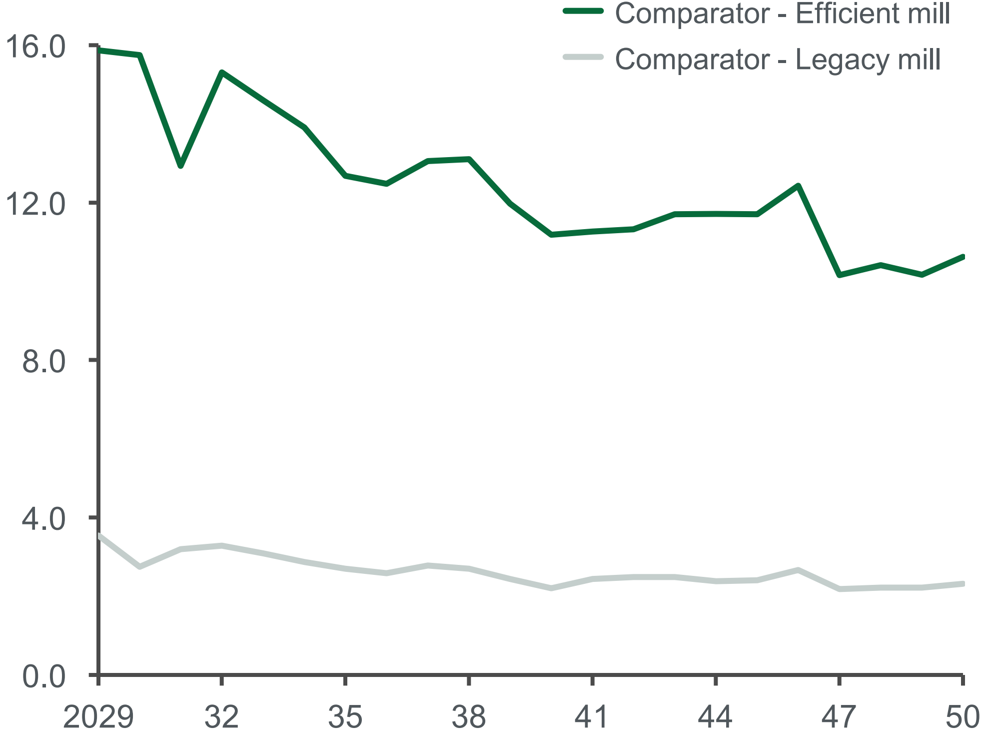
Augmenting cogeneration has the potential to deliver revenues that may justify the required capex, particularly if external support is available to mitigate market and development risks

Indicative

Annual revenue by archetype (FY29F-50F)
Millions of AUD (real 2023)



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Note: * IRR calculated as difference between revenue earned by efficient mill and legacy mill over 22 years modelled, capex spent in year one, no operating costs accounted for (IRR is the discount rate which makes the NPV of these values zero). Generation capacity of legacy mill: 9MW, generation capacity of efficient mill: 31MW; ** Capex range sources include ASM member feedback

Source: ASM member interviews; Endgame; L.E.K. research and analysis

In addition to capital cost, mill augmentation and optimisation for cogeneration would require some non-trivial changes to mill operating practices

1	**Operation outside of traditional season**	Post-augmentation revenues (and consumer benefit) are generally earnt outside of the sugar crushing season, which will require changes to the operating calendars and resourcing of mills
2	**Compressed maintenance windows**	In order to be available for the highest demand days (and support the energy system most effectively), mills need to be available to generate for as much of the year as possible. Current maintenance periods of c.3 months will need to be compressed to c.1 month
3	**More intensive overnight operations**	Post-augmentation revenues (and consumer benefit) are often earnt overnight, as cogeneration can provide generation into the evening demand peaks. While many mills will operate overnight, the increase in operational activity at these times may require changes to scheduling, labour deployment and other operating arrangements
4	**Energy risk management capability**	Mills will need to develop capabilities to engage with the electricity market, as required by the regulator. For example, facilities may become scheduled generators, requiring real-time reporting, communication services, and integration with AEMO etc
5	**Energy trading capability**	Mills will need to develop energy trading capabilities, to ensure they are responding to price signals by matching generation to the highest price periods, and meeting compliance obligations of large energy market participants

Source: ASM member interviews; Endgame; L.E.K. research and analysis

Mills must extend their operations outside the crushing season and compress their critical maintenance windows, as a large portion of electricity revenue is earned outside the crushing season

Redacted for public release

2 Compressed maintenance window

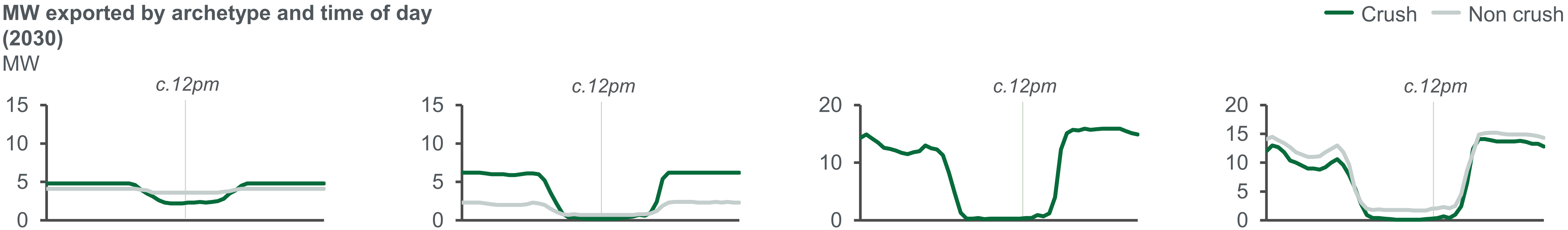
- Significant revenue could be earnt outside of the traditional sugar crushing season, a time in which the mills would usually be shut down for c.3 months to do major sustaining maintenance
- To earn the revenues modelled in the non-crush season, maintenance windows would be reduced from c.3 months to c.1 month
- Price ‘spikes’ during the non-crush season mean that mills need to be available for as much of the season as possible, so they can step in during periods of tightness in the energy market. Much of the revenue is earnt during over a few days in which the energy market is particularly tight

3

Revenues are earned primarily overnight, which may require workforce and other operational changes

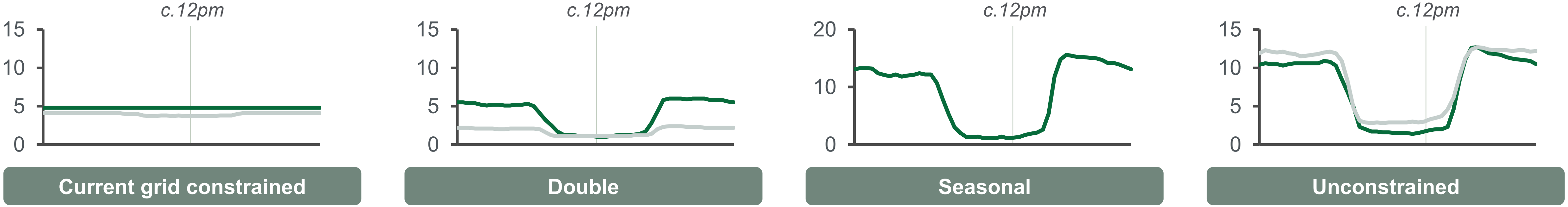
MW exported by archetype and time of day (2030)

MW



MW exported by archetype and time of day (2040)

MW



Revenue capture is dependent on reducing electricity export during the middle of the day, and conserving energy availability for high price periods

Source: Endgame; L.E.K. research and analysis

Cogeneration would also require improvements in trading and energy risk management capabilities

4 Energy risk management capability

- Mills may become scheduled generators if they meet key requirements including the capacity threshold (currently 30MW) after they are augmented and upgraded. Scheduled generators are obligated to adjust their output in response to AEMO dispatch instructions
- Becoming scheduled also would require mills to improve the infrastructure and capabilities necessary to interface with the market. For example, scheduled generators are more responsive to price signals and contribute to price stability, have more stringent reporting requirements, and are required to have real-time integration as well as contingency communications with AEMO and the NSP, amongst other requirements

5 Energy trading capability

- Currently, mills have limited ability to respond to energy price signals, often because of interdependencies between operational and energy export requirements, and an operational focus on sugar production over energy generation
- Augmentation revenues would require an improvement in energy trading capability. This is possible, with at least one mill having automated production responsiveness to price signals. However this is a significant investment, and there is complexity around market and operational dynamics

Source: Brolga Energy, Bio-Energy Commercial and Regulatory Considerations report; L.E.K. research and analysis

