AUSTRALIAN ALUMINIUM COUNCIL LTD

Alumina

Australia Will Help Develop Low Carbon Alumina Refining Technologies For The World

Primary aluminium is made from an ore called bauxite, which is refined to make alumina before being smelted to make aluminium.

It takes 4-6 tonnes of bauxite (depending on the grade) to make **~2 tonnes of alumina**, which then makes 1 tonne of aluminium.

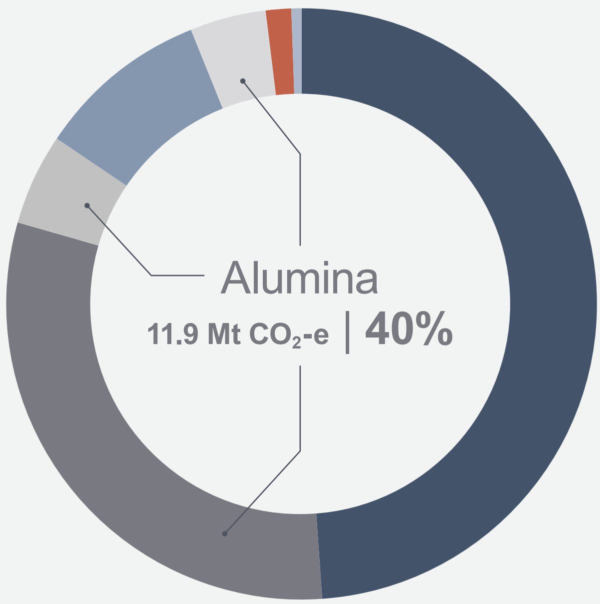
Australia is the world's second largest producer and largest exporter of alumina. We produce ~20 Mt of alumina a year, about 85% of which is exported and 15% is turned into aluminium here in Australia. Australia has more than 60 years of technical experience in bauxite mining and alumina refining technologies. This experience helps not only us, but our customers of bauxite, alumina and aluminium, to reach their sustainability goals. Global research headquarters for alumina for Alcoa, Rio Tinto and South32's Worsley Alumina operations are based in Australia, helping develop new technologies for the world.

Australian Renewable Energy Agency (ARENA)[1], in consultation with Australia's alumina refineries, has prepared a roadmap which considers the technical, commercial and market implications for emerging low emissions alumina refining and identifies key pathways to emissions reduction.

Australia's alumina already has some of the lowest emissions in the world, with an average emissions intensity for alumina of **<0.68 t CO_2-e/t** compared to the global industry average of 0.89 t CO_2-e/t [2].

However, as Australia is a large producer of alumina, it forms a large part of the Australian industry's emissions footprint, at **12.0 Mt CO_2-e**, or just around **40% of the aluminium industry's emissions**. As Australia is where global low emission alumina trials are being conducted, Australia is leading technologies for the adaptation of brownfield alumina refineries to even lower carbon technologies.

2024 Industry Emissions



	(Mt CO_2-e)
Aluminium - Indirect	14.6
Alumina - Direct	**9.1**
Alumina - Direct (Calcination)	**1.5**
Aluminium - Direct (Other)	2.8
Alumina - Indirect	**1.3**
Bauxite	0.4
Aluminium - PFCs	0.2

Alumina Refining

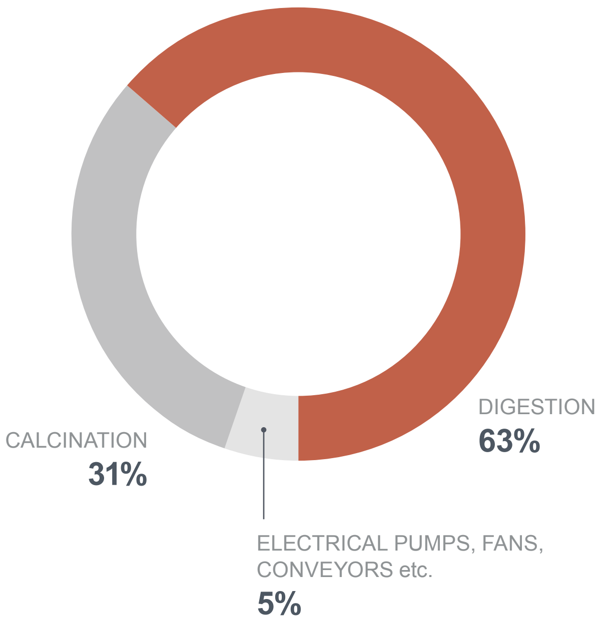
The Bayer refining process used by alumina refineries worldwide involves four steps - **digestion**; **clarification**; **precipitation**; and **calcination**.

