Estimating the CO_2 Intensity of a Novel HPA Process

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Abstract

Impact Minerals is developing a new process that will produce High Purity Alumina (HPA) from a lacustrine clay feedstock. The carbon footprint of the project must be estimated before the project can be undertaken. There are two main processing routes under consideration, known as the Sulphate process, and the Low Temperature Leach (LTL) process. The Scope 1 and Scope 2 emissions for each process were predicted using research and calculations. The emissions associated with the Sulphate Process were 4.5 tonnes of CO_2 per tonne of HPA produced, and 3.1 tonnes of CO_2 per tonne of HPA for the LTL Process. The CO_2 emissions were calculated based on the mass of fuel required, multiplied by an emission factor for that fuel source. Electricity was assumed to be sourced from the South West Interconnected System (SWIS), which has its own associated emissions. The CO_2 emissions under a scenario using SWIS were also compared with a renewable energy case, where all SWIS electricity was assumed to be renewable energy. The emissions associated with the Sulphate process reduced to 1.3 tonnes of CO_2 per tonne of HPA, and the emissions associated with the LTL process reduced to 1.4 tonnes per tonne of HPA.

1. Introduction

Impact Minerals is developing a novel process to produce High Purity Alumina (HPA) using a lacustrine, alunite feedstock from playas in South-Western Australia. The unique physical and chemical properties of alunite render it liable to dissolution and conversion to HPA, with Impact Minerals identifying it as potentially economic.

HPA is the high purity form of alumina and is in high demand, demanding high prices. Four nine, or 4N, HPA, which is 99.99% pure, is the target of this project, and demands prices between \$20,000 USD/tonne and \$30,000 USD/tonne. 4N HPA has a high thermal conductivity, 30W/mK, and a high electrical resistivity, $>1\times10^{14}$ ohms-cm (Superior Technical Ceramics, 2021). This makes it useful as a coating for lithium-ion batteries, acting as a cathodic separator (Critical Minerals Group, 2023). It's also used in the production of synthetic sapphire, predominantly used to create substrate wafers for Light Emitting Diodes (LEDs), phosphor production, as a catalyst, and as a catalyst support structure due to its high porosity and therefore surface area.

Most high purity alumina is currently produced via the alkoxide process. In the alkoxide process, aluminium alkoxide is synthesised from aluminium and alcohol through dissolution

(ISE, 2021), and then is purified via hydrolysis and calcination (Altech Batteries Ltd., 2023). This process has an extremely high carbon footprint particularly due to the 'double' calcination required; one stage during processing the smelter grade alumina, and another stage to produce the HPA. One of the advantages of Impact Minerals' processes are the potentially lower CO_2 emissions.

The carbon footprint of the project is important, as CO_2 emissions have a detrimental effect on the environment, contributing to global warming, which will affect the sustainability of the process. It is also important from an economic point of view, as there are government regulations regarding, and taxation surrounding carbon emissions. The aim of this project was to estimate the scope 1 and 2 emissions of these two processes, and to compare the results.

2. Methodology

The Project is considered to consist of three major physical complexes; a mine where ore is excavated and stored on a Run of Mine (ROM) stockpile; a transport complex involving the transport of ore to the processing plant and, reagents, products, by-products, and wastes from the processing complex; and a processing complex where ore is converted into products, wastes and emissions. For CO_2 emissions accounting, the project will be split into 4 main sections, mining emissions, transport emissions, processing emissions and imported emissions. The processing stage was divided into further substages as it is the most complex and requires the most steps. A portion of the emissions were also assigned to the by-product streams, as the emissions were not relevant to producing HPA. Simplified representations for each process are show in Figure 1 and 2; note that transport is also inclusive of transporting products.