Contents

A separate report prepared by Brolga Energy is advising the ASM on mechanisms to support investment and management of regulatory and other risks

Summary of key findings – please refer to the separate report from Brolga Energy for additional detail

1 **A range of regulatory mechanisms currently operate in the power sector, but none offer clear support for cogeneration**

- A range of regulatory mechanisms were considered, including the Capacity Investment Scheme (CIS) Guarantee of Origin, Large-scale Generation Certificates (LGCs), Australian Carbon Credit Units (ACCU) and the Safeguard Mechanism
- Of these, the Capacity Investment Scheme offers long-term revenue support for low carbon technologies, including dispatchable capacity. However, it is unclear if cogeneration would meet eligibility and timing requirements

2 **Mills may be classified as Scheduled Generators by AEMO, so operators would need to consider operational requirements in planning**

- Electricity generators may be classified as Scheduled Operators if they meet the requirements for capacity (e.g. >30MW) and dispatchability. If classified as Scheduled, generators are subject to several obligations, including integration with AEMO systems and other requirements
- If ASM members become classified as scheduled, they have options to operate and minimise their risk – as detailed in the final section and in Brolga Energy's Bio-Energy Commercial and Regulatory Considerations report

3 **There are various commercial models mills might consider to help address operational and market risks**

- Different operational models have distinct implications, with some being most appropriate for those seeking to hedge price changes, and others to reduce administrative burden. Four models that might be considered are:
  - Power Purchase Agreement (PPA's)
  - Virtual power plant
  - Outsource to a third-party service provider

4 **A range of government support options may be pursued by the ASM to address the risk, given the public benefit of cogeneration**

- Given the public benefit associated with cogeneration augmentation, including emissions reduction and improvements in network reliability, ASM should seek government support to help de-risk investments in cogeneration augmentation
- Forms of external support could range from regulatory and policy support, to upfront capital contributions

Source: Brolga Energy, Bio-Energy Commercial and Regulatory Considerations report

1

A range of regulatory mechanisms exist to underpin investment. Features of the Capacity Investment Scheme are most prospective for ASM members, but it is not clear that cogeneration would qualify

Summary of key findings – please refer to the separate report from Brolga Energy for additional detail

Regulatory mechanisms	Explanation	Applicability to ASM
Capacity Investment Scheme	• The Capacity Investment Scheme supports the deployment of low-carbon energy generation by providing revenue guarantees • Most projects are expected to begin operating between 2026 and 2028	**High** **(Design principles only)**
Guarantee of Origin	• Internationally-aligned assurance scheme to track and verify emissions • Certifies renewable electricity generation and emissions intensity of products • Initial focus on hydrogen, then green metals, low-carbon fuels, and others	**Low**
LGCs	• Supplies renewable energy certificates to renewables projects, which can be sold to improve profitability and help achieve renewable energy targets • Certificates will not be issued after 2030	**Low**
ACCUs	• Tradable units representing tons of emissions stored or avoided • Created through approved methods such as reforestation, soil carbon sequestration, energy efficiency, and industrial emissions reduction	**Low**
Safeguard mechanism	• Designed to cap emissions from Australia’s largest emitting facilities in line with Australia’s emissions targets • ASM members’ facilities are not covered by the Safeguard Mechanism	**Low**

Source: Brolga Energy, Bio-Energy Commercial and Regulatory Considerations report

2

A key regulatory barrier to increasing electricity production and exports to the wholesale market is it may require facilities to register as scheduled generators

Summary of key findings – please refer to the separate report from Brolga Energy for additional detail

Risk of mills becoming scheduled generators

- Mills risk becoming scheduled generators, given augmentation will mean they exceed capacity thresholds under energy rules and play a greater role in the energy market
- Typically, generators are classified as scheduled if they are greater than 30MW of capacity, and can control their output in response to dispatch instructions from AEMO
- For mills, becoming scheduled will entail new obligations, though may also provide opportunity for participation in additional market services (e.g. possible PPA's, long term hedge contracts)
- The risk is heightened by proposed operational rule changes to lower the non-scheduled generation threshold and increase compliance obligations

Obligations for Scheduled generators

- Higher performance standards for response to system changes
- Forecasting of output capacity
- Energy Management System (EMS) / Supervisory Control and Data Acquisition System (SCADA)
- Market Systems Interface (MSI)
- Automatic Generation Control (AGC)
- Telemetry and status monitoring
- Outage and availability reporting systems
- Voice communication (hotline or dedicated phones)
- Cybersecurity protocols and compliance

Source: Brolga Energy, Bio-Energy Commercial and Regulatory Considerations report

3

There are various commercial models for ASM members, each with distinct implications

Summary of key findings – please refer to the separate report from Brolga Energy for additional detail

Commercial model	Explanation	Implications for ASM members
PPA	• Significant growth from corporates, who often use it as a long-term hedge against energy prices, while also providing emissions reduction credentials	• Would need to source either individual or collective purchasers and negotiate an agreement • Provides secure long-term pricing, potentially underpinning investment cases
Virtual power plant	• Join a virtual power plant to integrate with other energy sources, but would mean cogeneration timing and output is subject virtual control	• Integration of other sources would be required to enable year-round contributions • Would require complex systems to ensure no unwanted interactions with sugar milling
Third party service provider	• Collectively sub-contract market bidding and settlement operations to a third-party provider, which allows most requirements to be outsourced	• Generally service providers require a fee, but may reduce administrative requirements such as IT system interfaces • Would still require compatibility with NEM requirements at the mill level

Source: Brolga Energy, Bio-Energy Commercial and Regulatory Considerations report

④

There are several avenues for support that could assist ASM members to mitigate the risks posed by cogeneration augmentation

Summary of key findings – please refer to the separate report from Brolga Energy for additional detail

Regulation and policy

Avenue for support	Features of support	Examples of types of support
Regulatory support	Includes planning or regulatory changes to energy or other markets to support project development, delivery, or operations	Exemptions or derogations from scheduled generator thresholds, or planning or zoning support to facilitate more storage. For example, leverage NEM policy review to align with cogen expansion
Operational support	Support to establish or operationalise key generation capabilities, such as trading operations	A partnership for an external party to manage energy market trading operations
Revenue support	Ongoing revenue support to mitigate energy market risk, either through risk-sharing or minimum revenue guarantees	‘Cap and floor’ supports such as the CIS, or a guarantee for minimum revenue levels subject to meeting operational conditions
Upfront capital support	Direct grants to mills to contribute to the capital costs of generation upgrades	Direct grants at a project-level or support to build a generation portfolio

Direct contributions

Source: Brolga Energy, Bio-Energy Commercial and Regulatory Considerations report, L.E.K. research and analysis

5

Summary of implications for ASM members – approach and options for ASM members under an expanded cogeneration strategy

Decision criteria

Sugar Mill Rationale

- Economics => PPA prices, Gov't support,
- Regulatory => Risk profile of business changes
- Operational => implementation effort / cost

Government / Market

- Dispatchable and renewable energy from sugar industry directly contributes to addressing several of the NEM's market and system challenges.
- Supports energy policy, regional development, jobs, Queensland pricing by removing price spikes,

No Expansion

Rationale:

- For one or more reasons, economics, regulatory or operational, sugar mills decide not to proceed with expanding cogeneration capacity.

Implications for ASM and sugar industry

- Risk of tightening classification thresholds, market requirements => may end up as scheduled generator or with similar obligations,
- Already undertaking plant upgrades require GPS modelling, connection agreements => bearing high cost for little benefit to sugar industry,
- Continue short term strategy to maintain exemption status as required,
- Cost continue to increase but no market upside,
- Develop long term strategy for sugar industry (mills) to mitigate against tightening regulatory settings whilst maximizing revenues from plant facilities.

CoGen Expansion

Rationale:

- Sufficient revenue options and risk mitigation strategies to support investment case across one or all criteria.

Implications for ASM and sugar industry

- Potentially significant long-term benefits to sugar industry (mills), market and Queensland => positive for reputation and industry's future,

However, implementation strategy matters:

- Potentially complex implementation process with many moving parts (PPA's, government agreement, regulatory support, EPC in place, approvals),
- Potential for unforeseen time / costs with NSP and AEMO process,
- Will sugar mills make cogen investment without exemptions in place in the NEM?
- What needs to be in place for sugar mills to make the decision to move ahead? => informs strategy and approach to government.

