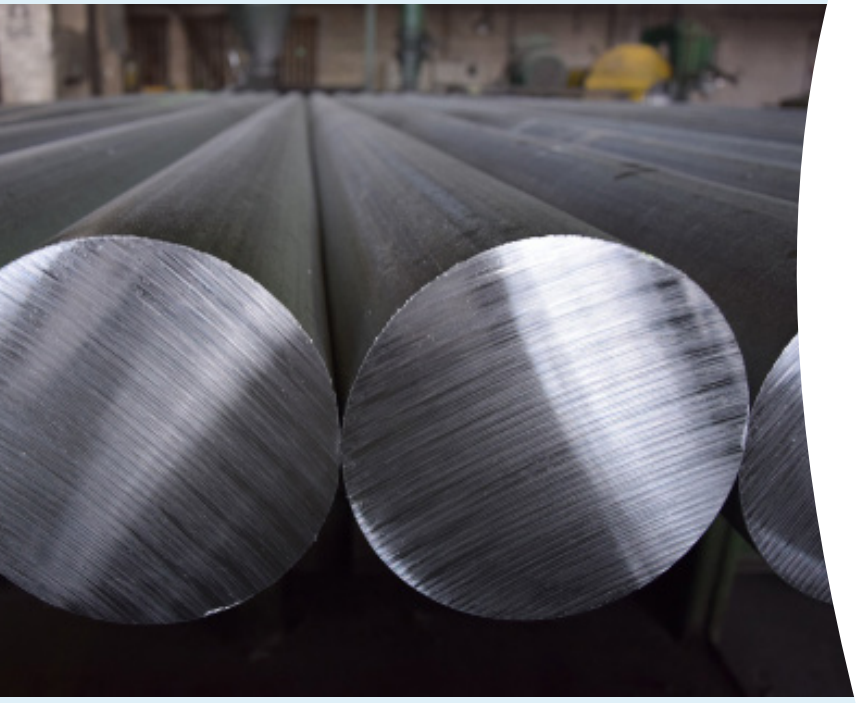
TransitionAsia

ACCELERATING EAST ASIAN CORPORATE CLIMATE ACTION

EXPLAINER—

ALUMINIUM PRODUCTION, DEMAND, DECARBONISATION OPPORTUNITIES FOR THE SECTOR

January 2025



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CONTENTS

Introduction 2

Production Processes 2

Primary Aluminium Production 2

Secondary Aluminium Production 5

Demand 6

Evaluating the Aluminium Process Abatement Potential and TRLs Focus Needs to be on Scrap & Renewable Energy 7

INTRODUCTION

Aluminium is a lightweight, corrosion-resistant, highly malleable and infinitely recyclable material. It can be easily spotted in daily life from beverage cans to vehicle frames, building facades, grid lines and renewable energy facilities. Aluminium production is an energy intensive process accounting for around 2% of global GHG emissions. China accounts for the lion share of global primary aluminium production currently standing at 60%. [1]

PRODUCTION PROCESSES

Aluminium can be made either via primary production or secondary production. In primary production, new aluminium is made out of bauxite ore while the latter is made out of recycled aluminium scrap. Primary production is energy-intensive mainly due to large electricity consumption with average GHG intensity at 14.8 tCO_2e/t Al.[2]

Secondary production, the production of aluminium from scrap, is made without going through an energy intensive processes such as alumina refining and aluminium smelting. It has significantly lower processing intensity, averaging just below 1 tCO_2e/t Al.

PRIMARY ALUMINIUM PRODUCTION

After the mining of bauxite, core production steps include alumina refining, and aluminium smelting.

ALUMINA REFINING

Bauxite contains soluble and insoluble impurities such as quartz, hematite and rutile. Bayer process is the principal industrial means of refining bauxite to produce alumina that is pure enough for aluminium electrolysis. Alumina refining is the second energy intensive process, at 2.4 tCO_2e/t Al;[3] nevertheless, 90% of its energy consumption comes from fossil fuels (Figure 1).

Bayer process includes 4 steps:

Digestion Process

Bauxite ore is finely-grounded and mixed with a caustic soda solution, then steamed in digester vessels operating at high temperature, ranging from 100–300°C, and pressure. The resulting solution is a sodium illuminate solution, commonly called slurry. Soluble impurities such as silica will be removed by reacting with caustic soda.

