



Rio Tinto



Finding better ways

Decarbonising our Australian alumina refineries

2023

A decorative graphic consisting of several white, wavy, horizontal lines that flow across the bottom of the red background, resembling stylized waves or topographical contours.

Alumina refining is the second step in the three-stage process to produce aluminium metal. In Gladstone, Queensland, Rio Tinto owns and operates the Yarwun alumina refinery and owns 80% of Queensland Alumina Limited (QAL) in a non-managed joint venture. These assets contribute approximately 15% of Rio Tinto Group's total emissions¹ and are some of the hardest to abate within our portfolio.

Decarbonisation solutions for the alumina refining industry are technically challenging and, in some cases, do not exist at the required scale. The alumina refining process requires large-scale energy to generate process heat and, in Australia, the industry's success has been underpinned by access to low-cost fossil fuels, predominately coal and gas.

Decarbonising alumina refining requires new, large-scale renewable electricity to generate the zero-emissions process heat currently provided by fossil fuels, and significant upgrades to the electrical infrastructure supplying refineries. This substantial capital investment in technology development and deployment is challenging for what are relatively low-margin assets.

The two Gladstone refineries are closely integrated with Rio Tinto's other aluminium assets in the region, which support more than 8,000 direct and indirect jobs.

These challenges exist in an industry where 17 new refineries (28 Mt of capacity) will be added globally between 2021 and 2026, primarily in China and Indonesia, and all sourcing their energy from coal. This new production will suppress the price of alumina, reducing the capacity of Australian refineries to economically fund their decarbonisation.

50% **net zero**

reduction by 2030

reduction by 2050

Figure 1: Rio Tinto's Scope 1 and 2 emissions targets

Yet aluminium is a critical component of the global energy transition so meeting this challenge is key, not only to reducing our emissions and meeting Scope 1 and 2 emission reduction targets, but to the production of low-carbon raw materials required for a low-emission aluminium value-chain.

Rio Tinto has a key role to play in the technology developments and process changes required to produce low-emissions alumina economically and efficiently.

How aluminium is made

Rio Tinto is a global leader in aluminium with a large-scale, integrated business incorporating the three stages of aluminium production.

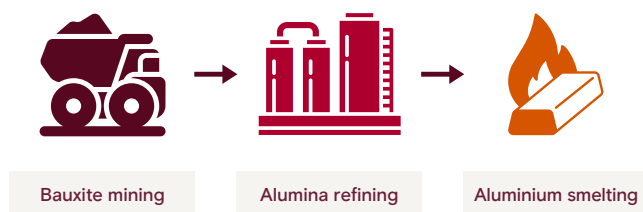


Figure 2: Overview of the aluminium process

We produce some of the highest quality, lowest-carbon footprint aluminium in the world, largely from hydro-powered smelting operations in North America, Europe, New Zealand, and in Australia at the Bell Bay Aluminium smelter.

Lightweight and recyclable, aluminium has a vital role to play in the transition to a low-carbon economy as a lightweight metal in vehicles and to upgrade energy grids and renewable energy infrastructure. We expect the global need for materials required for the energy transition could increase in demand by 25% for our key products.

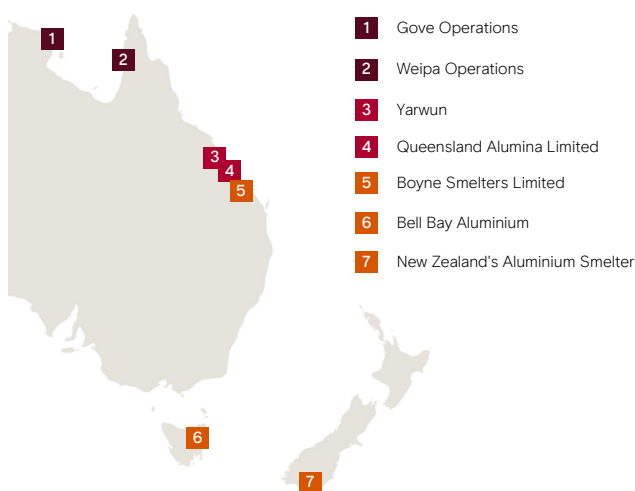


Figure 3: Rio Tinto Aluminium Pacific Operations assets

¹ Rio Tinto share of 2022 production from Yarwun and QAL = 5 MtCO₂e

Decarbonisation opportunities

Alumina refining process

The four-stage Bayer refining process is used to produce alumina, or aluminium oxide, which is a white granular powder required for aluminium production.

