The Decarbonisation Journey of the Aluminium Industry – Opportunities and Challenges to Achieve Net-Zero

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Abstract

The aluminium industry plays a critical role in the decarbonisation of many sectors of society, but it is also a significant contributor to global greenhouse gas emissions. The challenge for the industry is to continue enabling positive developments while minimising negative environmental impacts. The production process for aluminium generates three primary sources of GHG emissions: CO_2 emissions from electricity production for the electrolysis process (65 %), direct emissions from the smelting process (12 %), and fuel consumption for calcination, melting, and heating purposes (23 %). However, decarbonisation of the entire supply chain through renewable energies, biomaterials, inert anodes, carbon capture and storage (CCS) etc., is possible. The paper provides a high-level overview of the steps, costs, and necessary policies to transform the aluminium industry to become carbon-neutral and achieve Net-Zero solutions. Furthermore, aluminium has the potential as an energy carrier due to its energy density, transport safety and economics, and storage capacity. The industry can contribute to the fight against climate change and help decarbonize society by providing massive amounts of aluminium required for Net-Zero emissions in transport, energy generation/storage/distribution, building, and packaging. Aluminium is the third most abundant element in the earth's crust, and its exploration is less abrasive to the environment than the extraction of alternative metals (e.g., copper). Aluminium smelters can help to transport renewable energy via aluminium instead of hydrogen, making it relevant for new greenfield smelters or regions with potential surplus renewable energies. The paper also highlights the low-carbon aluminium trends and industry targets, such as establishing a green premium for low-carbon aluminium products. However, accounting loopholes and relabelling of renewable electricity may hinder the creation of a substantial low-carbon aluminium premium early in the cycle.

Keywords: Net-Zero, Variable renewable energy (VRE), Carbon capture and storage (CCS), Hydrogen, Energy carrier.

1. Introduction

Reducing GHG emissions and mitigating climate change has become paramount to governments, societies and NGOs. The aluminium sector has been an early adaptor of concepts and transparency. The industry has focused on energy efficiency in the last 50 years, which made sense in terms of resource conservation and economics. The Club of Rome and the idea of peak oil marked the previous 50 years. The question hovered around the concept of conventional energy resource scarcity. However, we learned in the last 20 years that peak oil was delayed and that coal reserves are plenty for the following centuries. We also learned that absolute scarcity is the deposition level of CO_2 in the atmosphere. Hence, CO_2 emissions need to be the leading indicator, and energy efficiency can be a sub-category if supportive of CO_2 savings.

Aluminium production is an energy-intensive process that contributes to greenhouse gas emissions. It accounts for 4 % of global electricity consumption and 3 % of global GHG emissions, mainly from power generation. The specific CO_2 emissions from aluminium smelting range from 2.5 to 25 tonnes per tonne of aluminium, depending largely on the energy source used. The shift in the power mix, with a decrease in hydroelectric power and an increase in coal-based electricity, has contributed to the rise in CO_2 emissions from the aluminium sector over the past 40 years. The following chart (**Figure *1***) displays this trend:

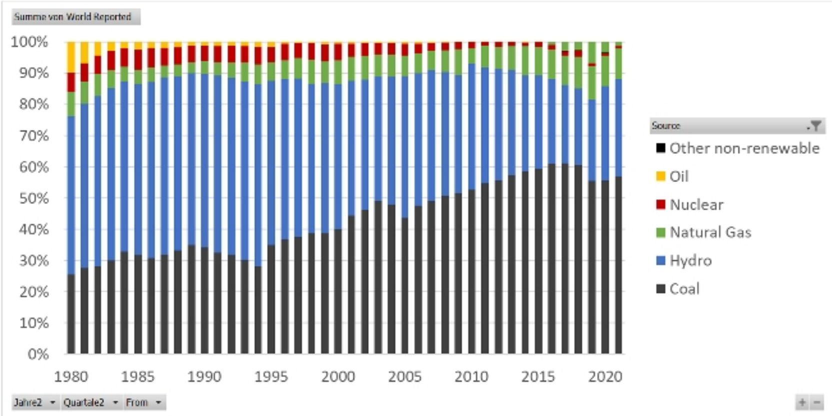

Figure 1. Primary aluminium smelting power IAI statistics 2022 [1].

