Queensland Aluminium Industry Emissions:
2024 Status, 2030 Reduction Targets and Decarbonization Roadmap

Chung-Hao Lee, May 2025

Outline

Queensland Aluminium: Current Carbon Footprint

- Queensland Aluminium Industry: Economic Growth Engine and Carbon Emissions Challenge
- Carbon Emissions Breakdown of Rio Tinto’s Queensland Aluminium Operations in 2024

The Path to 2030: Target vs. Reality

- 2030 Emissions Target vs. Current Status: A 3.8 Mt CO2e Shortfall
- Bridging the 3.8 Mt Gap: Charting Our Path to the 2030 Emission Target

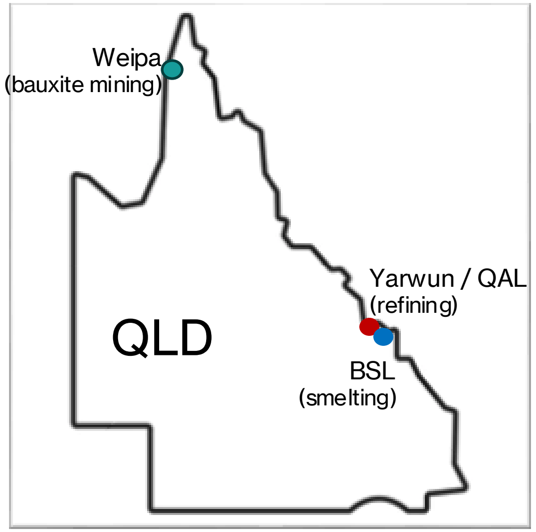
Our Decarbonization Toolkit: Key Solutions

- Decarbonization Solution 1 - Renewable Energy (Solar and Battery)
- Decarbonization Solution 2 - Mechanical Vapor Recompression
- Decarbonization Solution 3 - Electric Boilers
- Decarbonization Solution 4 - Hydrogen Calcination
- Decarbonization Solution 5 - Inert Anodes

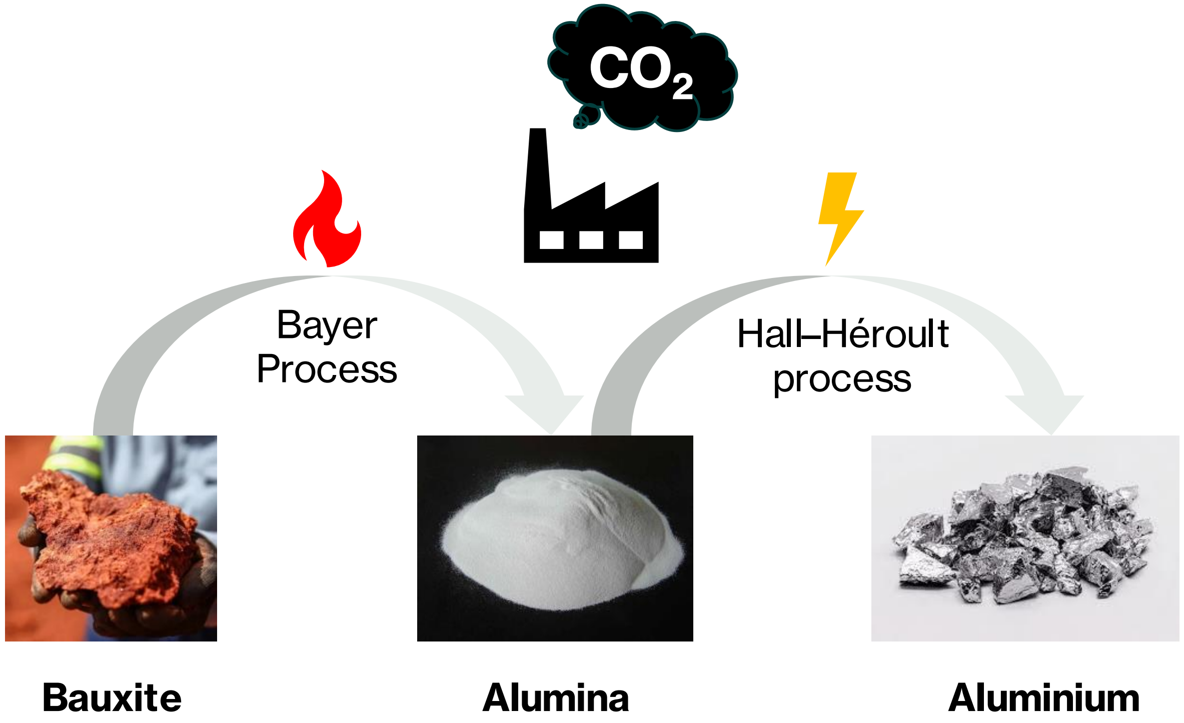
The Journey Ahead: Our Implementation Roadmap