Source: Brolga Energy, Bio-Energy Commercial and Regulatory Considerations report

Contents

Densification is technically feasible but high capital and operational costs, combined with limited benefits, make it economically unattractive for mills with the option to expand cogeneration

Densification summary

Densification of bagasse is technically feasible and has benefits

- Densification of biomass has a range of benefits, including improved energy density, and it is technically feasible for use with bagasse. There are several plants already in operation
- Queensland mills could create up to c.1.5m-2.3m tonnes of densified bagasse if various investments are made. This is significantly larger than typical plants that are observed globally which are closer to 400kt
- If Queensland mills were to densify bagasse, it would reduce transport cost, truck movements, and carbon costs associated with transport. The reduction is driven by an increase in the weight density of densified bagasse compared to raw bagasse

Densification's high capital and operational costs mean it is unlikely to be economical for most mills. However, it could be considered on a site-by-site basis as a next best alternative to cogeneration

- Densification may not be economically attractive for most mills. While densification has some benefits, these are more than outweighed by associated increases in costs
  - Using densification to minimise transport or storage costs at a mill does not breakeven, even in the best-case scenario. Transport costs only offset the densification cost for transport distances over c.200km but at this distance the total additional cost is so high that most use cases are uneconomic
  - Using densification to more effectively utilise a given storage area, and shift electricity generation towards higher priced periods does not breakeven. Higher electricity prices received do not offset the densification cost and loss of energy from densification
  - ***Redacted for public release***
- Other producers have established economically viable operations only with significant government support, favourable operational conditions, and where mills have low opportunity costs from densification

Densification of biomass, traditionally done to produce wood pellets, is technically feasible for bagasse. It is likely to improve storability and energy density, amongst other benefits

Studies suggest a range of material benefits from densification…

- Improved energy density
- Enhanced microbial resistance
- Reduced ignition risk
- Improved combustion efficiency
- Improved grindability
- Improved hydrophobicity
- Improved homogeneity
- Improved ratio of carbon to useful gases

… and densification is technically feasible with bagasse

- 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 as a result of the torrefaction process
- 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

Source: Biomass magazine; BioEnergy Insight; L.E.K. research and analysis

Densification can take several forms. In this analysis we focus on a process including torrefaction and compaction to produce black pellets (the lowest-cost form), over other forms of densification

Raw bagasse

Compaction *(Compression of biomass under high pressure to form dense, uniform pellets)*

Torrefaction *(Thermal treatment to create a dry, brittle material)*

	Black pellets *(Dry torrefaction)*	**White pellets** *(Wet torrefaction)*	**Steam exploded pellets**
Extent of use in cogeneration	Less commonly used in cogeneration	Relatively commonly used in cogeneration (where biomass is used)	Limited use in bagasse cogeneration
Suitability for bagasse densification	Well suited to bagasse as a dry biomass	Poorly suited to bagasse, as wet torrefaction requires more energy when processing a dry biomass	Technically feasible for use with bagasse, however limited practical usage
Ease of transport and storage	High ease of transport and storage, and low moisture absorption	Moderate ease of transport and storage, susceptible to moisture absorption	Moderate ease of transport and storage, improves mechanical strength and stability
Estimated cost to produce	***Redacted for public release***		

Source: L.E.K. research and analysis

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

	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

- Across all Queensland mills considered, **c.1.5-2.3m tonnes of pellet could be produced annually, if all output was combined**
- At either output level, this would be **a large production region**. Facilities worldwide tend to be c.50,000 tonnes to 350,000 tonnes of pellet annually
- 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
- 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**

Source: L.E.K. research and analysis

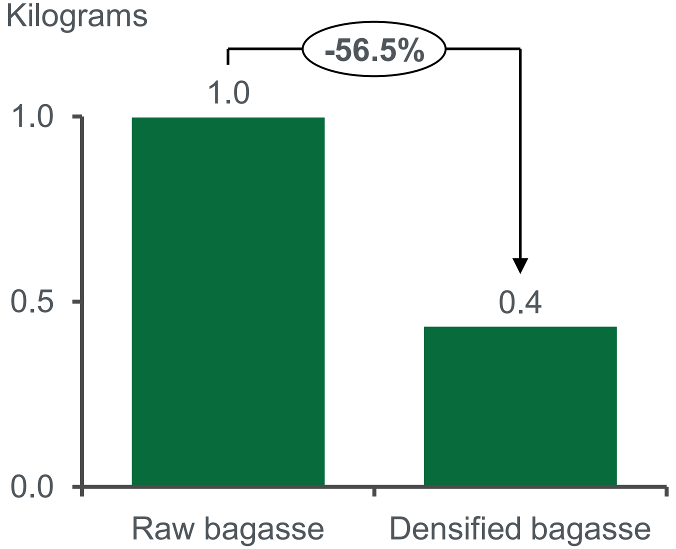
Densification could reduce transport emissions by c.2,250 tonnes per annum and c.250 daily truck movements on 230,000 tonnes of bagasse (which produces 100,000 tonnes of pellets)

Densification reduces bagasse's volume

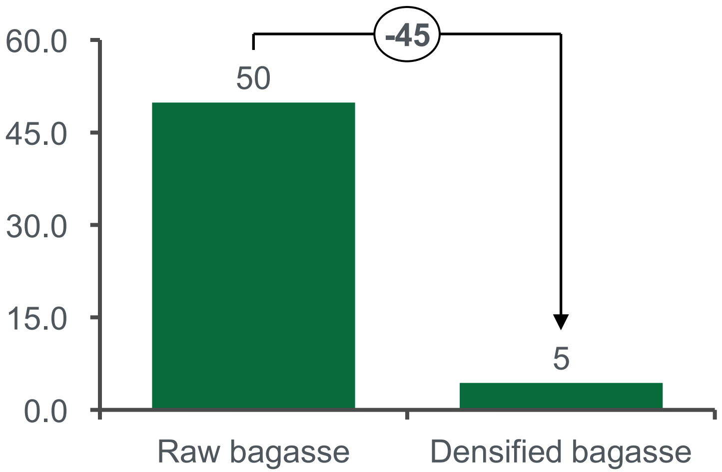
Which reduces the truck movements required to transport material

Reducing truck movements has various efficiency benefits

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



Truck movements required to transport 230kt of bagasse (2024)
1,000's annual truck movements*



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

	Required to transport 230kt of material 20km	
	Raw bagasse	**Densified bagasse**
Carbon emissions	c.2,500 tonnes	c.225 tonnes
Cost	c.$5.7m	c.$0.5m
Daily truck movement	c.275	c.25

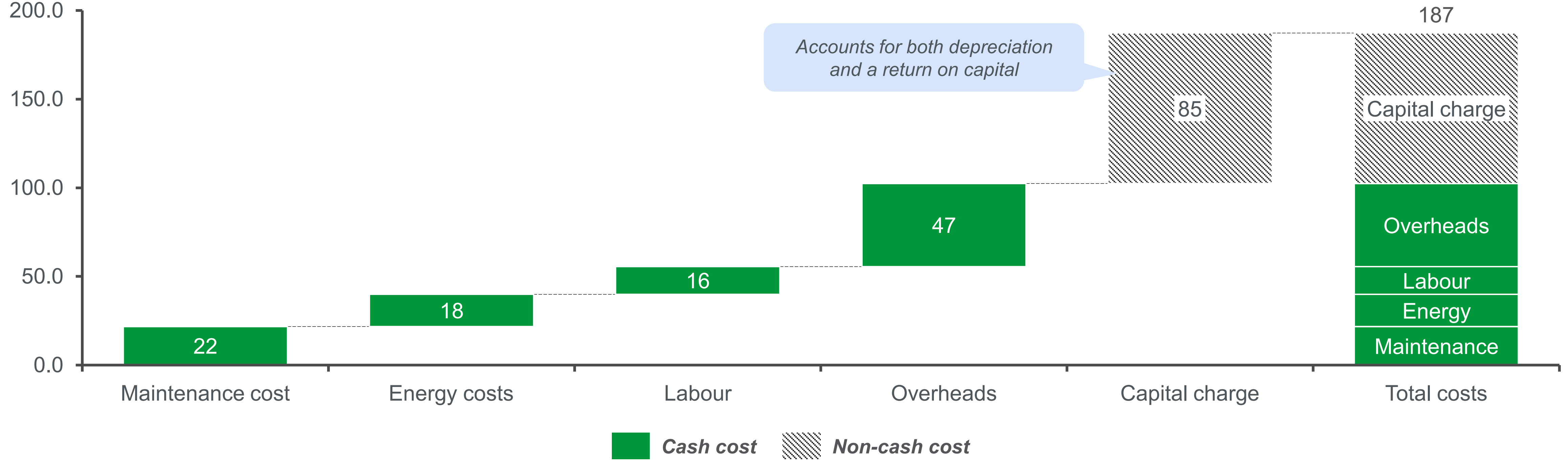
If all bagasse produced (c.8.9m tonnes) was transported 20km, emissions would reduce from c.22kt to c.10kt and daily truck movements would be reduced by c.700