1. During digestion, bauxite is finely ground in mills, then mixed with a caustic soda solution and steam in digester vessels operating at high temperature (150-270 degrees depending on the ore used) and pressure to dissolve the alumina content of the bauxite.
2. The impurities which remain undissolved are removed during clarification.
3. Alumina crystals are precipitated from the caustic solution by mechanically stirring the solution in open-top tanks.
4. The precipitated material (called hydrate) is calcined at temperatures exceeding 1,000°C to form aluminium oxide (alumina).

Generally, bauxite from southwestern Australia requires lower temperatures for digestion than bauxite from northern Australia. This means that technology applications may differ by source of bauxite, as well as refinery configuration for existing refineries.

Alumina refining is an energy intensive process, using about 11.5 GJ / t produced. Digestion and calcination are the two most energy intensive steps, with digestion consuming around two thirds of this energy. Currently, this energy is largely derived from gas and coal, as well as electricity. All of Australia's alumina refineries have some combined heat and power generation (cogeneration) facilities which use coal, gas, or biomass fuels. This cogeneration results in the refineries using, and in some circumstances, where the co-generation is large scale, exporting low emissions electricity. About 5-10% of the alumina refinery's energy is used in electrically driven pumps, fans and conveyors.

Energy Use (GJ / t)



Alternate Technologies

Electrification

There are a number of potential pathways which would enable renewable electricity to be used as the primary source of energy in alumina refining.

- Swap of existing electricity supply to the refineries to partial use of renewable energy.
- Mechanical Vapour Recompression (MVR) which uses electricity to drive mechanical vapour compressors to upgrade waste steam. Using renewable electricity for MVR would displace fossil fuel derived thermal energy. MVR technology is widely used in other industries.
- Electric boilers can be used to generate steam and are commercially available for low to medium pressures. However, these are only likely to be commercially competitive when combined with an existing planned capital replacement and renewable energy. Electric boilers are currently being piloted in the alumina industry in Canada, Brazil[3] and Ireland[4]. Technology for high pressure electric boilers is at early stages of development.
- Electric calcination is currently being tested by Alcoa in Western Australia.
- ARENA estimates that 3-5 GW of new firmed renewable energy supply would be required to power potential low emissions technologies and/or to produce sufficient renewable hydrogen.

CALCINATION ELECTRIFICATION CASE STUDY

Electric pressure calcination produces pure, uncontaminated steam exhaust, which can be captured and reused, reducing demand for steam from natural gas boilers. Electric calcination could potentially reduce Australian alumina refining emissions by 40% when powered by 100% renewable electricity. Alcoa is undertaking a $19.7 M project in conjunction with ARENA ($8.6 M) and the WA Govt ($1.7 M) to test this process. The project also aims to improve understanding of load flexibility and the provision of essential systems services to the South West Interconnected Grid (SWIS)[5].

Alternate Energy Sources

Cogeneration plants can be co-fired on biomass[6]. Despite the technical feasibility of this option, the volume of biomass required given the high heat requirements for alumina refineries is limiting.

ALTERNATE ENERGY SOURCES CASE STUDY

Worsley Alumina completed a biomass trial in 2018. The pre-feasibility trial tested the use of waste from pine logging, referred to as biomass, as a renewable energy fuel in its multi fuel cogeneration facility, trialling the use 30 per cent biomass fuel load. During the trial, the suitability of the current infrastructure, storage locations, material movement and handling, and boiler feed systems were analysed to understand what role biomass can play in the biomass long-term energy mix for Worsley Alumina.

Hydrogen

The industry is currently investigating options which include the production[7] and use of renewable hydrogen in its processes, particularly in calcination, as the required temperatures would be difficult to achieve with electrification. Additionally, hydrogen could potentially be used to replace gas in boiler technologies for digestion.

HYDROGEN CASE STUDY

In 2021, Rio Tinto commenced a technical feasibility study investigating the use of renewable hydrogen as part of the strategy to decarbonise alumina refining at Rio Tinto's Yarwun alumina refinery in Gladstone. This was partially funded by ARENA[8].