Digestion Process Energy and Emissions

Digestion consumes more than half energy used in alumina refineries, most of it from onsite combustion of gas and coal. To decarbonise the process, electric boilers are a relatively mature technology especially in low temperature environments (TRL 9) but to operate at the pressure

1 "Primary Aluminium Production." International Aluminium Institute, 18 Nov. 2024.

2 "Primary Aluminium Greenhouse Gas Emissions Intensity." International Aluminium Institute, 18 Nov. 2024

3 Same as footnote 2

required for high temperature (around 50 bar, TRL 4–5) has not been proven commercially.

Clarification

The aim of this process is to further remove solid impurities via physical means. The slurry obtained from digestion goes through several flash tanks to reduce pressure and temperature before it is pumped to a settling tank where the solution is clarified via physical means such as in a rotary. The insoluble residuals, commonly known as red mud is filtered out of the slurry and sent to a disposal pond. The clarification process is also known as settling.

Precipitation

It is the process in which small aluminium hydrate crystals undergo cementation to form larger particles. The filtered solution is pumped through a series of six-story tall precipitation tanks. Seed crystals are added and cause cementation of small aluminium hydrate crystals. They settle through the solution and dissolve alumina attached to them then grow to larger agglomerated crystals. The output of this step is aluminium hydrate.

Clarification and Precipitation Energy and Emissions

The clarification and precipitation process together accounts for around 5% of total energy consumption in alumina refining. The subsequent emissions from these processes are small compared to the overall primary aluminium production process.

Calcination

The aim of calcination is to dry off chemically bonded water from aluminium hydrate to obtain alumina. This is achieved by heating aluminium hydroxide in a calciner at around 1000°C.

Calcination Energy and Emissions

Calcination is the second large energy intensive process due to high temperature needed accounting for around 30% of energy consumed in the refinery. Current decarbonisation methods focus on fossil-fuels replacement with electricity, heat or hydrogen. For example, electric calciners (TRL 4), solar process heat (TRL 6–7) and hydrogen calcination (TRL 4) are all nascent technologies undergoing industrial pilot studies.

ALUMINA SMELTING

Aluminium Smelting Process

Aluminium smelting is the process of extracting aluminium from its oxide. CO_2 is emitted by reaction with a carbon anode, and aluminium is collected as liquid metal at this step. The refined alumina is dissolved in a bath of molten cryolite (sodium aluminium fluoride) and other materials at temperature around 960–980°C. Anodes are attached to rods and suspended into the electrolytic cells in the pot. A high electric current is then passed through pots via the anode maintaining the temperature at about 950°C and enabling the alumina to split into aluminium and oxygen.

Aluminium Smelting Energy and Emissions

The Aluminium smelting process has the highest GHG intensity in primary production at around 11 tCO_2e/t Al.[4]This process alone accounts for 3% of world electricity demand and 7% in China. Fossil fuels remain the primary source of electricity used in smelting, with coal accounting for 50% globally