Note: * Calculated with a truck of 46 m3 capacity and 22 tonne weight limit. Raw bagasse has a density of c.100 kg / m3, and densified bagasse has a density of c.700 kg / m3, 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: Australian emissions factors; Member data; L.E.K. research and analysis

Densification is costly. Black pellets, the lowest cost form of densification studied, add c.$190/t-pellet of cost, on top of investments required to liberate significant amounts of bagasse

Economic cost of densification of 230kt raw bagasse annually* (2024)
$AUD / t-pellet



Accounts for both depreciation and a return on capital

This analysis does not include costs associated with significant upgrades and augmentation works that would be needed to increase the availability of bagasse, which is currently used to power mills

Note: * Capital charge calculated on a 10% cost of capital, with c.$70m capital investment
Source: L.E.K. research and analysis

Three pathways have been analysed to assess whether the potential returns from densification justify the investment required. In each pathway we have presented the 'best-case' scenario

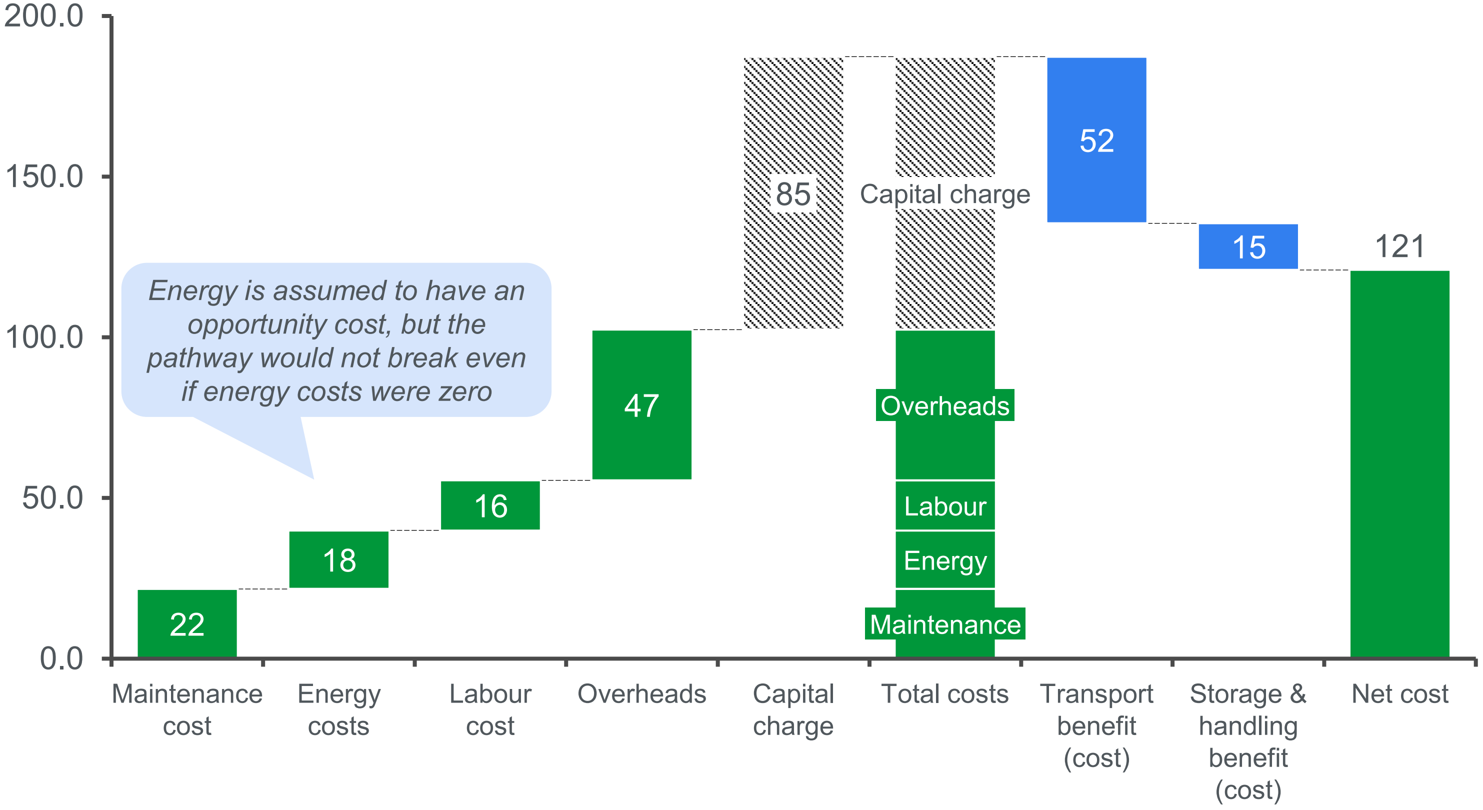
	① Cost minimisation	② Cogeneration extension	③ Making to sell
Description	**Uses densification to minimise the transport and handling costs of bagasse** • Assumes storage and transport costs are reduced in line with pellet to raw bagasse ratios (and associated constraints)	**Fixed storage capacity allows mills to store increased amounts of energy, allowing more generation during periods of high energy prices during the off-season** • There is no transport benefit, and energy is assumed to carry an opportunity cost	**Sell torrefied and pelletised bagasse on the commodity market, agnostic of its end use** • Assumes pellets are sold and priced at the 'mill gate', and energy is assumed to carry an opportunity cost
Operational changes	• Boiler modification necessary to accept densified fuel (minor modification included) • No ongoing operational changes, except reduced transport and storage requirements	• Increased generation outside the crush season, which allows the mill to earn more revenue	• Supply agreements expose mills to commodity markets and may require them to produce pellets even when it is uneconomical
Costs and benefits	• Reduced transport and handling costs due to increased weight density of pellets over raw bagasse	• Improved energy export price, given pellets are produced during the crush period, but used during the non-crush period (at relatively high energy prices) • Energy yield loss during pelletisation and torrefaction reduces energy availability from bagasse by c.10%	• Mills forego exporting excess energy; this is captured as an opportunity cost in this pathway
Key question being tested	***Does the reduction in transport and handling cost justify densification investment?***	***Does the potential to capture higher energy prices via increased energy storage justify densification investment?***	***Does sale of bagasse pellets on the commodity market justify densification investment?***

Note: * Although energy yield per tonne of raw bagasse is reduced by c.10%, energy density per tonne of black pellet remains greater than per tonne of raw bagasse, which is the key benefit of densification
Source: L.E.K. research and analysis

1

The cost minimisation pathway does not break even, given the transport and handling benefits are small compared to the total cost to densify bagasse

Economic cost of densification of 230kt raw bagasse annually* (2024)
$AUD / t-pellet



Energy is assumed to have an opportunity cost, but the pathway would not break even if energy costs were zero

The 'Cost Minimisation' pathway tests the feasibility of densification by considering the savings that densification could provide

- Mills that are already incurring some transport cost or have large storage costs will benefit most from pursuing this pathway. E.g. some mill groups may transfer bagasse between mills to 'feed' a large cogen-oriented mill
- The key cost levers applicable to the 'Cost Minimisation' pathway are:
  - **Transport cost:** reduced to account for the increased weight density of pellets, assuming a 20km transport distance (typical movement of bagasse occurring today)
  - **Storage & handling:** reduced to account for the reduced volume of densified material, and improved material handling rate (on an energy basis)