Digestion

Bauxite ore is ground and mixed with caustic soda solution and steam at high temperatures and pressure to dissolve alumina from the bauxite.

Clarification

The undissolved impurities that remain settle in thickening tanks, while the alumina and caustic soda solution is further clarified by filtration.

Precipitation

Alumina crystals are recovered from the caustic solution by mechanically stirring the solution in open-top tanks.

Calcination

The precipitated material (called hydrate) is washed and dried at temperatures exceeding 900 degrees Celsius. This forms the dry white aluminium oxide powder, alumina, which is cooled and stored.

There are two primary pathways to reduce emissions from the current process, either carbon capture and storage or electrification. Rio Tinto's preferred decarbonisation strategy, based on technical merit and commercial viability, is electrification. This will require large-scale and capital-intensive transformation of electricity generation and transmission infrastructure to provide renewable power to the refineries.

Rio Tinto's refineries process high-temperature bauxite from mines in Queensland and Northern Territory. The bauxite from Rio Tinto's Weipa Operations is more energy-intensive than other ore bodies as it requires higher temperatures to process.

To abate emissions from these refineries, Rio Tinto is:

- 1 Reducing the amount of energy required through process changes and improvements.
- 2 Improving energy efficiency and use by recovering low-grade waste steam and electrifying existing processes.
- 3 Switching to lower carbon fuels, including hydrogen to generate heat.

Each process stage offers different opportunities and timescales for decarbonisation.

Decarbonisation projects underway target the digestion and calcination process stages.

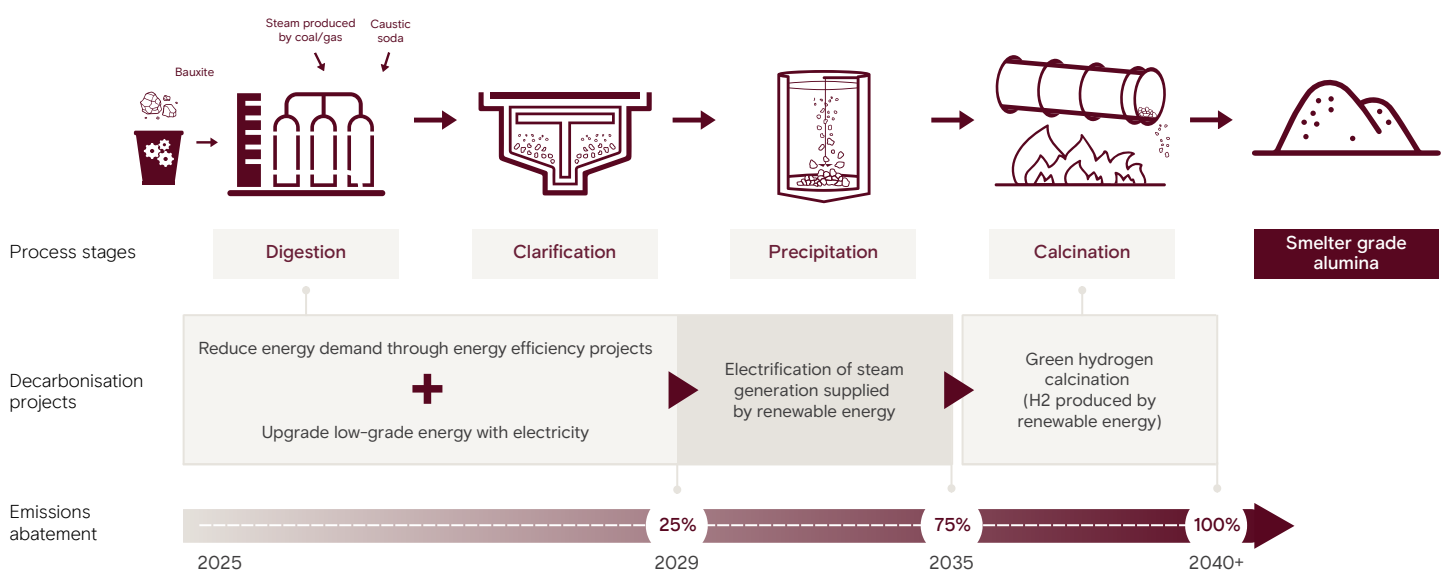


Figure 4: Alumina process and decarbonisation projects underway

Digestion opportunities

Reducing emissions in the digestion process, representing approximately 75% of refinery emissions, requires changes to the production process to reduce energy use and electrify steam generation. Electrification requires development of new enabling technologies, including thermal energy storage and electric boilers, to meet the scale and technical requirements for steam production.