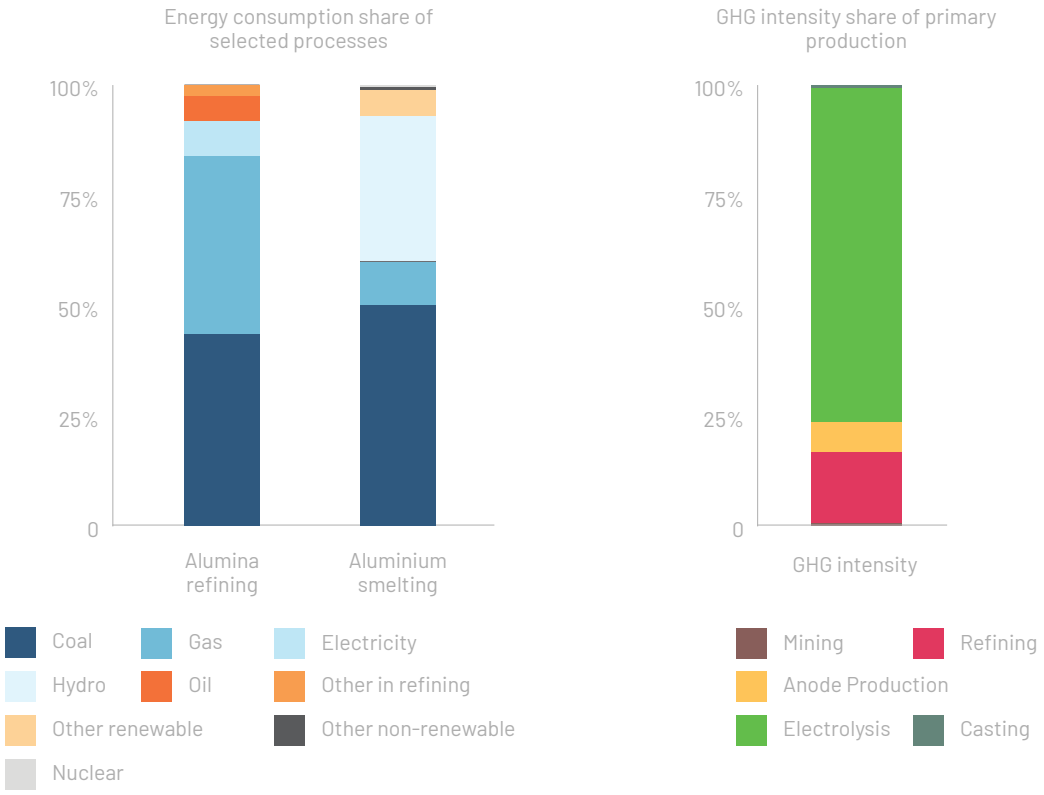
4 Same as footnote 2

(Figure 1), more than 80% of which is consumed in China. The carbon anode emits carbon dioxide as byproducts when consumed during the smelting process.

Aluminium smelting is a continuous electrolytic process that requires significant quantities of electrical energy. The key to decarbonisation is to increase renewables energy (TRL 9) consumption share. By shifting to 100% renewable energy for this process, 80% of global aluminium electrolysis related emissions can be reduced.

Replacing carbon anodes (TRL 7) with inert anodes is another aspect in decarbonising primary aluminium production as inert anode emits oxygen instead of carbon dioxide as byproducts. Research into using inert anodes has decades of R&D behind the technology however scaling this to be used in commercial functions has so far remained elusive.

Figure 1. Share of Energy Consumption and GHG Intensity of Different Stages in Primary Aluminium Production



Source: International Aluminium Institute, TA analysis

SECONDARY ALUMINIUM PRODUCTION

SECONDARY ALUMINIUM PRODUCTION PROCESS

Secondary aluminium, composed of various types of scrap, goes through a sequence of different processes. This typically involves processes such as shredding, crushing, sorting, de-coating which removes coatings like paint and plastic from surfaces before being loaded to a large furnace, a re-melter. Once the secondary aluminium is re-melted, an additional purification process takes place typically utilising chlorine and nitrogen gas. Auxiliary alloys are then added according to the required grade of aluminium wanted.
In theory, aluminium can be remelted and cast infinitely without compromising quality and with minimal loss. In reality, various treatments are needed to remove impurities based on scrap types:

Types of Aluminium Scrap

Old scrap / Post-consumer	Scrap resulting from collection systems after the final product has been used and scrapped.
New scrap	Scrap within the supply chain after semis production.
Internal scrap	Scrap within semis production and after the cast house. It typically has internal scrap loop processes, where common alloys are recycled backwards to their upstream supply.
Pre-consumer scrap	New and internal scrap.

Post-consumer scraps are normally and thus collected in combination with various metals such as steel, copper and zinc. Compositional information is the key for a smooth impurification process, otherwise, the most common solutions are downgrading or diluting with primary aluminium to make higher-alloyed scrap. This leads to negative economic outcomes due to added cost, inferior quality of final products, and often, lower sales price.

SECONDARY ALUMINIUM ENERGY AND EMISSIONS

Increasing scrap use might be the most viable solution for aluminium industry decarbonisation in the near future as average scrap processing CO_2 intensity is lower than 1 tCO_2e/t Al.[5] In China, scrap's energy consumption is approximately only 6% of primary aluminium production.[6]