In 2023, Rio Tinto and Sumitomo Corporation signed an agreement to build a first-of-a- kind hydrogen plant in Gladstone as part of a A$111.1 million program aimed at lowering carbon emissions from the alumina refining process. The Yarwun Hydrogen Calcination Pilot Demonstration Program is partially funded by ARENA[9] and is aimed at demonstrating the viability of using hydrogen in the calcination process. Construction started 2024. The hydrogen plant and calciner are expected to be in operation by 2025.

Electricity, Demand Response and Thermal Storage

Alumina refineries already provide some demand response to the grid. However, if there was to be an increased supply of competitively priced zero emissions electricity, there is the potential to materially increase the electrification of alumina refineries combined with demand response, which could supplement electricity firming. Electrification of alumina refineries would materially impact total grid demand, with a large fully electrified alumina refinery potentially consuming electricity of the same order of magnitude as a smelter (i.e., ~1,000MW of electricity).

Thermal storage is a particularly important enabling technology as it provides refineries with greater flexibility to reduce grid electricity imports during periods of high electricity pricing or a lack of renewable generation capacity. This ensures reliable power supply to refineries to sustain operations and improves the overall business case of low emissions technologies by mitigating uncertainty of long-term power prices and volatility.

Summary of Pathways

The biggest pathways for decarbonising the alumina refining industry lies in the decarbonisation of the grid, and the increased electrification of refinery processes, using internationally competitive, low or zero emissions electricity.

TECHNOLOGY SOLUTION	STATUS[10]
READY Grid Connected Electricity	Grid connected refineries may be able to offer some demand management. Increased electrification would substantially increase grid demand. The grid has increased penetration of renewable energy. Potential for commercial contracting arrangements to allow more rapid decarbonisation of electricity supply[11].
Electric Boilers	Technologically deployable, although not yet commercially viable in Australia (dependent on electricity cost). Industry pilot underway. Reduces emissions when combined with decarbonised electricity supply.
Mechanical Vapor Recompression	This technology is untested for alumina refining and may be better suited to lower temperature digestion. Reduces emissions when combined with decarbonised electricity supply.
Electric Calcination	Currently only at test stage. Reduces emissions when combined with decarbonised electricity supply.
Concentrated Solar Thermal	This technology provides a pathway to produce renewable steam to offset refinery steam.
Thermal Energy Storage	This technology provides a pathway to produce renewable steam by converting renewable electricity to heat stored in a thermal mass. Currently at research and development stage.
Bioenergy Cogeneration	Technically viable for up to 30% co-firing but industry-wide deployment limited by biomass availability.
Hydrogen for Digestion	Not currently being trialled. There are also uncertainties relating to the long-term cost, scale and supply for green hydrogen.
Hydrogen for Calcination	Currently at the pilot trial stage. There are also uncertainties relating to the long-term cost, scale and supply of green hydrogen.

1 https://arena.gov.au/knowledge-bank/a-roadmap-for-decarbonising-australian-alumina-refining/
2 https://www.alcoa.com/sustainability/pdf/2023-Sustainability-Report.pdf#page=28
3 https://www.hydro.com/en/global/media/news/2021/hydro-makes-final-build-decision-on-alunorte-fuel-switch-project/
4 https://www.alcircle.com/news/rusals-aughinish-alumina-refinery-secures-eu-funding-to-reduce-carbon-footprint-68947
5 https://arena.gov.au/projects/alcoa-renewable-powered-electric-calcination-pilot/
6 https://www.south32.net/news-media/latest-news/worsley-alumina-biomass-trial
7 https://www.riotinto.com/en/news/releases/2023/rio-tinto-and-sumitomo-to-build-gladstone-hydrogen-pilot-plant-to-trial-lower-carbon-alumina-refining https://arena.gov.au/projects/yarwun-hydrogen-calcination-pilot-demonstration-program/
8 https://arena.gov.au/projects/rio-tinto-pacific-operations-hydrogen-program/
9 https://arena.gov.au/projects/yarwun-hydrogen-calcination-pilot-demonstration-program/
10 Partially derived from Energy Transitions Initiative, Phase 2 Technical Report available from https://www.energy-transitions.org/publications/australian-industry-eti-phase-2-report/
11 https://www.riotinto.com/en/news/releases/2024/rio-tinto-signs-australias-biggest-renewable-power-deal-as-it-works-to-repower-its-gladstone-operations