- A Technology-Driven Path to Our 2030 Target and Beyond
- Summary
- Suggested Next Actions

Queensland Aluminium Industry: Economic Growth Engine and Carbon Emissions Challenge



- Queensland hosts significant integrated aluminium operations, which are vital to Australia's industrial base, economic contributor and the global aluminium supply chain.
- Major Aluminium operations in Queensland, including bauxite mining (e.g., Weipa), alumina refining (e.g., QAL, Yarwun), and aluminium smelting (e.g., BSL).



- Primary aluminium production is inherently energy-intensive, presenting a substantial carbon footprint and a complex decarbonization challenge.

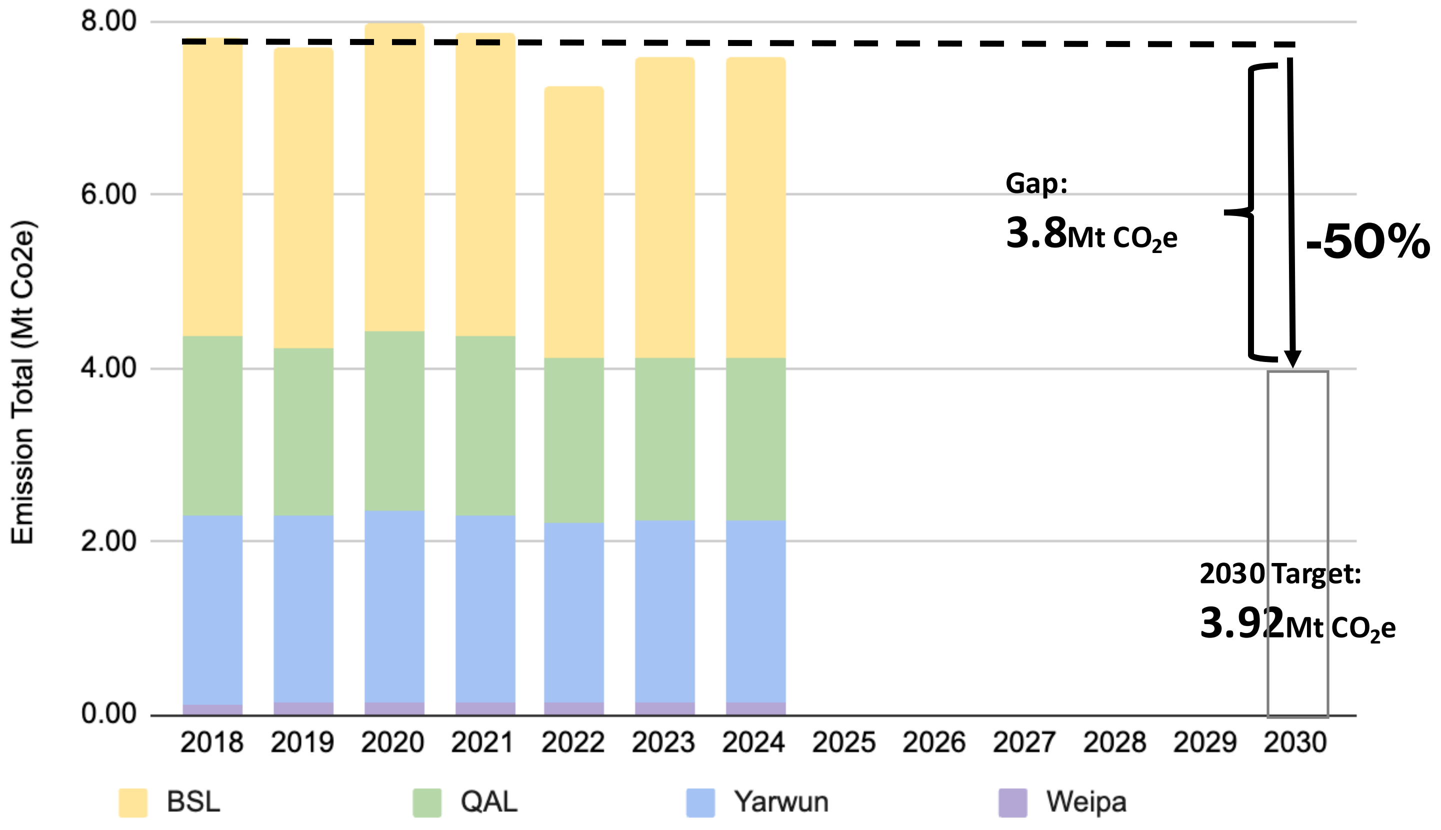
Carbon Emissions Breakdown of Rio Tinto's Queensland Aluminium Operations in 2024

