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China Primary Aluminium production: Headwinds and Tailwinds for Decarbonisation

China is the world's largest producer of primary aluminium and long-term demand for this material is expected to rise.

With China's electric vehicle sales hitting 9.5 million units in 2023 (40% of global sales), demand for high-strength alloys could grow 15% annually through 2030. Additional drivers of aluminium consumption include solar PV frames, wind turbine nacelles, and grid expansion.

China's grid infrastructure must triple by 2050 to meet its decarbonisation goals, requiring 5 million tons of aluminium annually for cables and components[1].

Meeting this demand comes with environmental challenges. The smelting process alone accounts for 7% of China 2023 electricity demand with 70% of power consumption stemming from coal.

The abundant availability of domestic coal resources and the logistical convenience of transportation have firmly established fossil fuel as a dominant energy source, not only within China's electricity generation mix but also as the preferred option for aluminium plant operators with captive power plants.

In China, more than 80GW of captive coal power plants are still in use, accounting for 6% of the country's total coal capacity installed.

Regions with the highest captive power production – Shandong, Xinjiang, and Inner Mongolia – rely almost exclusively on these plants, with minimal need for grid electricity. These plants are extremely polluting. In 2021, the total emissions from all the captive plants are three times higher than the total emissions from Chinese aluminium smelters using grid electricity.

More than 50% of captive power capacity for aluminium production is still based on inefficient, subcritical combustion technology. If existing plants continue to operate at current levels and without effective, deep abatement retrofits or fuel changes, the resulting total locked-in emissions would be almost 18 times the current annual aluminium sector emissions in China. Without a phaseout of captive plants, emissions are set to grow until a peak in 2045. **Fig 1**.

While reducing reliance on captive coal plants may seem like a pathway to lower emissions, shifting to grid electricity presents its own challenges. The average grid emission intensity in the top three aluminium-producing provinces is 0.65 kg CO_2/kWh, higher than the national average, and six times higher than Yunnan where grid electricity is the cleanest thanks to its abundant hydropower resources. As a result, Yunnan has attracted many aluminium companies over the past few years. The second largest aluminium company in China, China Hongqiao Group, explicitly stated in its annual report

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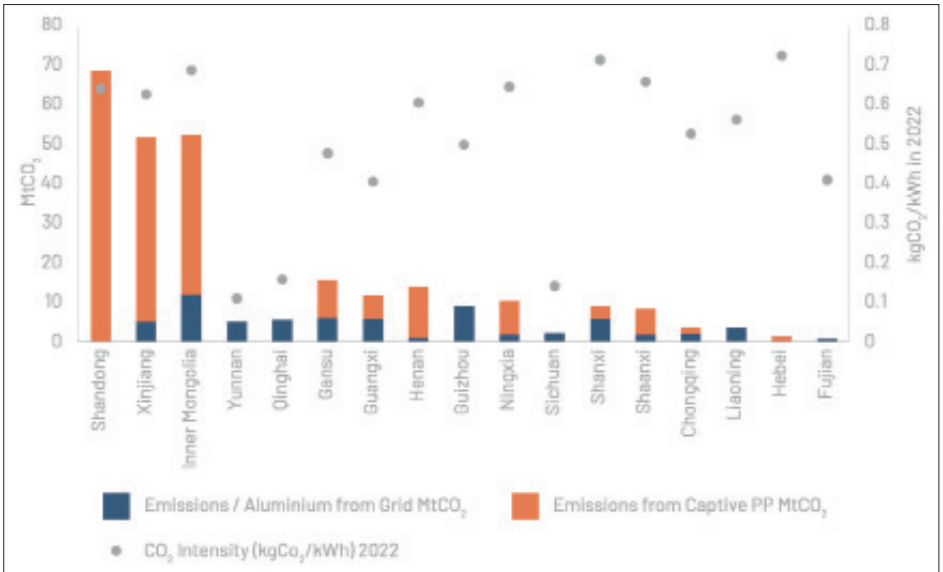

Fig 1. Emissions by types based on provincial production and correspondent grid CO_2 intensity
Note: Provinces in the x-axis are in descending order based on production from left to right Source: MEE[2] , Tan et al., 2025[3] , TA analysis

the intention to transfer capacity from Shandong to Yunnan.

By 2022, of the 6.46 million tons of compliant electrolytic aluminium capacity held by Weiqiao Chuangye Group (a subsidiary of Hongqiao Group), approximately four million tons had been relocated to Yunnan for the development of hydropower-based aluminium production.

Unfortunately, hydropower in southern China is not a quick or long term fix for the aluminium industry's decarbonisation. Frequent droughts in the southeast have led to unstable hydropower supply, making electricity shortages increasingly prominent. During the dry seasons of 2022 and 2023, electrolytic aluminium companies were forced to reduce or halt production multiple times as local governments prioritised electricity for essential public needs. This has put power supply for high-energy-consuming industries, particularly regional electrolytic aluminium production, under greater uncertainty.

Ensuring that zero carbon renewable electricity powers the sector is the most material lever available to setting primary aluminium production on a decarbonisation trajectory.

By shifting to 100% renewable energy for this process, 80% of global aluminium electrolysis related emissions can be reduced.

China has set corresponding targets requiring the green electricity share in total electricity consumption for the industry to reach 21% - 70%, varying by provinces. Companies are also stepping up on building captive renewable plants. For instance, Yunnan Aluminium has launched 175.4 MW distributed PV projects across six industrial parks and 80% of the power used for production is green.