🟦 *Cash benefit*
🟩 *Cash cost*
▨ *Non-cash cost*

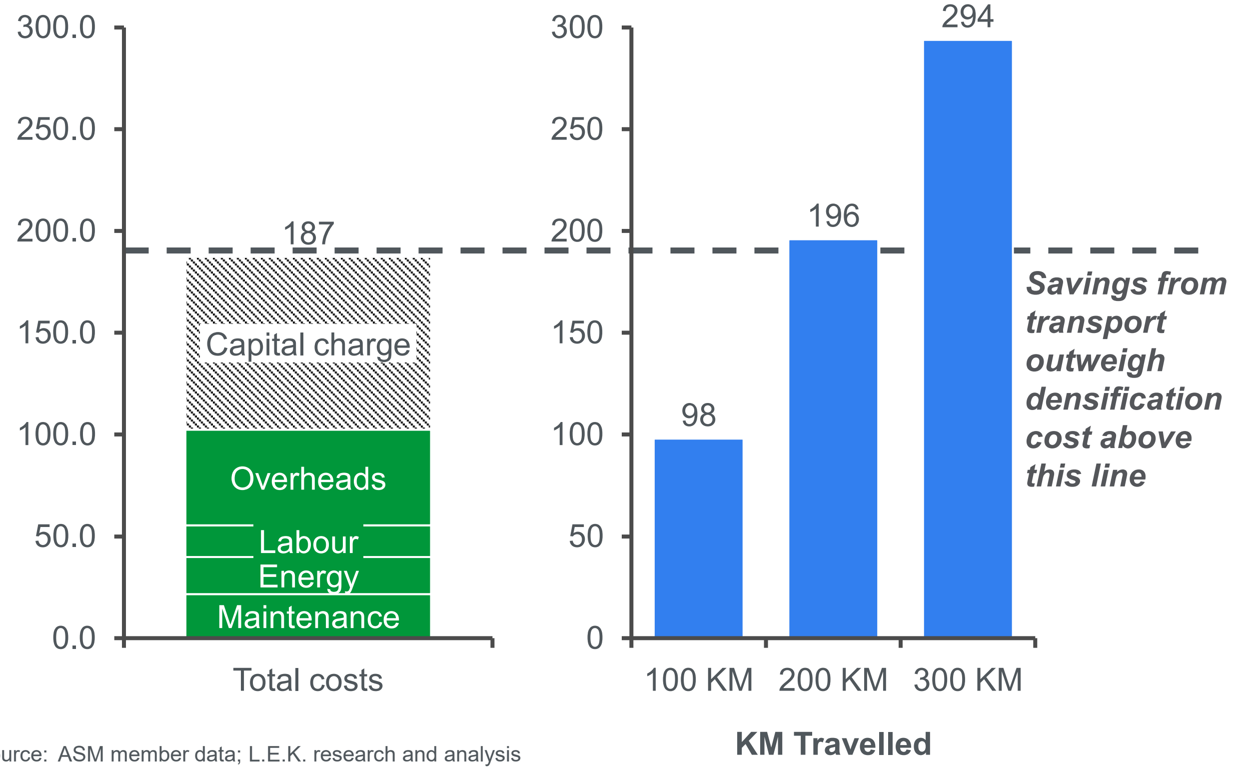
Note: * Capital charge calculated on a 10% cost of capital, with c.$70m capital investment, with standard economic cost annualization factor
Source: L.E.K. research and analysis

Transport costs only offset the densification cost for transport distances over c.200km, but at this distance the total additional cost is so high that most use cases are likely to be uneconomic

Pelletised bagasse would need to be transported c.200km for it to be cheaper to transport densified bagasse than raw bagasse

Economic cost of densification of 230kt raw bagasse annually* (2024)
$AUD / t-pellet

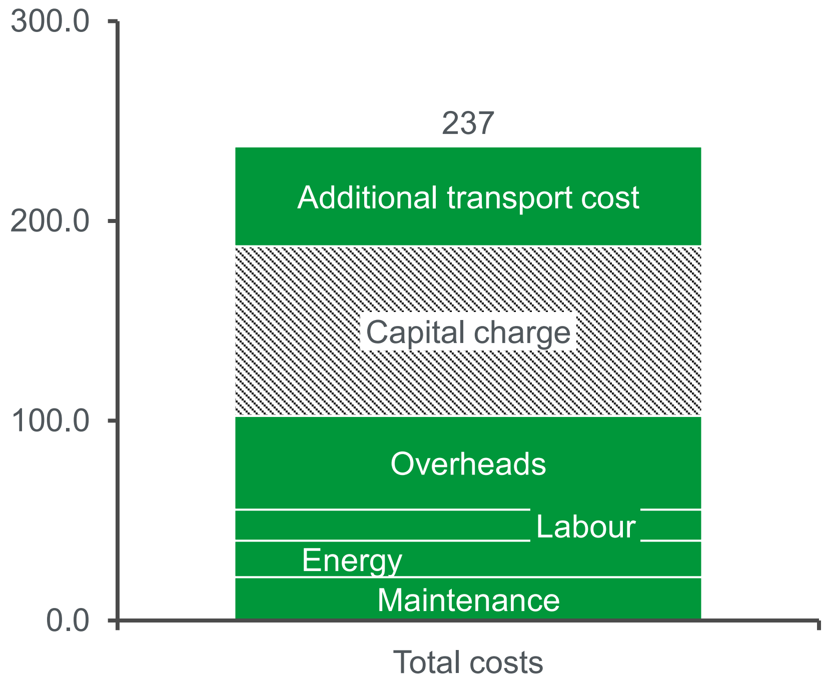
Transport savings from transporting densified bagasse compared to raw bagasse (2024)
$AUD / t-pellet



Savings from transport outweigh densification cost above this line

But mills would not transport this far because so much cost has been added

Economic cost of densification at c.200km transport (2024)
$AUD / t-pellet

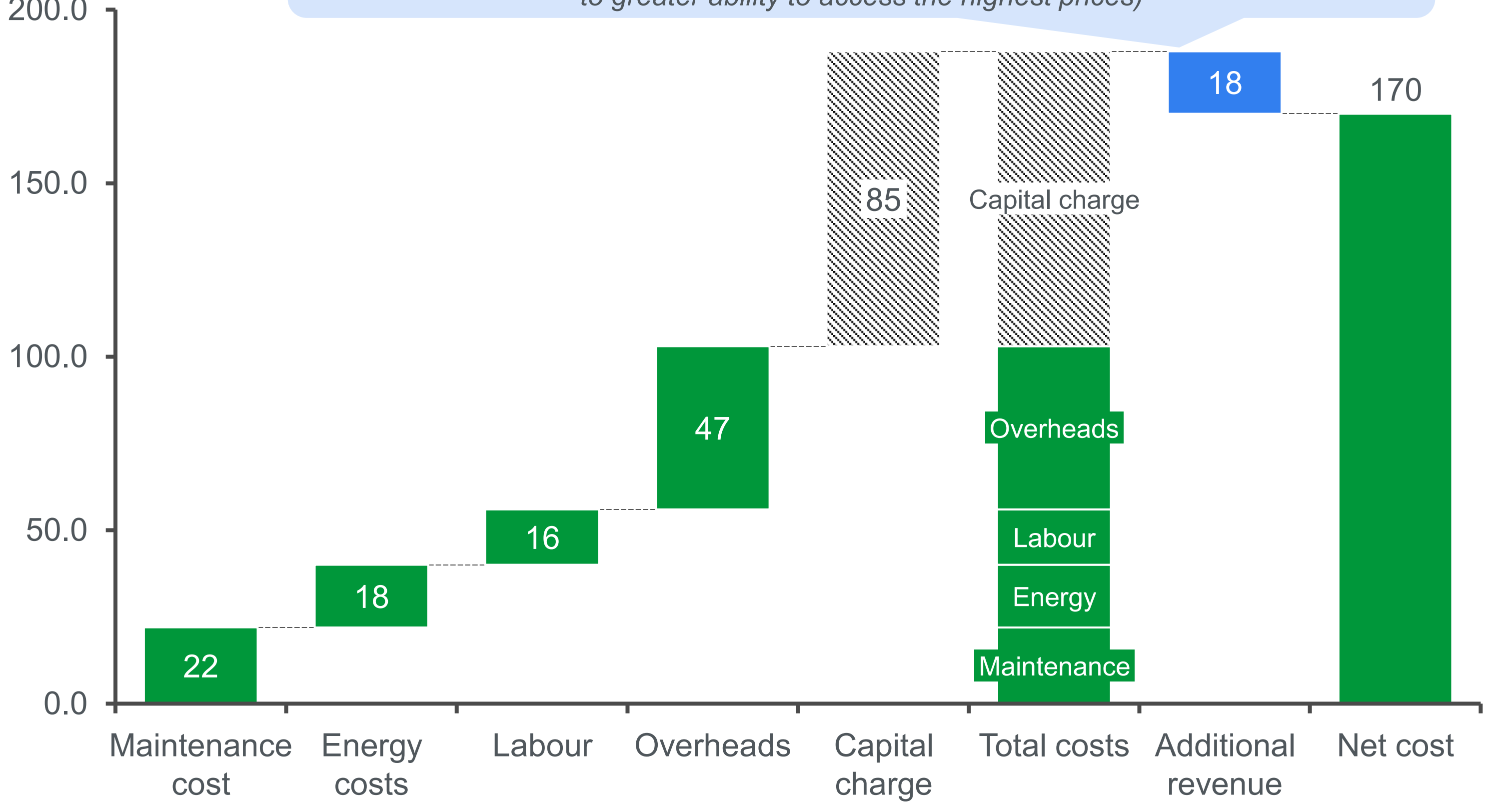


Source: ASM member data; L.E.K. research and analysis

2 The cogeneration extension pathway does not break even, as the benefits of shifting generation are limited compared to the cost to densify bagasse