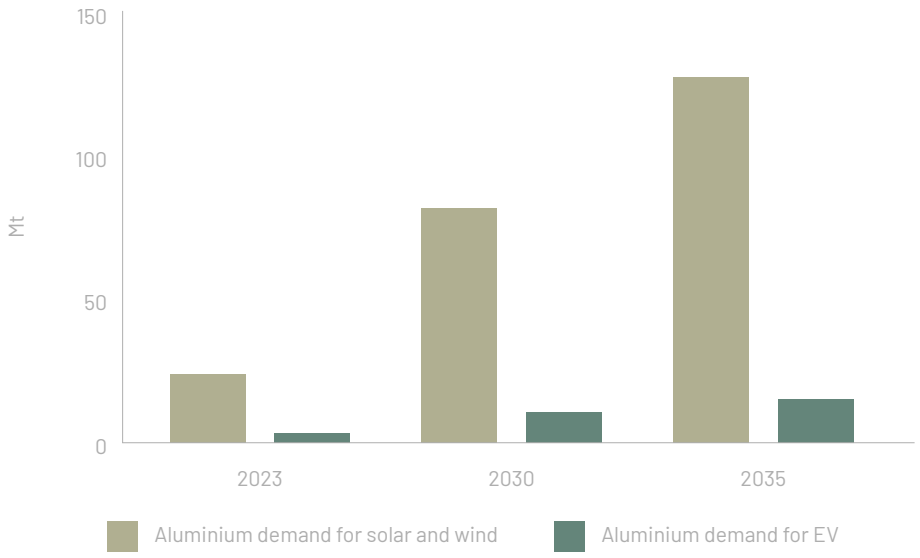
5 Same as footnote 2
6 Peng, Tianduo, et al. "Life-cycle analysis of energy consumption and GHG emissions of aluminium production in China." Energy Procedia, vol. 158, Feb. 2019, pp. 3937–3943, https://doi.org/10.1016/j.egypro.2019.01.849.

DEMAND

Globally, aluminium demand is driven strongly by the transport and construction sector today each accounting for 30% and 20% followed by electrical applications and packaging. In China, aluminium is widely used in construction, contributing to 32.8% of the total demand in 2023. As the property crises slow down new constructions, the transport sector is rapidly increasing demand currently contributing 25% of the total demand. The electrical sector is the second fastest growing sector following transport contributing 16% of current demand.

Energy transition is the backbone of continuous demand growth. Aluminium demand for renewable energies (solar PV and wind) and electric vehicles (EV) is set for a fivefold increase to 2035 (Figure 2). The expansion of solar and wind energies means increasing aluminium demand in solar PV's modules, mounting, inverters and cells as well as windmills nacelle, internal and external facilities. Due to aluminium's nature of high corrosion resistance, it is also a popular material for floating technologies such as floating offshore wind power or floating solar power systems. EVs, the key decarbonisation lever for the road transport sector, use more aluminium than traditional internal combustion engine vehicles. In vehicle structures, aluminium can reduce weight while maintaining durability. In battery housing, aluminium is an optimal choice for its thermal conductivity and lightweight.

Figure 2. China's Solar and EV Growth and Corresponding Aluminium Demand, 2023–35



Source: IEA WEO2024, CRU Opportunities for aluminium in a post-Covid economy, TA analysis

Note: Projections are based on IEA Global Energy and Climate Model's Stated Policies Scenario. EVs include plug-in hybrid electric vehicles and battery electric vehicles.

EVALUATING THE ALUMINIUM PROCESS ABATEMENT POTENTIAL AND TRLS FOCUS NEEDS TO BE ON SCRAP & RENEWABLE ENERGY

Aluminium is making its unique contributions to support the clean energy transition as it not only reduces an increasing block in global emissions but also decarbonises the skyrocketing build-out of solar photovoltaics, wind turbines and EVs. Tapping this potential requires actions from international initiatives to raise awareness and collective efforts to minimise the barriers for renewables electricity access as well as improve scrap recyclability. Multiple international efforts are made to decarbonise the aluminium industry. The Aluminium Stewardship Initiative has been working on globally applicable standard settings and certification systems for aluminium value chain. Aluminium International aluminium institute launched Aluminium Industry Greenhouse Gas Initiative at COP28 committing to report aluminium industry global GHG emissions and tracking companies' emission targets. First Movers Coalition is another initiative led by the World Economic Forum. Members commit to procure 10% low carbon aluminium by 2030 and are encouraged to use secondary aluminium. In the short term, aluminium primary production processes need easier access to clean electricity either through building captive renewable power plants or via grids through power purchase agreements. Scrap utilisation rate should also be improved to achieve rapid emission reduction. In the longer term, decarbonisation technologies need further development and investment to level up its TRL before reaching commercial scale.

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