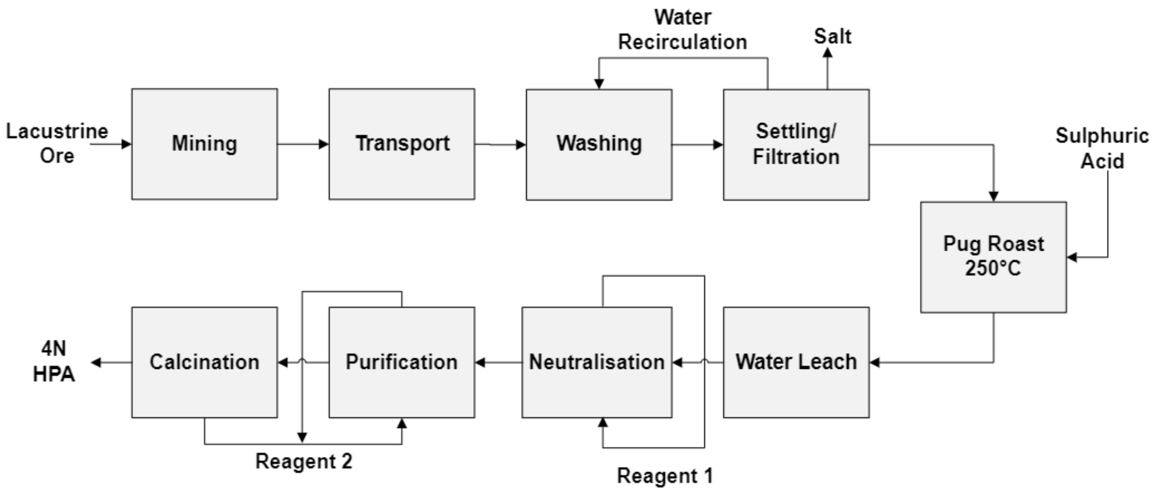

Figure 1 Basic block process flow diagram for the Sulphate process.

2.1 Mining

The mining stage includes the CO_2 emissions from combustion of fuel by vehicles used on the mine site and the electricity used on the mine site, as a Scope 2 emission. It accounts for all the emissions associated with extracting the ore from the earth, until it is loaded onto a truck to be transported from the mine site to the processing plant. The mining stage emissions were calculated using fuel consumption data from a study done by The Mining Engineer (van Anen, 2023), multiplied by an emission factor for the fuel type (diesel) to determine the associated

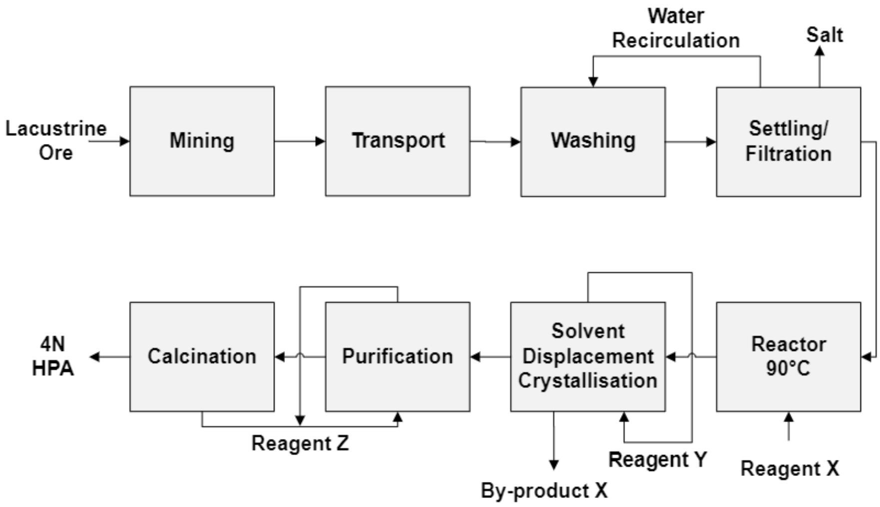

Figure 2 Basic block process flow diagram for the LTL process.

emissions. At this stage in the study, the two processes being considered are not expected to differ significantly in the ore feed requirement, hence mining stage emissions are estimated to be the same for each process, at 0.01 tonnes of CO_2 per tonne of HPA produced.