Economic cost of densification of 230kt raw bagasse annually* (2024)
$AUD / t-pellet

It is coincidental this chart value is the same as the energy cost. Assumes average electricity price of $100/MWh pre-densification, rising to $150/MWh post-densification (due to greater ability to access the highest prices)



The Cogeneration Extension pathway tests whether access to higher energy export prices justifies investment in densification

Densifying bagasse allows mills to store greater amounts of energy, and utilise that storage to export when prices are highest

- Mills with **limited storage** that could leverage the **increased weight density of fuel** to extend cogeneration beyond the crush period are best positioned to benefit from this pathway
- The cogeneration extension pathway **assumes that the amount of fuel (bagasse) available to a mill remains constant** (purchasing additional bagasse would result in a lower return due to fuel purchase costs)
- While fuel densification increases the energy density of fuel (energy per kg), **the densification process also reduces the energy yield per weight of bagasse** that is processed – i.e. densified fuel produced from a tonne of bagasse will contain less energy than the tonne of raw bagasse

🟦 *Cash benefit*
▨ *Non-cash cost*
🟩 *Cash cost*

Note: * Capital charge calculated on a 10% cost of capital, with c.$70m capital investment, with standard economic cost annualization factor
Source: L.E.K. research and analysis

3

The ‘Make to Sell' pathway would need to offer returns of c. Redacted of pellets for commodity sales to break even with revenue from producing electricity

Economic cost of densification of 230kt raw bagasse annually* (2024)
$AUD / t-pellet

Redacted for public release

🟦 *Cash benefit*
🟩 *Cash cost*
▨ *Non-cash cost*
▨ *Opportunity cost*

Source: L.E.K. research and analysis

The ‘Making to Sell’ pathway tests whether the sale of bagasse pellets on the commodity market justifies an investment in densification

If contracts for sale of densified fuel offered more than Redacted pellet, there would still be several risks associated with this pathway:

- The **market for biomass pellets is thin and underpinned by foreign government subsidies**, which Australian producers will have limited ability to influence
- If market access is secured, supply contracts may mean that mills are **obligated to produce densified fuel, even when it is not advantageous to do so**
- Fuel densification represents a **significant capital investment, changes in operational practices and risks from expanding into a non-core business area**

While fuel densification to sell may not make sense at the portfolio level, there are particular conditions under which it may be viable

Illustrative example

Economic cost of densification of 230kt raw bagasse annually* (2024)
$AUD / t-pellet

Redacted for public release

Source: L.E.K. research and analysis

In certain situations, densification could be an attractive alternative to cogeneration:

***If capital costs can be limited**, because the mill has access to some pre-existing equipment, and if the opportunity cost is limited, the total cost is significantly reduced*

***If transaction costs are limited,** which would allow parties to transport, and contract at a price which will not impede profitability*

***If market access can be secured**, for example at Japanese power plants, then sufficiently high prices may justify the cost of densification*

Case study: Delta Biofuel's Louisiana plant benefits from several commercial advantages which enable it to overcome the economic challenges associated with densification

Bagasse pellet plants have been constructed overseas…

…however, they have often benefitted from several advantages

DELTA BIOFUEL

Louisiana fuel pellet plant

- In 2021 Delta Biofuels announced they would construct a new bagasse fuel pellet plant in Iberia Parish, Louisiana. Construction started in 2023, and is on track for full delivery by end of 2024
- The plant required capex of c.$100m USD (c.$160m AUD), and is expected to process 340,000 t-bagasse annually

Government incentives

- The Louisiana plant benefits from an industrial tax exemption program, $1m USD infrastructure grant, jobs program support
- Further, permitting and licensing authorities were highly responsive, working collaboratively with Delta Biofuel

Operational advantages

- Able to collocate with the largest mill in the surrounding area and limited storage costs, as storage costs were borne by the mills until bagasse was delivered
- Secured exclusive use of a newly constructed port storage and loading facility

Limited opportunity cost

- Several surrounding mills had recently shut down, meaning mills still in operation had large and growing stockpiles of excess bagasse which they were unable to burn through
- Electricity prices in Louisiana are not expected to increase to the same extent as in Australia

Subsidised buyers

- Sell to European utilities, who benefit from large government subsidies (e.g. 2024 French scheme worth c.900m euros)

Source: Lousiana Economic Development; Louisiana Forest Products Development Center; L.E.K. research and analysis

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Contents

Expanding cogeneration warrants further study given its commercial potential and benefits to Queensland's energy market but may need external support

Conclusions and next steps

Expanding cogeneration warrants further technical and economic analysis of costs

- The additional revenue available to sugar mills that are augmented to maximise cogeneration are significant, and merit detailed site-specific technical feasibility and project cost studies
- Expanding cogeneration may deliver an additional 2.1TWh of green, firm and dispatchable power to the Queensland grid, reducing prices for Queensland electricity customers
- The introduction of additional cogeneration also reduces Queensland's COe-2 by c.1.5% of its carbon emissions reduction target by 2035
- Expanding cogeneration introduces a set of operational, regulatory and market risks to mill operators. Avenues for external support are available to ameliorate these risks, ranging from direct up-front financial support, to regulatory support

Bagasse pelletisation is not compelling where expanding cogen is viable

- Pelletising bagasse is expensive and requires a large capital investment. The cost of pelletisation means that its use to reduce mill operating costs, and extend cogeneration are not economic
- ***Redacted for public release*** In instances where economically viable operations have been established, this is possible only with significant government support, favourable operational conditions, and in instances where mills have low opportunity costs from densification

ASM Members should strengthen confidence in the cogeneration business case through detailed analysis of technical feasibility, cost and risk

- Site-specific, detailed technical feasibility studies should be conducted to inform accurate cost estimates for upgrades and augmentation
- Mill operators should evaluate the investment, technology upgrades, organizational changes, and trading models needed to meet regulatory, operational, and market requirements for a scheduled cogeneration portfolio
- Mill operators, in partnership with the ASM, should secure external support to strengthen the investment case for cogeneration and mitigate the operational and regulatory risks associated with cogeneration expansion

For mill operators, the economics of mill augmentation justify further work to explore capital costs, but mills may require incentives to overcome the operational challenges and investment risks

Indicative

IRR by capex invested for unconstrained mill*
(FY29F-50F)

Redacted for public release

The additional revenue available to augmented mills warrants **undertaking detailed technical feasibility and project cost assessments of mills** to better understand if projects could meet required rates of return

Initial capex estimates suggest projects to upgrade transmission and augment mills may require **some level of external support** to underpin the case for investment

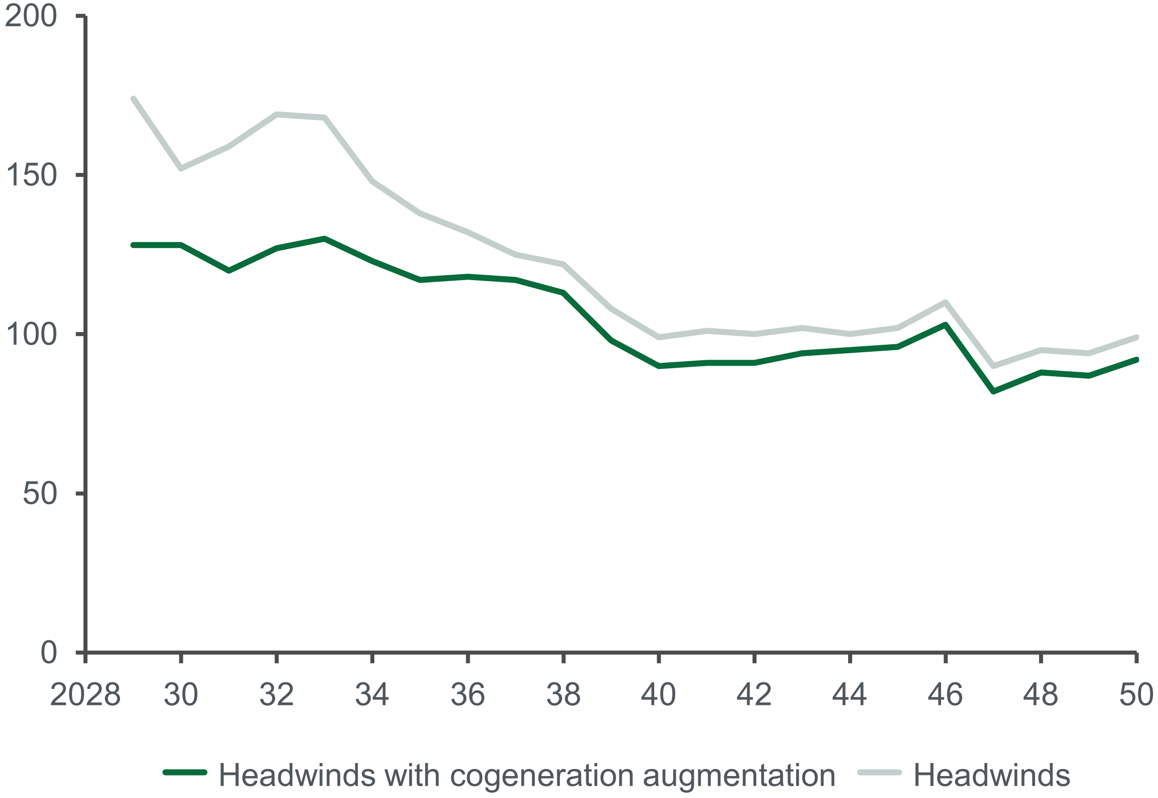
The required rate of return may need to be set at a **premium to core business investments** to account for:

