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Towards Carbon Neutral Primary Aluminium Smelting via Carbon Dioxide (CO_2) Capture

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Abstract

There is a growing awareness that primary aluminium smelters must reduce the Scope 1 direct-related GHG emissions of the smelting processes. In this study, the options of CO_2 capture technology for these Scope 1 reductions in lowering the GHG footprint will be discussed.

Since the use of carbon anodes as a leading technology is still in the forecast for many decades to come, technology is needed to reduce the direct CO_2 emissions from the electrolysis process. Presented will be the potential of the application of CO_2 capture from pot ventilation gases. This is challenging, and shown will be what hurdles need to be overcome and how to integrate this technology in a smelter operation to arrive at a good, viable technical solution and economically feasible capture of CO_2. A review of worldwide activities in this industry is provided and reveals that this is all new. Therefore, comments are provided about how the application of CO_2 capture technology can be moved closer to commercial implementation. A technology roadmap is suggested, along with comments on how not only suppliers, but the industry must work together to advance the development of CO_2 capture processes.

Keywords: Carbon capture and storage (CCS), Carbon neutral aluminium, Greenhouse gas emissions (GHG), GHG footprint, CO_2 capture, primary aluminium.

1. Introduction

All industries are affected by measures to combat climate change. The primary aluminium industry is not different and must introduce changes to reduce its GHG emission impact. If we focus on primary aluminium smelting, the use of carbon anodes is a critical part in the equation. There is no question that the Holy Grail is to be able to operate the electrolysis process with inert anodes but there is now a common belief that we are still some years away before ~~we see~~ large scale commercial application of the technology will be possible. An important question for an existing smelter is "Is it possible to convert the traditional process to the inert anode process?" and if so can, "When can the conversion be realized and at what cost?". Today, there is no answer to those questions. What is known is that options are needed so alternative strategies can be evaluated. In this paper, the focus is on the option of applying (post) CO_2 capture technology for the direct process emissions from the electrolysis process.

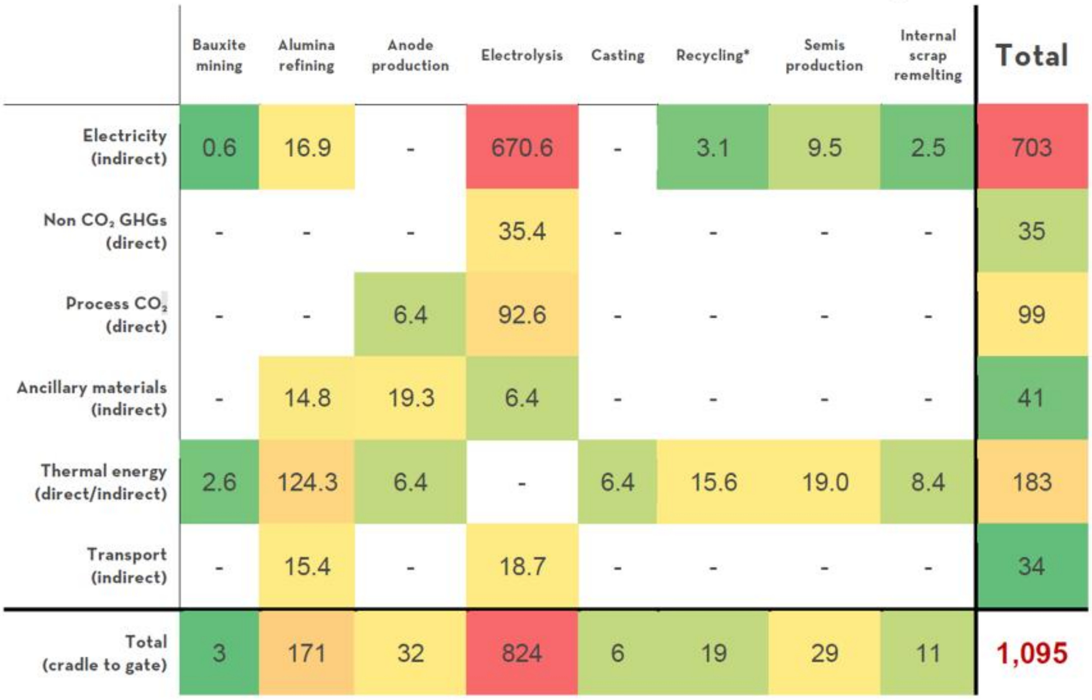
2. GHG Emissions from the Aluminium Industry

First, it must be identified in what position, with respect to GHG emissions from the aluminium as a whole. A lot of good work is done by the International Aluminium Institute (IAI) to provide a large amount of information on this and other relevant topics. It is recommended to visit their website to retrieve a copy of their documentation. Using this, only a short summary is required as an introduction.

