A Case Study for Emissions Free CPC

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Abstract

For aluminium smelters operating with emissions free power like hydroelectric, nuclear and renewables, the carbon raw materials supply chain accounts for around 15 % of the total smelter CO_2 footprint. The calcined petroleum coke supply accounts for 85 % with the balance from coal tar pitch. Work aimed at reducing CPC related emissions can have a meaningful impact on the smelter CO_2 footprint and this paper provides a review of calciner CO_2 emissions including a carbon capture solution.

The two primary contributors to CPC emissions are green petroleum coke (GPC) production (40 %) and calcination (60 %). Rain Carbon (RC) has done a substantial amount of work to quantify calciner process emissions. A key enabler was the development of a method which utilizes online CO_2 concentration and flowrate analyzers to quantify emissions in real time. Reducing GPC fines carryover during calcination is a key means of reducing CO_2 emissions. The calciner technology, operating conditions and GPC quality also play a key role.

CO_2 capture and storage can be used as a final reduction method. RC has undertaken a detailed capital and operating cost analysis to add a CO_2 capture system to its Lake Charles Calciner. The plant is located less than 20 km from a qualified CO_2 sequestration site in Louisiana and would qualify for US CO_2 sequestration tax credits. Relative to a smelter, CO_2 can be captured more efficiently at a calciner due to higher CO_2 concentrations. The technology exists today to execute a project like this, but the primary challenge is achieving a satisfactory return on investment. Without a price premium for low-CO_2 CPC, the investment return remains a major hurdle.

Keywords: Carbon, Anode, CO_2 Capture, Petroleum coke, Decarbonization.

1. Introduction

The amount of work being done around the world to decarbonize the primary aluminium production is growing rapidly. In its 2021 report [1], the International Aluminium Institute makes estimates of the emissions reductions needed by the aluminium industry to help the world achieve a 1.5 °C global warming limit by 2050. Collectively, the industry will need to reduce scope 1-3 emissions from 1.1 billion tonnes in 2020 to 53 million tonnes in 2050 representing a 95 % reduction. Decarbonizing the power supply represents the biggest opportunity but improvements will be required across the entire supply chain. Production of aluminium from recycled scrap will also need to grow to 81 million tonnes to support the 1.5 degree warming limit.

The contributors to scope 1-3 emissions for primary aluminium production have been well documented [2, 3, 4]. In a 2022 study [5], a detailed breakdown was provided for the Alouette primary aluminium smelter which operates with 100 % hydroelectric power. The total scope 1-3 emissions per tonne of aluminium were estimated at 3914 kg CO_2. Smelter direct emissions from anode consumption, fluoride emissions, anode baking and casting represented 47 % of the total and the alumina supply chain contributed 35 %. The next largest contributor was scope 3 emissions related to production of carbon raw materials used for anode production – calcined petroleum coke (CPC) and coal tar pitch (CTP). The paper provided a further breakdown that showed ~85 % of the carbon raw material emissions were due to CPC and GPC (green petroleum coke) production.

The purpose of this paper is to provide a more detailed review of the contributors to CO_2 emissions for CPC production. As more researchers undertake detailed CO_2 footprint studies, the need for reliable data on scope 3 emissions is increasing. Aluminium smelters making estimates of their scope 1-3 emissions are now turning to raw material suppliers to help provide this data. A recent paper [6] provided the first detailed product carbon footprint analysis of graphitized cathode blocks and this is a good example of the sort of data needed by aluminium smelters.

Rain Carbon (RC) operates six calcining plants in the US and two in India and has studied CO_2 emissions in detail to look for reduction opportunities. In 2022, RC started to investigate online measurement of CO_2 emissions for comparison against emissions calculated using a mass balance approach. The results of some of these studies will be presented in this paper. Carbon capture remains the only way to substantially reduce (> 90 %) calciner CO_2 emissions and the technology is available today, albeit at high capital and operating costs.

2. Review of Calciner Emissions

An overview of the calcining process and GPC production is provided in a 2015 review paper [7]. The primary goal of calcination is to remove volatile matter (VM) from GPC which is typically at levels of 9–13 %. At normal calcining temperatures (1250–1350 °C), the VM level is reduced to < 0.2 % in CPC. The VM level and composition varies by coke type, but all GPC contains carbon, hydrogen, nitrogen, oxygen, sulphur, and trace metals like vanadium and nickel. Table 1 shows some typical ranges for C, H, N, and S in GPC and CPC. Oxygen levels are not measured directly but calculated by subtracting the sum of C, H, N, S and ash levels from 100 %. The table also shows the average change in C, H, N, and S levels from GPC to CPC for a wide range of samples.

Table 1. Typical ranges for GPC and CPC

	GPC %	CPC %	% Change GPC to CPC
Carbon	86–92	92–97	+ 6.5
Hydrogen	3.4–4.4	< 0.2	- 98
Nitrogen	1.3–2.5	0.8–1.5	- 38
Sulfur	0.3–6.5	0.3–5.7	- 10

A detailed description of the chemical species generated during VM loss has been described previously [8] but the condensable tars, methane and hydrogen evolved are eventually combusted to form CO_2 and H_2O in the kiln and pyroscrubber. As shown in Table 1, nearly all the hydrogen in GPC is lost during calcination. Some sulphur is also lost [9] and the amount varies as a function of the GPC S level and temperature and is typically 7–8 % for low S cokes and up to ~15 % for high S cokes (> 5 % S). The loss of nitrogen and oxygen varies by coke type but is significantly lower than the loss of H.

Most calciners operate with strict emission limits for SO_2 and many also have NOx emission limits. At RC, five of eight calcining plants use SO_2 scrubbers to reduce SO_2 to permitted levels. The extent of SO_2 removal varies by plant and depends on the permit limit and the sulphur level required to achieve target real densities. This will be eliminated once rates exceed ~85 % of the design level.

Calciners that operate with a higher yield of CPC per tonne of GPC have lower CO_2 emissions and changes that reduce GPC fines carryover have a positive benefit on reducing CO_2 and SO_2 emissions. WHR in combination with SO_2 scrubbing has a significant benefit for society in reducing SO_2 emissions and net CO_2 emissions. Calciners that operate with these systems offer a more sustainable solution for production of CPC.

Carbon capture technology offers the potential to substantially eliminate calciner CO_2 emissions and is both proven and available today. The paper presents a case study for a carbon capture option at the Lake Charles calciner which could be fully powered by the WHR system. The technology comes with a high capital and operating cost however and would not be feasible without a significant price premium for a low CO_2 CPC product.

The other long-term option which would eliminate CPC emissions and all smelter related anode emissions is inert anode technology. It is not clear if this will ever be successfully developed and implemented however, and the broader industry must continue to work on all options to reduce supply chain emissions.

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