- **Operational changes** post-augmentation, with increased activity overnight and during the non-crush period
- **Development and operational risks** (e.g., construction risks, market trading and dispatch, etc) in areas where members have limited previous experience
- The need for constrained sites to address **transmission and storage constraints**, creating cost uncertainty, potential delays, or challenges for technical viability

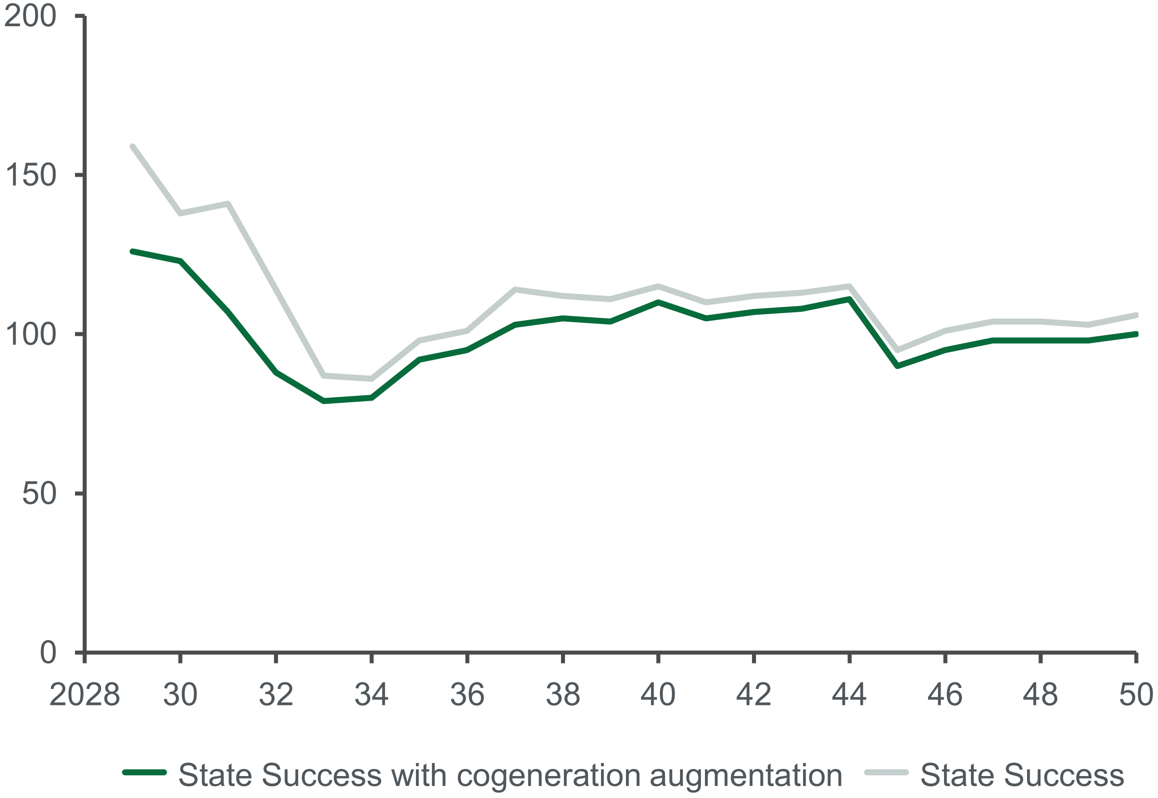
Note: * IRR calculated as difference between revenue earnt by efficient mill and legacy mill, capex spent in year one, no operating costs accounted for (IRR is the discount rate which makes the NPV of these values zero)
Source: ASM member interviews; L.E.K. research and analysis

Cogeneration can support the Queensland market through the energy transition by providing dispatchable energy and therefore reducing prices. The largest impact is in c.2029-35

Headwinds scenario
Regional wholesale pricing with augmented cogeneration, 2029F-2050F
$AUD/MWh (volume-weighted average)



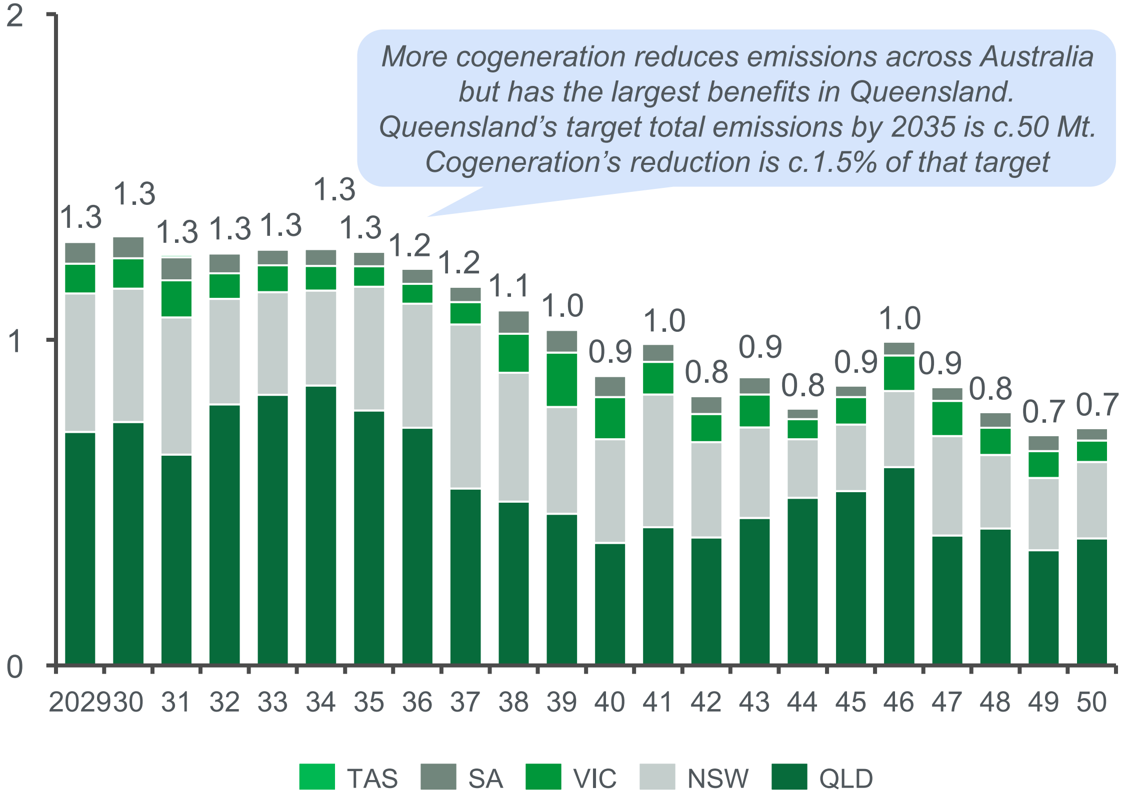
State Success scenario
Regional wholesale pricing with augmented cogeneration, 2029F-2050F
$AUD/MWh (volume-weighted average)