2.2 Transportation

The transportation stage includes the transport of all feedstocks, reagents, products, and fuel within the project. The products must be transported to the point of sale, and the reagents and feedstocks from the point that they are purchased from. It was assumed that diesel trucks would be used to transport material. A diesel consumption rate was calculated using journey details and typical truck fuel consumption from the Truck Impact Chart (Australian Trucking Association, 2018). The Sulphate process was predicted to emit 0.3 t CO_2/t HPA, and the LTL process, 0.2 t CO_2/t HPA.

2.3 Processing (Sulphate Process)

The processing stage was the most complex to estimate as the energy consumption from each stage of the process had to be estimated, and an emission factor for the associated energy source was then used to calculate the CO_2 emissions. the two energy sources used were either electricity from the SWIS, or natural gas. The energy use for each stage was generally estimated either using previous work done by Sam Salter (Salter, 2021), which modelled the process in HYSYS, or, via calculations of heating/cooling requirements using specific heating capacities and heats of reaction. The Sulphate Process was divided into a washing/filtration, roasting, leaching, crystallisation, purification and calcination stage. The energy requirement from the crystallisation stage was deemed to be negligible due to the nature of the reaction.

2.4 Processing (LTL Process)

The CO_2 emissions for the LTL Process were estimated using the same methodology. The LTL process was divided into a washing, leaching, crystallisation, purification and calcination stage. The roasting stage could be omited in the LTL Process. The washing, purification and calcination stages are virtually identical for each process, hence the same values were used.

The major difference in the LTL process was the lower energy requirement since there was no roasting at 250°C, that step being replaced by a leach at 90°C.

2.5 Renewable Case

The CO_2 emissions were also estimated for a case where the SWIS is supplied by 100% renewable energy. To calculate the emissions, the SWIS emission factor was changed to zero. It was assumed that all vehicles were still fuelled by diesel, meaning that if the project could use electric, or hybrid vehicles, the emissions could be reduced further. The other portion of the remaining emissions were from the calcination stage, which currently can only be done using natural gas.

3. Results

The total CO_2 emissions associated with HPA for the Sulphate Process were 4.5 t CO_2/t HPA, shown in Figure 3. The processing stage was clearly the most CO_2 intensive, with the calcination stage being associated with 1.2 t CO_2/t HPA. Therefore, a large focus should be on maximising the energy efficiency of the processing plant.

The total estimated CO_2 emissions for the LTL Process are 3.1 t CO_2 /t HPA, significantly lower than the emissions associated with the Sulphate Process. Again, the calcination step has the highest emissions factor, not changing between the Sulphate and LTL Process since the two processes are virtually the same at that stage.