Global efforts to address global warming led to establishing of the Intergovernmental Panel on Climate Change (IPCC), the Kyoto Protocol, and the Paris Agreement. The Greenhouse Gas Protocol was developed in the private sector to measure, report, and reduce company-specific emissions. The protocol introduced the concept of "scopes" to categorise direct and indirect emission sources.

The industry is now moving towards reporting total emissions along the entire value chain, including all three scopes. The International Aluminium Institute (IAI) has provided guidelines for reporting emissions at different levels, with Level 3 being the Cradle-to-Gate disclosure that covers the entire aluminium production process. The IAI has also published decarbonisation scenarios, such as the B2DS and 1.5DS, which set emission reduction targets for the industry.

Figure *2* shows the different scenarios that IAI has published on its website, “Aluminium Sector Greenhouse Gas Pathways to 2050” [2]. The blue line shows the historical development of the Cradle-to-Gate emissions for primary aluminium between 2005 and 2018. Based on IEA scenarios, the forecast scenarios use a top-down approach and calculate the emission targets based on the maximum bubble emissions from the sector. The B2DS (red triangles) targets 14.5 t/t in 2030 and 2.5 t/t in 2050, while the 1.5DS (red circles) achieves 11.5 t/t in 2030 and 0.5 t/t in 2050.

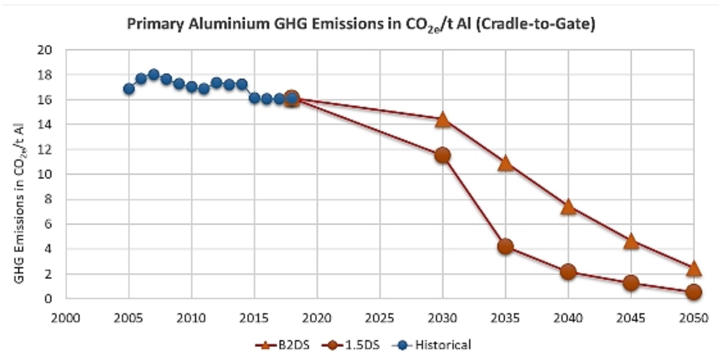

Figure 2. IAI decarbonisation scenarios for primary aluminium [2].

There will be different strategies for existing facilities and new greenfield investments. Existing facilities are generally (partly) written off and bear a lower cost pressure than greenfield investments. However, their location is fixed, and thus they need to deal with their current environment. This needs to be addressed by policies to create low-carbon incentives for existing facilities and low/zero-carbon incentives for greenfield investments. The advantage of greenfield investments is the ability to choose the best location and act with the highest degree of freedom for the design.

Markets, Politics and Industry need to get a feeling/vision for the decarbonization cost of the industry, which consists of additional upfront CAPEX and ongoing OPEX. In the long run, the costs need to be borne by the market, while during the first transition, it could be necessary that the extra costs are subsidized by Governments.

What can/should be paid by the customer/user?

- Direct Emissions in Smelting are roughly 1.5 t CO_2/t Al. Additional GHG emissions from other Scope 1 and Scope 3 (upstream) contribute a minimum of 1 t CO_2/t Al, resulting in 2.5 t CO_2/t Al. Thus, a price tag of 100 \$/t CO_2 would result in extra costs of 250 \$/t or 10 % of the current LME market price for primary metal. This would be the order of magnitude for CCS and could decarbonise this part of the value chain. It would also represent an incentive for inert anode projects and low carbon alumina.

What should be paid/supported by Governments?

- The integration of renewable energies into aluminium smelting and alumina refining should be supported by Governments with direct subsidies (CFDs), CAPEX and financial guarantees.
- Infrastructure for renewable energies (transmission grids and hydrogen hubs) should be supported and financed by Governments to create competitively priced backup capacities

What should be paid/borne/developed by Producers?

- Producers are required to decarbonize the upstream production with competitive renewable heat, bio-gas and electricity
- Producers need to develop and supply flexibility and other demand response services in response to their access to competitively priced VRE

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