Additionally, Inner Mongolia Jinlian Aluminium and Henan's Yulian Industrial Park have completed solar PV projects of 80 and 40 MW separately.

Despite these developments, the aluminium industry is still facing obstacles and is misaligned with a net zero pathway.

Headwinds

Coal-fired power dominates smelting operations in China. Captive coal plants, which account for 6% of the total installed coal capacity, exacerbate emissions. The plants using outdated subcritical technology are still relatively new and if unaddressed, could lead to locked-in emissions, derailing China's carbon neutrality goals. While these plants secure stable and low cost electricity they are expensive to retrofit or phase out, making them a persistent challenge.

While grid electricity offers a costlier alternative to cheap captive power, it is not a quick fix if regional grids remain dependent on coal-fired plants. Shandong, Xinjiang, and Inner Mongolia – responsible for 60% of production – rely on grids with average emissions intensity 25% above the national average.

This is due to the high proportion of coal fired power plants delivering power to the grid in those provinces. Hydropower-rich provinces with lower grid intensities are no longer an easy option for decarbonisation. Seasonal shortage in rainfall and regular curtailment to industries are expected to remain as the effects of climate change compound. The aluminium sector needs long term, stable electricity supply from zero carbon sources.

Policy Constraints

China's aluminium smelting capacity is approaching its 45-million-ton ceiling, with new projects requiring strict capacity swaps[4]. Under the capacity swap system, new additions can only be built when old capacity is phased out. This adds to the administrative burden and some companies may lack the necessary capacity quotas or capital for demolishment and rebuilding.

The current electricity market in China is still underdeveloped and lacks a market-based mechanism, limiting baseload renewable energy options for aluminium smelters. It also remains a challenging environment for sourcing corporate PPAs and there is little recognition of a renewable power plant's ability to provide ancillary services.

Even with China's Emission Trading System (ETS) being implemented across the power and aluminum sector, the impact may be limited. If benchmarks do not become more stringent over time, the allowance surplus is likely to continue, pushing the carbon price downward and ultimately limiting the original decarbonisation goal.

Tailwinds

Green Energy Transition

Integrated projects are being developed to combine renewable energy with the aluminium industry in one region. For instance, Inner Mongolia's Green Electricity-Aluminium clusters are using wind and solar power to replace coal. Yunnan Aluminium installed 175 MW of rooftop solar, cutting costs and emissions. Meanwhile, policies continue to add pressure to aluminium companies to increase renewables consumption by setting targets, requiring minimum green electricity use in aluminium smelting. Stricter environmental regulations including tiered electricity pricing and China ETS are raising costs to coal power usage[5]. Significantly, captive coal power plant expansion is banned and a phase-out of old capacities has begun.

A contract-for-difference (CfD) mechanism will apply to new renewable projects built after June 2025, with auction-based pricing expected to further reduce costs. A market-driven power system benefits renewables paired with storage, allowing for arbitrage – charging when prices are low and discharging at peak demand. While still in transition, China's evolving market structure could provide the ingredients set to improve cost competitiveness for renewables, as long as policies ensuring coal power plants dominance are simultaneously restricted[6].

Turning Tariffs into an Advantage

The recent US tariff hike on aluminium could accelerate China's decarbonisation efforts by redirecting trade to climate-conscious markets. This policy raised the aluminium tariff to 25% and cancelled tariff exemptions to Canada and Mexico. Around 15% of Chinese aluminium products exports are under direct threat by this policy.

Those exports can be absorbed by countries such as Australia, UK and southeast Asian countries which are among China's top destinations today and also have mechanisms favourable to decarbonisation.

For instance, Australia is reviewing the feasibility of a Carbon Border Adjustment Mechanism (CBAM), Thailand is drafting a climate change bill incorporating CBAM and the UK plans to implement its own CBAM by 2027.

These emerging carbon border policies present an opportunity for Chinese aluminium companies with lower carbon footprints to gain a competitive edge when exporting to these markets.

China's ETS

While the power sector ETS already covers most captive coal plants supplying aluminium smelters with electricity, its impact has been limited due to lenient benchmarks and low trade volumes. That said, after three years of power sector implementation, the intensity of thermal power plants has decreased marginally. The reward-penalty mechanism has been established and added carbon costs to companies. The recent inclusion of the aluminium sector targets direct emissions, including CO_2, CF_4, and C_2F_6, mainly from anode effects in electrolysis[7].

Initial free allowances and delayed benchmarking will limit short-term effects until after 2027. However, if the regulatory design of the ETS evolves to reward low-carbon aluminium production for its emissions profile and penalise high-carbon production, decarbonisation of the sector should follow.

In the longer term, if stringent benchmarks are set and allowance auctions introduced, this policy could act as the most material decarbonisation measure for industrial decarbonisation in China. ■

1. https://www.iea.org/reports/electricity-grids-and-secure-energy-transitions/executive-summary
2.https://www.mee.gov.cn/xxgk2018/xxgk/xxgk01/202412/t20241226_1099413.html
3. https://www.nature.com/articles/s41558-024-02193-x
4.Capacity can be swapped via mergers and acquisition, capacity transfer within company or capacity quota trading.
5.Tiered electricity pricing is a progressive pricing mechanism based on electricity intensity of smelting process. The higher the intensity, the higher the electricity price charged to aluminium companies. Before this, aluminium companies could enjoy preferential electricity tariffs offered by local governments.
6.https://www.rechargenews.com/opinion/chinas-reforms-show-renewables-can-hold-their-own-but-it-s-not-yet-a-fair-fight/2-1-1778209
7.https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202503/t20250326_1104736.html