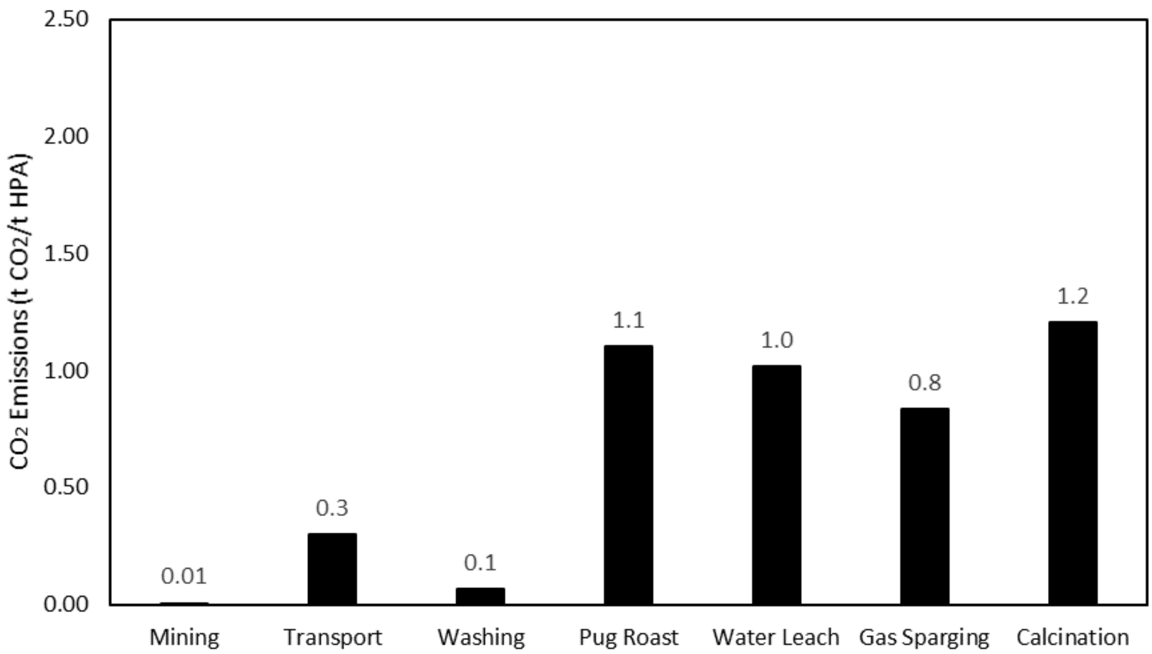

Figure 3 Sulphate Process CO_2 emissions associated with HPA.

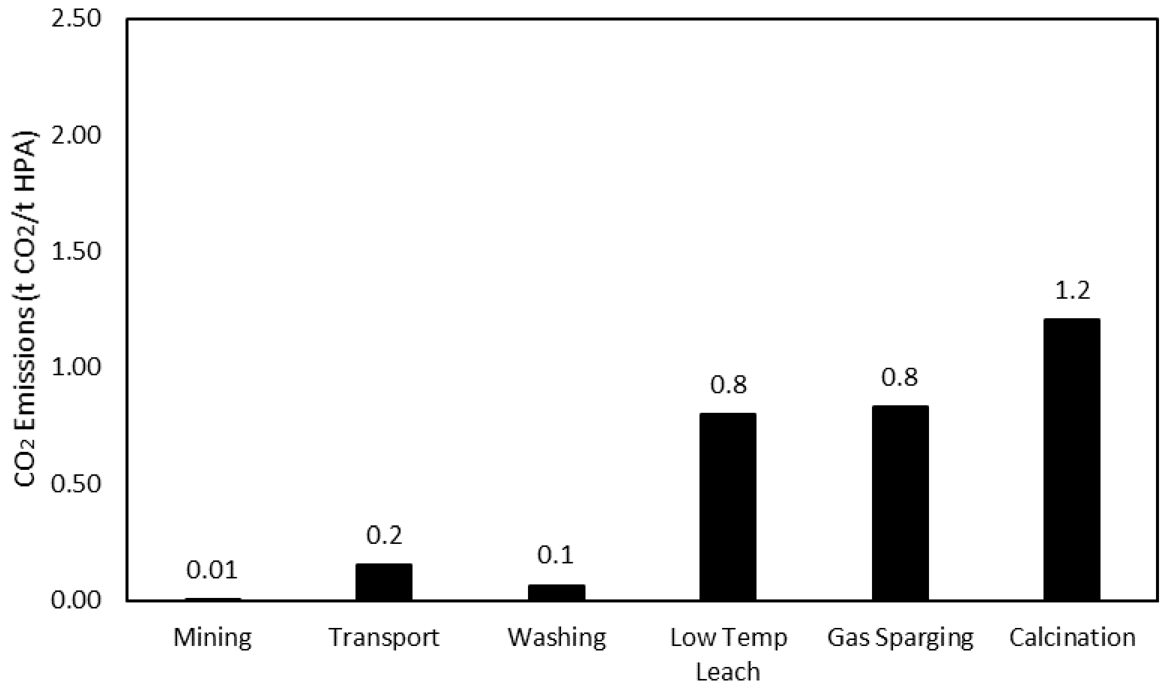

Figure 4 Low Temperature Leach CO_2 emissions associated with HPA.