- Since no public data is available, 2024 emissions for Queensland's aluminium operations are estimated based on emissions per unit of operation.
- The data indicates that carbon emissions from aluminium operations in Queensland in 2024 was **7.72Mt CO_2e**, with the majority coming from **alumina refining (49%)** and **aluminium smelting (48%)**.

Facility (Stage)	Production 2024 ('000 tonnes)	Emission Rate (t CO_2e/t)	Emission Total in 2024 (Mt CO_2e)
Weipa (bauxite mining)	37,039 [1]	0.004 [2]	0.15
Yarwun (Alumina refining)	2,762 [1]	0.7 [3]	1.93
QAL (Alumina refining)	2,707 [1]	0.7 [3]	1.89
BSL (Aluminium smelting)	319 [1]	11.74 [4]	3.75
2024 Total emission of aluminium operation in Queensland			7.72

2030 Emissions Target vs. Current Status: 3.8 Mt CO_2e Shortfall

- The carbon emissions from 2018 to the present can be estimated using the same methodology as previous slide presented.
- The 2030 carbon emission target is **50% reduction** (compared to the 2018 baseline) [13].
- According to Target 2030, carbon emissions should be reduced to 3.92Mt CO_2e. Carbon emissions in 2024 amounted to 7.72Mt CO_2e, leaving a **gap of 3.8Mt CO_2e**.



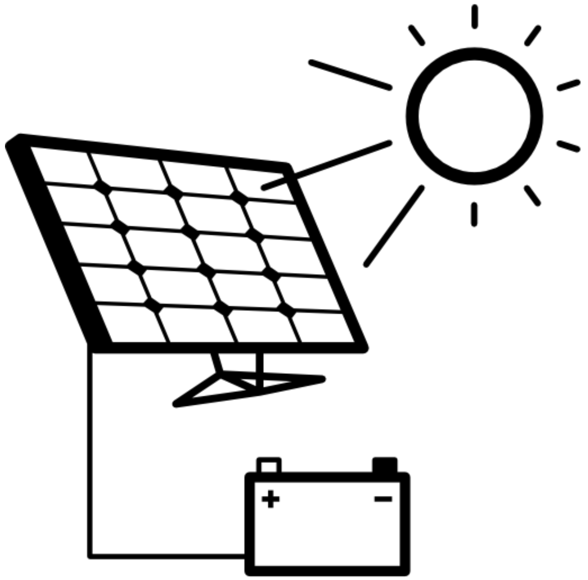
Bridging the 3.8 Mt CO_2e Gap: Charting Our Path to the 2030 Emission Target

Based on prior analysis, there remains a **3.8 Mt CO_2e** shortfall against the 2030 target. Accordingly, we must implement measures to curb carbon emissions.

The following solutions can help bridge this gap:

- **Renewable Energy (Solar and Battery)**
- **Mechanical Vapor Recompression**
- **Electric Boilers**
- **Hydrogen Calcination**
- **Inert Anodes**

Decarbonization Solution 1 - Renewable Energy (Solar and Battery)