Step change carbon abatement at these facilities is not possible without the development of a large-scale, competitive and firm renewable energy in eastern Australia.

We are focused on reducing the emissions of the digestion phase through three main projects:

1 Reducing baseload energy requirements through double digestion

The digestion process at QAL requires temperatures of 250 degrees Celsius to process high-temperature Australian bauxite.

Double digestion is a less energy-intensive technology that exists today. It requires investment in significant capital equipment to lower energy requirements. In this alternative process, bauxite is initially processed at lower temperatures, dissolving around 80% of the alumina. The remaining 20% is then processed at the required higher temperature, reducing energy use by up to 30%.

We are currently piloting double digestion at QAL, including the conversion of digestion units and testing for alumina recovery. This is a technically complex change requiring a technology pilot, which is under construction at the refinery. If successful, the pilot will need to expand to industrial scale, which requires retrofitting a complex 50-year-old refinery. Process changes that reduce energy demand have the multiplying effect of reducing operating costs and the scale (and therefore investment required) of subsequent electrification projects.

We expect this transition could be completed between 2025 to 2030 and could reduce CO₂ emissions by around 350,000 tonnes per year.

The refineries collectively use 1.9 million tonnes of thermal coal each year to generate steam for the digestion process. Some steam could be generated by alternative fuels, including gas and biofuels, during the transition to renewable electricity sources. However, modifications to boilers and pipeline infrastructure would be required to use more gas in the refineries, and this is primarily challenged by limited availability of competitively priced gas.

It is also important to consider the investment required and the time that any alternative fuel sources will be used, as these are a transitional pathway and not a long-term decarbonisation option.

2 Upgrading energy with heat pumps and mechanical vapour recompression (MVR)

Approximately 25% of energy at the refinery is lost as waste heat through cooling towers, pump power and steam ejectors. If waste heat was recovered and upgraded, it would reduce the total energy required to generate steam for site demand. This technology is an energy multiplier and works by recovering waste energy (steam) otherwise vented to the atmosphere and compressing it to higher pressure. The recovery occurs at low temperatures, using relatively small amounts of energy, and allows waste steam to be recycled through the process.

Significant development and investment in heat pump and MVR technology is required to achieve the steam pressure levels required by high-temperature refining processes at QAL and Yarwun.

3 Fuel switching through electric steam generation

There are several technical options and projects to electrify the remaining steam requirements currently supplied by traditional fossil fuels, including coal and gas. The main challenges to electric steam raising projects are the economics and availability of stable, firm renewable energy from the Queensland grid at a competitive price, as well as the technology development required to operate at higher temperatures and pressures. The capital investment associated with new energy infrastructure to transport energy to both the region and to the refineries is significant.

3.1 Electric boilers

Coal-fired or gas boilers (or a combination) are the primary source of steam generation for the digestion process at alumina refineries. Electric boilers are an alternative option to generate electric steam, powered by economical, firm green energy.

Although electric boilers are a relatively mature technology, electric steam generation at the pressures and scale required for the high-temperature refining processes has not yet been developed. The treatment of process water for electric boilers presents an additional cost, specifically at QAL where condensate (steam condensed and captured) is of lower quality than Yarwun due to the digestion process design.

The main challenge with electric boiler technology is the availability and cost of firm renewable power requirements.

3.2 Thermal energy storage

There are many variations of this technology that allows energy to be stored and used on demand. It relies on heating large thermal masses, for example large blocks of concrete, when renewable electricity is available, allowing steam to be generated from this energy storage when renewable energy is not available. It decouples electricity use from steam production, allowing the refinery to work with grid operators to take advantage of intermittent renewable energy, reduce peak demand, manage costs, and allow rapid load response during periods of instability. This firming capability is expected to have mutual advantages for grid operators and Rio Tinto.

The current challenge for thermal storage technology is scale; the size and steam pressure, and the investment required. A key consideration is balancing the value generated from this investment in additional storage capacity with securing energy.

Calcination opportunities

The calcination process accounts for approximately 25% of the refineries' emissions, equivalent to approximately one million tonnes of CO₂ each year from QAL and Yarwun.