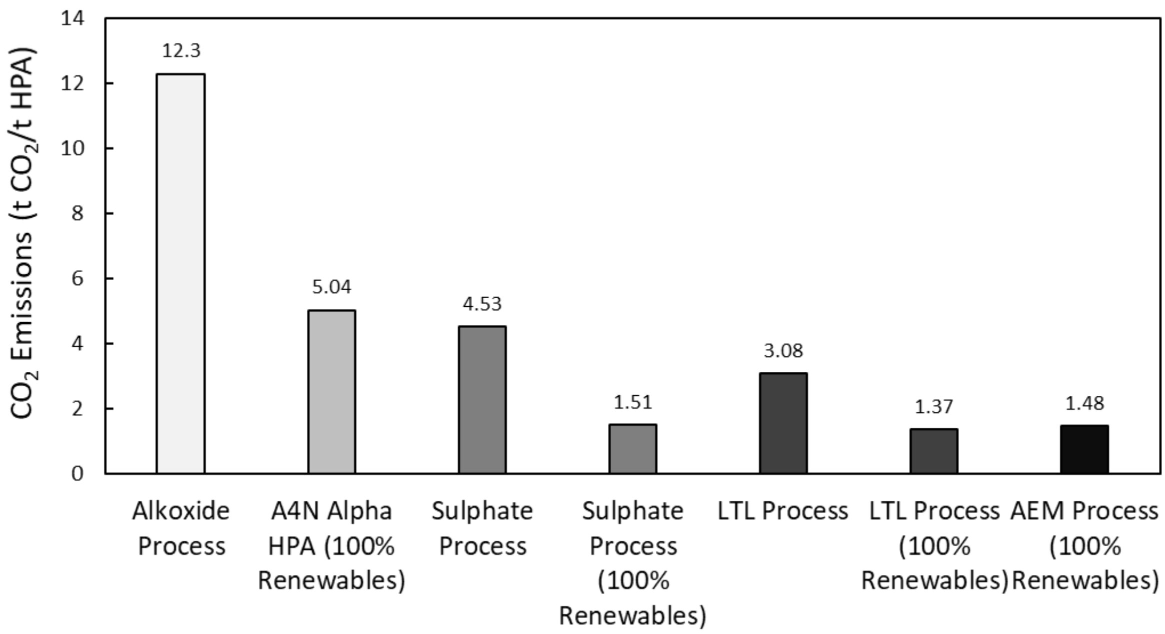

Figure 5 Summary of CO_2 emissions for the Sulphate and LTL process compared to other processes. (Alpha HPA, 2021; Foster, 2023)

The overall emissions for each process are considerably lower than the incumbent alkoxide process, as shown in Figure 5. Figure 5 also shows that the LTL process has lower CO_2 emissions than the Sulphate process, and that if 100% renewable electricity can be used, each process would be amongst the lowest CO_2 footprint HPA projects worldwide. Due to the nature of the calculations for these estimates, and the uncertainty surrounding some stages of the two processes, the error margin in these estimates is ±30%.

4. Conclusions

Out of the two processes proposed by Impact minerals, the LTL process appears to be the more feasible option in terms of carbon dioxide emissions and energy use. The LTL Process is predicted to produce 3.1 tonnes of CO_2 per tonne of HPA, compared to 4.5 tonnes per tonne for the Sulphate Process. Both options are modelled to produce less CO_2 emissions than the prevalent alkoxide process, as well as other competitors. With a move to 100% renewable electricity, either of these processes could be among the lowest CO_2 producing HPA processes worldwide. The estimate is of feasibility level accuracy, adhering to the principles of CO_2 reporting as much as possible at this stage. These results show that this project has potential to be one of the lowest carbon footprint options for producing HPA.

5. Further Work

The results of this report give a baseline estimate for the CO_2 emissions for this process, however further work needs to be done to refine this work as the processing route evolves and the specific unit operations are defined. The recommendations for further work are as follows:

1. Perform heat integration to refine the energy consumption estimate.
2. Estimate the energy requirement for recovering HCl after gas sparging.
3. Determine the energy use and CO_2 intensity of the by-product circuit.
4. Forward model the SWIS to establish the pathway to 100% renewable electricity.

6. References

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