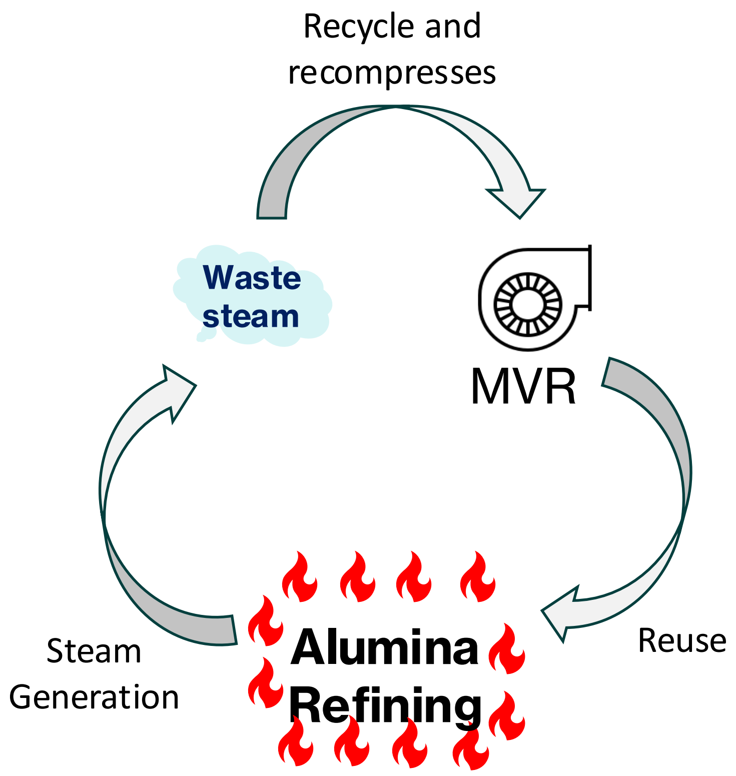
Description: Solar and battery energy storage, as key renewable solutions producing no CO_2 unlike fossil fuels (e.g., natural gas), seamlessly integrate with advanced process technologies like mechanical vapor recompression (MVR), electric boilers, inert anode, and hydrogen calcination to significantly cut carbon emissions in aluminium production.

Applied Stage: Alumina refining and aluminium smelting

Value: 70% reduction in carbon emissions in Gladstone operation (Yarwun, QAL and BSL) in long term [15].

Plan: Infrastructure construction is scheduled to commence in 2025, with operations expected to begin in 2028 [15].

Decarbonization Solution 2 - Mechanical Vapor Recompression



Description: Approximately 70% of the fossil fuel consumed in alumina refining is associated with steam generation in the boilers. Mechanical vapor recompression (MVR) is a potential alternative that uses renewable electricity to produce steam. MVR recompresses waste steam that would otherwise be discharged to the atmosphere and recovers it for reuse in the refining process. This technology has the potential to reduce emissions [12].

Applied Stage: Alumina refining

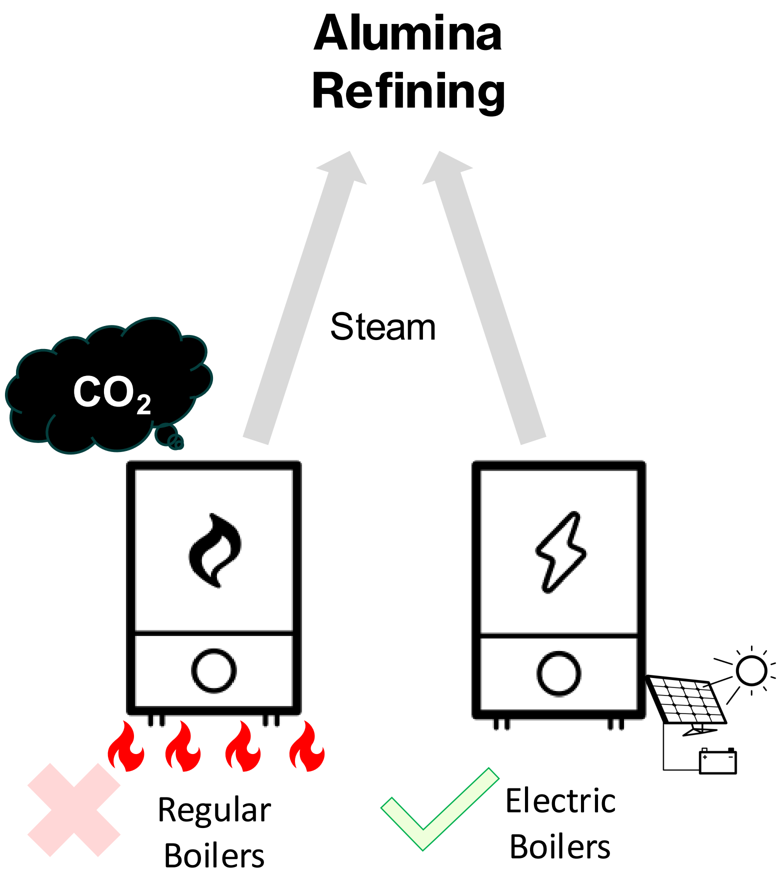
Value: Reduce carbon emissions in the refining stage by 70% in the long term [7], and cut emissions in Queensland by 2.6Mt CO_2e [14].

Challenge: Additional renewable energy is required to drive MVR [7], and additional investment is needed to build the infrastructure.

Cost: The capital cost of MVR is $220 - $260 per annual tonne of alumina production [14].