Calcination requires temperatures in excess of 900 degrees Celsius to remove chemically bound water in alumina. At QAL and Yarwun this process occurs in calciners that operate on natural gas. Substituting natural gas with green hydrogen has the potential to effectively calcine alumina and generate steam that can be reused in the refinery in a less carbon-intensive manner.

In July 2023, in partnership with the Australian Renewable Energy Agency (ARENA), Rio Tinto and Sumitomo agreed to build a hydrogen plant and retrofit process equipment at Yarwun to look to demonstrate the viability of using hydrogen in the calcination process.

Gladstone has been positioned as a Green Hydrogen Hub by the Australian Government and a number of large-scale hydrogen facilities for domestic consumption and export are proposed. If hydrogen calcination technology is successful, then the Gladstone refineries have the potential to be large-scale domestic customers supporting development of a green hydrogen industry. The technical and commercial lessons from these trials could potentially lead to implementation of hydrogen calcination across the alumina industry globally.

The economic price of hydrogen at scale for industrial use, which is underpinned by the availability of economically priced and firm renewable energy, remains the largest challenge with this technology.

Timeframe for emissions reduction

The challenge with these technology options is they require research and development and piloting, and subsequent deployment of, large-scale, competitive, firm renewable energy.

Due to development timeframes, this means that, with the potential exception of double digestion,

most of these projects do not result in significant emissions reductions for the Australian alumina refineries until after 2030.

In the interim, switching from coal to gas for steam generation and the potential to supplement with biofuels are under study to provide emissions reductions prior to 2030.

Policy backdrop

While business has a vital role in managing the risks and uncertainties of climate change, governments can support the challenge by providing enabling frameworks, including policy and regulations, which increase momentum towards shared net zero goals. Higher carbon prices and other forms of support are necessary to enable us to address harder-to-abate parts of our portfolio. However, these in isolation or on a standalone country basis in the absence of a global carbon price may not support global emissions reductions if they result in the offshoring of Australia's carbon emissions.

A range of policy measures are necessary to support early movers to innovate and deploy low-carbon technology in hard-to-abate sectors. Incentives, investment from, and partnerships with government and research partners are key to support industrial transitions and competitive green manufacturing. The available grant funding from the Australian Government (in addition to the Powering the Region Fund, Hydrogen Headstart and ARENA grants) needs to be commensurate with the level of capital investment required to transition to net-zero operations.

Transformative, leading-edge research and development is complex, and trials of low emissions technology are expensive. Collaboration and partnership between governments and industry through shared investment, grants and incentives, and creating forums and platforms to share ideas and expertise are important steps to support the technology required for the energy transition.

The successful reduction of emissions in our Australian alumina refineries relies heavily on the availability of large-scale renewable energy. Significant investment is required to structurally transform Australia's energy market and provide access to internationally competitive, large-scale, and reliable renewable energy over the long term, which will need to be shared between governments and industry. Australian governments should also directly provision large-scale transmission to support rapid electrification, while preserving competitiveness. Without access to firm renewable power, it is challenging to justify significant long-term capital investments in energy-intensive Australian manufacturing facilities with low profit margins.

Governments and industry should work together through the energy transformation to ensure the future renewable electricity needs of industry are included in demand modelling and appropriate frameworks exist to ensure long-term guaranteed supply for domestic industrial users.

To decarbonise the calcination process stage in the refineries with green hydrogen, we rely on the continued support from the Federal Government to develop external infrastructure and markets near domestic industrial users. It will be important to continue to prioritise the Gladstone region as a hydrogen hub and provide associated Federal Government funding to develop green hydrogen projects here to ensure cost-competitive renewable energy for our alumina refineries and the broader industry. The Hydrogen Headstart program is a positive step, however, program funding will likely need to be increased by an order of magnitude and use be quarantined to future-facing domestic industrial production to support rapid decarbonisation. And, while the focus on positioning Australia as a hydrogen exporter is understood, we consider that hydrogen is most effectively used where it is produced.

Transitioning to a low-carbon future requires diverse skills and expertise, including increased research knowledge, and renewable energy installation and construction skills. Key to meeting this demand will be investing in these skills early through educational and vocational training, allowing flexibility for gaps to be filled internationally through efficient skilled migration programmes, and creating vibrant accessible regional hubs with attractive community infrastructure and housing. Additionally, investments should be phased over time to support access to appropriately skilled labour for both government and private sector projects, while also underpinning the competitiveness of capital-intensive investments.



RioTinto