To put things in perspective, according to the International Aluminium Institute (IAI), the global aluminium industry emits an equivalent amount of CO_2 of 1.1 billion tonnes per year [1]. That contributes to 2 percent of the total GHG emissions from all industrial sources.

A breakdown is provided in the following table:

Table 1. 2018 Total Aluminium Sector Emissions (Mt CO_2eq) [1].



	Bauxite mining	Alumina refining	Anode production	Electrolysis	Casting	Recycling*	Semis production	Internal scrap remelting	Total
Electricity (indirect)	0.6	16.9	-	670.6	-	3.1	9.5	2.5	703
Non CO_2 GHGs (direct)	-	-	-	35.4	-	-	-	-	35
Process CO_2 (direct)	-	-	6.4	92.6	-	-	-	-	99
Ancillary materials (indirect)	-	14.8	19.3	6.4	-	-	-	-	41
Thermal energy (direct/indirect)	2.6	124.3	6.4	-	6.4	15.6	19.0	8.4	183
Transport (indirect)	-	15.4	-	18.7	-	-	-	-	34
Total (cradle to gate)	3	171	32	824	6	19	29	11	1,095

From this data it is directly clear that the largest contribution is made by the electrolysis process. In the next section, this is looked at in more detail, also because the objective is to capture the CO_2 from the process gases.

3. GHG from Aluminium Reduction

3.1. General Overview

For a smelter, the breakdown is well known and was reported many years ago by Lorentzen et al. [2]. The following table is retrieved from this publication:

Table 2. Life-cycle GHG emissions from a modern primary aluminium smelter [2].

Source	Hydro Electric Power	Gas-fired Power	Coal-fired Power
Unit	kg CO_2 eq/kg Al	kg CO_2 eq/kg Al	kg CO_2 eq/kg Al
Alumina production	1.80	1.80	1.80
Anode production	0.30	0.30	0.30
Electrolysis - Carbon	1.50	1.50	1.50
Electrolysis - AE	0.30	0.30	0.30
Casthouse	0.06	0.06	0.06
Electric power	0.00	5.80	13.60
Total	**3.96**	**9.76**	**17.56**

Looking at the data, it can be recognized that there are direct emissions (Scope 1) and indirect emissions (Scope 2). The management of a smelter needs to address them all, but that requires can be overcome by further development of technologies. However, a large bottleneck exists in the design of electrolysis cells, and this will require significant changes in the design to make it work at high temperatures.

A new technology concept is pot gas recirculation with localized scrubbing on cells and integrated cooling. If this works as intended, then this is a potential solution to allow reduced gas flows from cells while maintaining temperatures where they are today. The concept is being tested on a small scale and a pilot is expected very soon.

A key conclusion is that CO_2 capture can be installed with the technical means we have available today. It will be applied at levels of 1 volume percent CO_2, but this can be done with standard solvents like MEA. It may not be the most economic approach yet, but there is still a lot to learn, and it is unknown where the development will take us.

The road map for CO_2 capture is basically starting with piloting solvent-based processes like with MEA. From this some scale up steps are required before we arrive at a commercial scale; however, in other industries the technology is already applied at commercial scale so many learnings of that are available to developers.

The road map also holds the development of enabling technologies. These are key technologies that can remove key bottlenecks. For example, the heat exchangers need to move into a new operating range to extract a lot more heat from the gases than is currently the case.

On the short term, there is likely to be a first pilot plant in France at Aluminium Dunkerque. This will be based on a solvent process and integrated with a GTC. Aluminium Dunkerque does have a baking furnace connected to one GTC so we may see the combination at work. Other than that, there are only a few developments in this field.

9. References

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