Plan: QAL is expected to commence trial operations in 2025 [13].

Decarbonization Solution 3 - Electric Boilers



Description: Electric boilers are a leading contender for decarbonizing high-temperature alumina refining by providing a fossil-fuel-free source for primary steam. They offer the most significant potential for emissions reduction in this sector. Overcoming their higher operating costs will likely necessitate low-cost renewable electricity or financial support, paving the way for greener alumina production.

Applied Stage: Alumina refining

Value: Cut up to 70% of alumina refinery carbon emissions by transitioning steam generation to electric boilers powered by renewables [7].

Challenge: Availability of electric boilers technology and cost of firmed renewable power requirements [16].

Plan: Feasibility study and expect to get approval in 2025 [13].

Decarbonization Solution 4 - Hydrogen Calcination

Description: During the alumina refining process—especially in the final calcination stage—a temperature of around 900°C is required. Traditionally, this calcination is carried out by burning natural gas, which generates significant greenhouse-gas emissions, such as carbon dioxide. In hydrogen calcination, hydrogen replaces natural gas, so that combustion at high temperature produces steam rather than greenhouse gases [5].

Applied Stage: Alumina refining

Value: In the short term, it can reduce CO_2 emissions by 3,000 tonnes per year [8]; in the long term, it can lower Yarwun's emissions by approximately 25% [6].

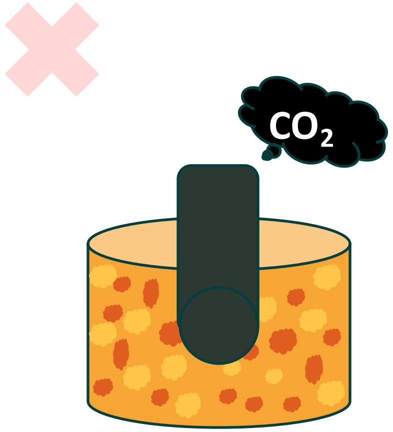
Challenge: It requires a substantial amount of additional energy to produce hydrogen. Additional external equipment is needed to store the hydrogen [7], and the calcinator must be retrofitted [8].

Cost: The cost of hydrogen is approximately $2 per kg [7]. If the Yarwun refinery were to fully adopt hydrogen calcination, it would require roughly 178,000 tonnes of hydrogen [6]. Scaling that up to all of Queensland would demand about 356,000 tonnes—at a total cost of approximately $712 million.

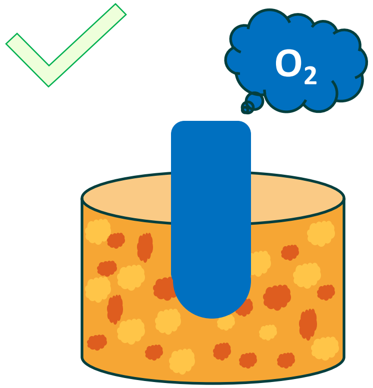
Plan: Construction began in 2024, and expect to be operational in 2025 [8].

Decarbonization Solution 5 - Inert Anodes

Carbon Anodes



Inert Anodes



Description: In aluminium production, alumina is electrolyzed to produce aluminium. Traditional carbon anodes emit CO_2 and other greenhouse gases, whereas inert anodes generate O_2 instead, thereby reducing carbon emissions [9].