Source: Endgame; L.E.K. research and analysis

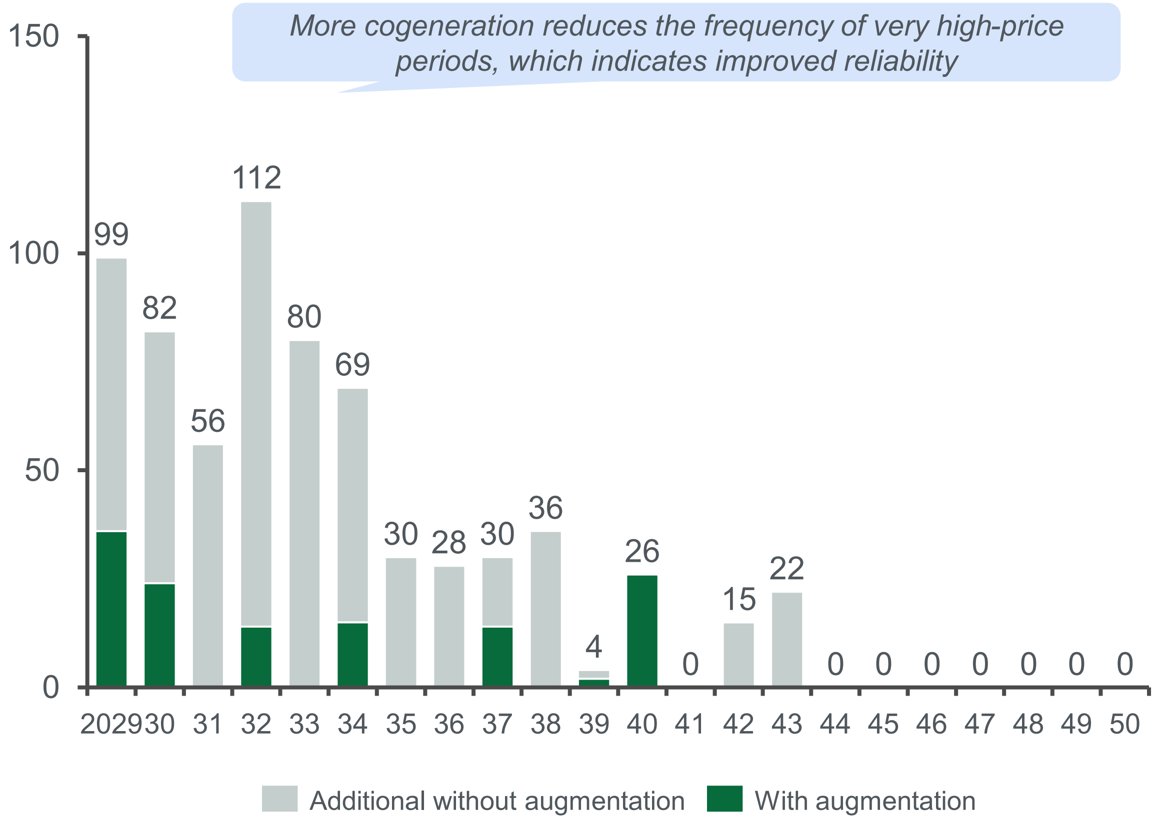
In addition to lower prices, upgrading and augmenting cogeneration would contribute to lower carbon emissions and a more reliable power system

Emissions reduction compared to no-augmentation scenario (2029F-2050F)
Millions of tonnes of emissions



More cogeneration reduces emissions across Australia but has the largest benefits in Queensland. Queensland's target total emissions by 2035 is c.50 Mt. Cogeneration's reduction is c.1.5% of that target

30-minute periods with market price greater than $500/MWh (Queensland) (2029F-2050F)
Number per annum



More cogeneration reduces the frequency of very high-price periods, which indicates improved reliability

Source: Endgame; L.E.K. research and analysis

External support to upgrade or augment mills could take a range of possible forms including regulatory support, ongoing revenue support, or grants

Regulation and policy

Avenue for support	Features of support	Examples of types of support
Regulatory support	• Includes planning or regulatory changes to energy or other markets to support project development, delivery, or operations	• Exemptions or derogations from scheduled generator thresholds, or planning or zoning support to facilitate more storage
Operational support	• Support to establish or operationalise key generation capabilities, such as trading operations	• A partnership for an external party to manage energy market trading operations
Revenue support	• Ongoing revenue support to mitigate energy market risk, either through risk-sharing or minimum revenue guarantees	• 'Cap and floor' supports such as the CIS, or a guarantee for minimum revenue levels subject to meeting operational conditions
Upfront capital support	• Direct grants to mills to contribute to the capital costs of generation upgrades	• Direct grants at a project-level or support to build a generation portfolio

Direct contributions

Source: L.E.K. research and analysis

See regulatory report for detail

The IRR is sensitive to capex spend, reinforcing the need for detailed cost studies to be undertaken. At the low end of capex spend average prices appear achievable on a 7-14 year payback period

Indicative

Price needed to reach IRR threshold by initial capex*
(2029F-50F)
$AUD/MWh (real 2023 prices)

Redacted for public release

Given the additional 2.1 TWh generated, each MWh provides up to c.$1,000 of benefit across all wholesale electricity prices in Queensland

	5-year average	10-year average	15-year average
Price reduction due to augmentation *(Volume-weighted average)*	$38 / MWh	$27 / MWh	$21 / MWh
x			
QLD consumption p.a. *(Volume-weighted average)*	58,000,000 MWh	62,000,000 MWh	66,000,000 MWh
=			
Value provided by mills to consumers p.a.	$2.2B	$1.6B	$1.3B
÷			
Additional MWh produced	2,100,000 MWh		
=			
Value provided by mills to consumers	$1,036 / MWh	$778 / MWh	$648 / MWh

- Sugar mills can significantly influence electricity prices by leveraging their dispatchable generation to supply power during peak price events at a lower cost than other sources
- Mill dispatchability means that augmentation can provide significant value to Queensland's consumers. This is reflected in an average c.$38/MWh reduction in electricity prices post-augmentation over the five-year average (peak prices would likely reduce by much more than that)
- As a whole, this reduction in prices means that consumers are paying $2.2B less for their electricity in the five- year average
- Mills generate an additional 2.1 TWh of electricity in order to provide the $2.2B consumer benefit, indicating that each MWh produced by the mills provides over $1,000 of benefit to consumers (on the five-year average)

Note: Undiscounted values presented
Source: ASM member data; L.E.K. research and analysis

Increasing cogeneration has many public benefits, including supporting the electricity network through decarbonization and supporting primary industries

Increasing cogen has many public benefits. These include:

Increased cogen

Price suppression
Expanded cogeneration can reduce wholesale electricity prices by c.$10-30/MWh in Queensland, benefit extending to other states connected to the NEM

Emissions reduction
Given its dispatchability and cost, Cogeneration can displace thermal generation in Queensland and abate the equivalent of c.1.5% of the State's 2035 CO2e- target

Diversification of energy supply sources
Many renewables generate at similar times, but cogeneration is dispatchable, allowing it to fill in supply when renewables are unavailable, enhancing grid reliability

Improved electricity system stability
Cogeneration plants use technology that enhances grid voltage and frequency stability – an advantage over most renewable energy sources

Avoided greenfield infrastructure investment and social licensing challenges
As cogeneration can more readily leverage existing network infrastructure, it can bypass the cost and social license hurdles faced by large greenfield renewable energy and transmission projects

Supply chain diversity
Cogeneration is less dependent on international supply chains for equipment and material, which can pose risks of delays and shortages to renewable projects

Supporting primary industries
Expanded cogeneration provides revenue support for regional communities and the sugar industry, which will have associated benefits for the Queensland economy

Source: ASM member data; L.E.K. research and analysis

ASM Members' immediate next steps should be to build confidence in the investment case for cogeneration by undertaking detailed technical feasibility and project cost assessments

Build confidence in the cogeneration investment case

- Undertaking detailed technical feasibility study of mill upgrades and using this assessment to inform accurate cost estimates for upgrades and augmentation on ASM Members' sites
- For constrained mills:
  - Assessing the technical feasibility and cost of unlocking grid constraints, and / or
  - Assessing the potential to increase fuel storage capacity

Assess the investment in capabilities that would be necessary to meet the regulatory and operational requirements of operating an expanded cogeneration portfolio

- Determine the cost of implementing the technology upgrades, organisational changes and capability changes necessary to meet a range of market, operational and regulatory requirements
- Assess options to determine if there is a viable trading model that would enable members to manage trading risks and licensing requirements associated with operating an expanded generation portfolio

In partnership with the ASM, secure external support to improve the investment case for cogeneration and mitigate the operational and regulatory risks of expanding it

If a detailed feasibility study finds cogeneration expansion at a mill unviable, bagasse pelletization for sale could offer an alternative revenue stream. Like cogeneration, this opportunity should be evaluated through a site-specific feasibility study before proceeding

Contents

Appendix removed for public release