Applied Stage: Aluminium smelting

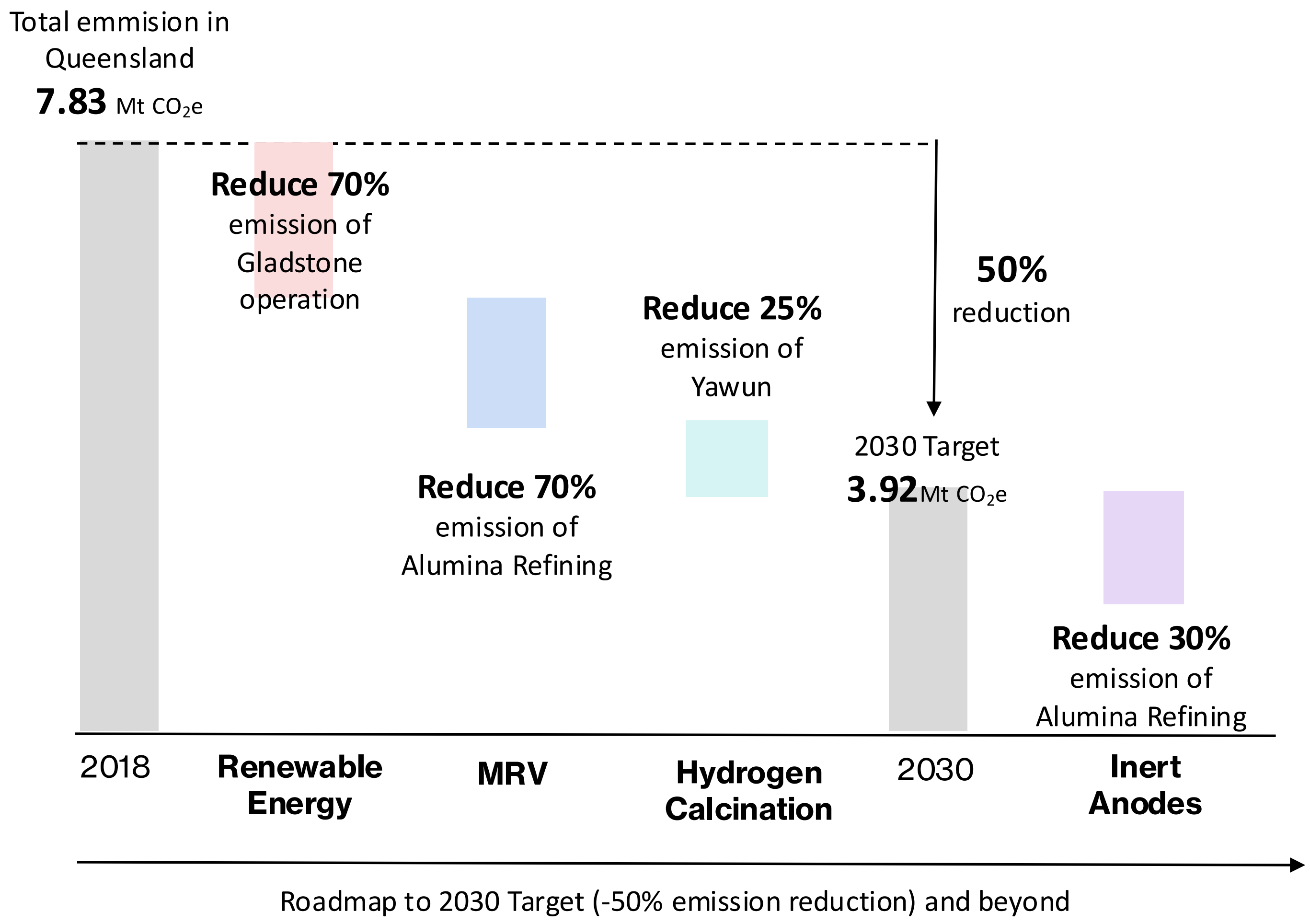
Value: Reduce carbon emissions by approximately 30% in the long term [11].

Challenge: Currently still in the validation phase, and the effectiveness at large-scale implementation remains unknown.

Plan: Inert Anodes is currently in use in Canada, with potential for future expansion to Queensland [10].

A Technology-Driven Path to Our 2030 Target and Beyond

- Greater renewable energy use is projected to cut refining and smelting operation long-term carbon emissions by 70%.
- Renewable energy lies at the core of Queensland's decarbonization roadmap: powering MVR, electric boilers, hydrogen calcination and inert anodes with renewables unlocks the synergy required for optimal carbon reductions.
- As these solutions scale and demonstrate their effectiveness, Queensland's emissions will bend downward—enhancing prospects for the 2030 target and paving the way for even deeper reductions through next-generation processes like double digestion and BlueSmelting™.



Summary

- **Current Emissions and 2030 Target Gap:** Rio Tinto's Queensland aluminium operations registered an estimated 7.72 Mt CO_2e in 2024, predominantly from alumina refining (49%) and aluminium smelting (48%). Against a 2030 target of 3.92 Mt CO_2e (a 50% reduction from the 2018 baseline), there exists a significant 3.8 Mt CO_2e shortfall that requires immediate and strategic action.

- **Key Decarbonization Levers:** A portfolio of five core technological solutions has been identified to bridge this emissions gap. These include:
  - **Renewable Energy (Solar and Battery)**: Foundational for long-term reduction, potentially cutting 70% of Gladstone's operational emissions.
  - **Mechanical Vapor Recompression (MVR)**: Targets steam generation in alumina refining, aiming to reduce refining emissions by 70% and Queensland's total by 2.6 Mt CO_2e.
  - **Electric Boilers**: An alternative for steam generation, also targeting up to 70% reduction in refinery emissions when powered by renewables.
  - **Hydrogen Calcination**: Replaces natural gas in the calcination stage, aiming for a 25% reduction in Yarwun's emissions long-term.
  - **Inert Anodes**: Targets the smelting process by replacing carbon anodes, potentially reducing smelting emissions by 30%.

- **Implementation Roadmap and Synergy:** The decarbonization strategy hinges on the large-scale deployment of renewable energy, which enables the effective implementation of MVR, electric boilers, hydrogen calcination, and inert anodes. Near-term actions include MVR trials (2025), hydrogen calcination operationalization (2025), and renewable infrastructure construction (starting 2025 for 2028 operation). Successful execution of this technology-driven roadmap is crucial to meet the 2030 target and establish a foundation for deeper, long-term emissions reductions.

Suggested Next Actions

Suggestion 1: Accelerate Renewable Energy Integration as the Core Enabler

Queensland's aluminium industry faces a 3.8 Mt CO_2e shortfall to meet its 2030 target, driven primarily by fossil fuel-dependent processes in alumina refining (49% of emissions) and smelting (48%). The decarbonization solutions outlined—Mechanical Vapor Recompression (MVR), electric boilers, hydrogen calcination, and inert anodes—all hinge on affordable, scalable renewable energy to achieve their full potential. Queensland's abundant solar resources position it to lead this transition [17]. Prioritizing large-scale solar and battery infrastructure investments will unlock synergies across technologies, ensuring emissions reductions align with the 2030 target and beyond.

Suggestion 2: Scale Pilot Technologies Through Strategic Partnerships

Critical solutions like hydrogen calcination and inert anodes remain in early-stage validation. To close the 3.8 Mt CO_2e gap, rapid scaling is essential. This requires:

- **Targeted R&D funding** to address technical bottlenecks (e.g., hydrogen storage retrofits, inert anode durability).
- **Pilot expansion** (e.g., Yarwun's 2025 hydrogen calcination operational launch, ELYSIS inert anode prototypes) to demonstrate commercial viability.
- **Industry-government collaboration** to de-risk investments and align infrastructure timelines (e.g., synchronizing renewable projects with MVR/electric boiler deployments).

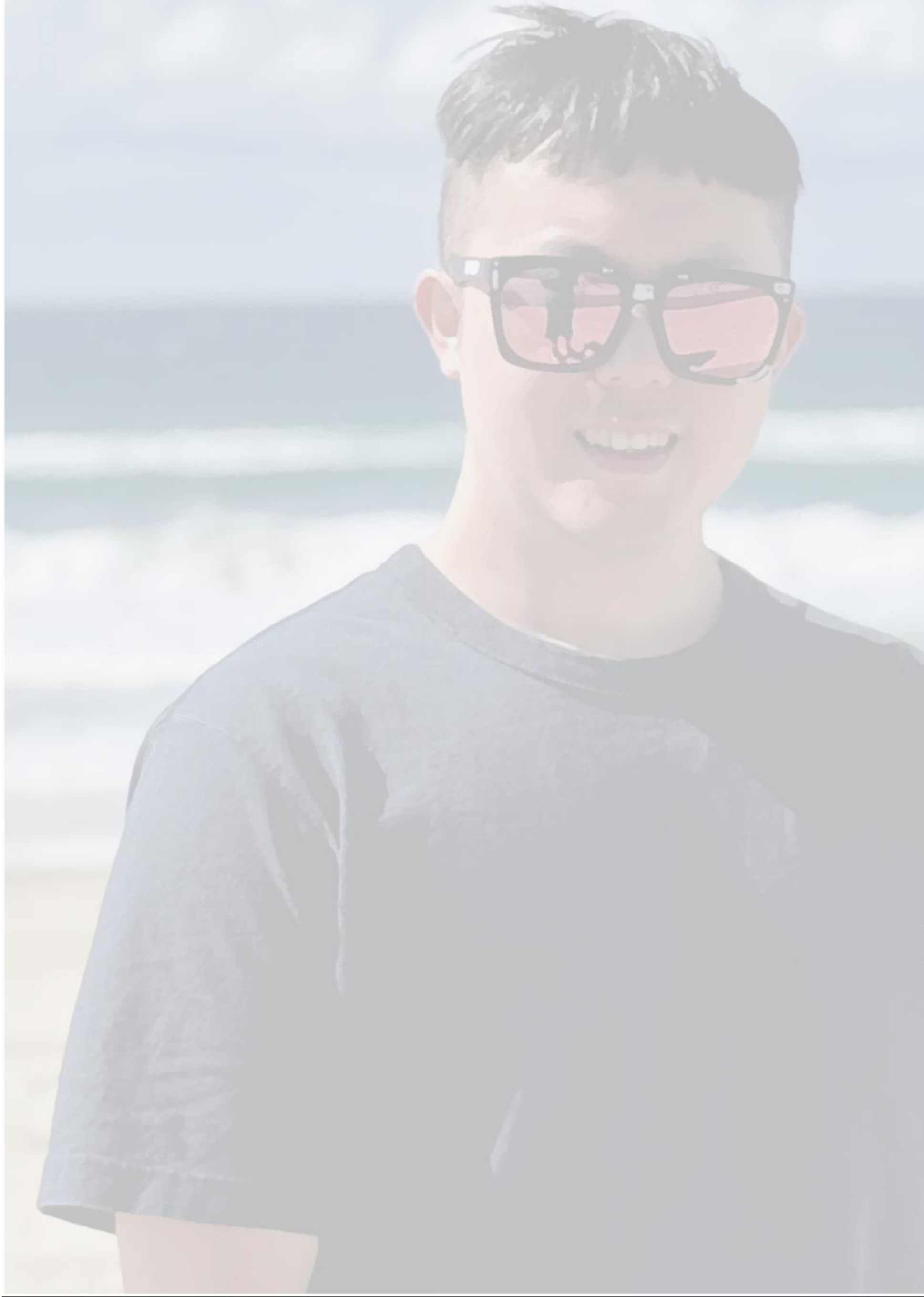
Supplimentary

Emission of Aluminium Operation in Queensland since 2018

	Emission Total (Mt CO_2e)						
Facility (Stage)	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Weipa (bauxite)	0.12	0.14	0.14	0.14	0.14	0.14	0.14
Yarwun (Alumina)	2.17	2.16	2.22	2.17	2.06	2.10	2.10
QAL (Alumina)	2.07	1.93	2.07	2.07	1.92	1.89	1.89
BSL (Aluminium)	3.46	3.48	3.56	3.50	3.13	3.46	3.46
Total emission of aluminium operation in Queensland	**7.83**	**7.71**	**7.99**	**7.87**	**7.25**	**7.59**	**7.59**

Reference

1. First Quarter Operations Review 2025 - production tables
2. 220719-PATHWAY-FACT-SHEET-02-BAUXITE.pdf (aluminium.org.au)
3. 220719-PATHWAY-FACT-SHEET-03-ALUMINA.pdf (aluminium.org.au)
4. 241023-FACT-SHEET-04-ALUMINIUM.pdf
5. Rio Tinto Hydrogen Feasibility Study Report - Australian Renewable Energy Agency (ARENA)
6. Yarwun Hydrogen Calcination Pilot Demonstration Program - Australian Renewable Energy Agency (ARENA)
7. roadmap-for-decarbonising-australian-alumina-refining-report.pdf (arena.gov.au)
8. Yarwun Hydrogen Calcination Pilot | Global (riotinto.com)
9. The Role of Inert Anodes in Aluminum Decarbonization (nrdc.org)
10. ELYSIS selects Alma smelter for commercial size 450 kA inert anode prototype cells | Canada (riotinto.com)
11. Rio Tinto and Corona Canada pilot Canada’s first specially-marked low carbon can leveraging ELYSIS technology | Global
12. Alcoa to investigate low emissions alumina - Australian Renewable Energy Agency (ARENA)
13. 2025 Climate Action Plan (Rio Tinto)
14. mvr-retrofit-commercialisation-study.pdf (arena.gov.au)
15. Rio Tinto and Edify Energy sign landmark solar and battery agreement for Rio Tinto’s Gladstone operations | Global
16. Decarbonising our Australian alumina refineries 2023 (Rio Tinto)
17. Queensland Renewable Energy Expert Panel Draft Report (epw.qld.gov.au)



Hello I'm CH Lee

I solve real business problems by using **Data Analysis** & **AI**

"Transform data into impacts: Insights discovered, solutions delivered."

With five years in tech, I specialize in **Data Analytics**, complemented by AI and Machine Learning, to **uncover critical insights** and translate complex data into actionable business strategies and actions.
I lead **analytically-focused projects** and foster cross-functional alignment, ensuring technical solutions are **validated by data** and effectively address core business challenges.

lch99310@gmail.com

Product Operation Manager
@TikTok

Sydney, AU

Univ. of Maryland, College Park
MBA (SCM major) dual **MSIS** (ML major)