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**MINING RESEARCH**  
HIGH PURITY ALUMINA  
SUPPLY & DEMAND  
HPA TECHNOLOGIES  
PEER GROUP ANALYSIS  
-STAGE OF DEVELOPMENT  
-PFS/DFS RESULTS  
-VALUATIONS  
COST COMPARISONS  
CONCLUSIONS



**Client:** InterGroup  
Mining

12 March 2020

## Kaolin to HPA processing technologies

### Review and analysis of the currently available technologies

- ❖ **Disruptive technologies allow kaolin to be processed into High Purity Alumina.** Kaolin is an aluminium rich fine white clay which results from the natural weathering of feldspathic rocks like granite. Several juniors have made great strides in advancing kaolin to HPA processing technologies and the first commercial plants are now starting to be built. The traditional route to HPA is expensive as a highly processed feedstock material such as aluminium metal is used. World demand for HPA has gained incredible traction with the product fetching prices US\$10,000 to 40,000/t (3N – 5N) on increasing purity.
- ❖ **Rapid HPA demand growth forecast for EV lithium-ion batteries and LEDs.** HPA is highly versatile and a key ingredient in the modern world. It is vital for lithium-ion batteries for EVs as well as LEDs and semiconductor substrates. Dramatic EV penetration rates are being forecast which are being driven by government's green regulations led by China and the EU. All of which is creating a burgeoning demand for HPA with CRU suggesting a 30% CAGR demand growth to 272,000tpa by 2028 creating a significant deficit.
- ❖ **Kaolin to HPA processing technologies are achieving 99.99% purity.** Besides lower production costs, these disruptive processing technologies have a big advantage in using low-cost low impurity kaolin feedstock as this material has already been purified over millions of years by natural weathering. In the right circumstances, and this action has served to reduce the level of impurities like iron, titanium, sodium, calcium, potassium and magnesium to low levels in the alumina compound. This is a highly important consideration for EV batteries, as HPA purity is critical to prevent battery ageing.
- ❖ **Feasibility studies for HCl leach and SX show highly compelling economics.** Our analysis suggests that there is no outright winning type of technology between HCl leach and solvent extraction (SX). However, HCl leach methods are based on open chemistry which makes this processing route more available to juniors to develop a bespoke derivative method or via a licensing deal. Looking at a select number of companies at an advanced stage of developing kaolin to HPA processes, the production costs lie in the range of US\$5,500 – 8,550/t with capital intensity, mostly, in the US\$12,000 – 33,875/t range.
- ❖ **Clear cost advantage over the traditional HPA production from bauxite.** Persistence Market Research has outlined the cost advantage that Altech Chemicals' HCl leaching process has over the traditional processes. Of the companies with these disruptive technologies, Altech's production costs are at the top end of the range which shows that its HCl leach competitors enjoy an even more significant cost advantage. On a purity basis, solvent extraction (SX) and HCl leach technologies have both achieved >99.99% 4N HPA and so are capable of matching or beating traditional producers.
- ❖ **InterGroup Mining's c100 million-ton kaolin resource could well become a world class asset.** It might be early days, but the Company has outlined a sizeable deposit by any standards, and should initial test results allow, substantial value may be added by driving such an opportunity up the valuation curve. HCl leach Enterprise Valuations are led by Altech (pilot plant stage - 12.7Mt resource) and Andromeda Metals (Scoping Study stage - 26.0Mt resource) which trade on US\$22.7m and US\$26.0m respectively. IGM's kaolin potential could easily open the doors to a whole raft of opportunities stemming from developing proprietary production with value-adding processes and off-take agreements.

## INTRODUCTION

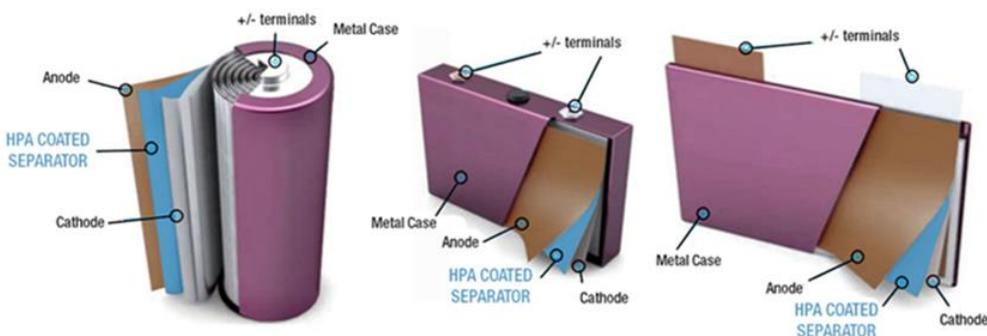
This report has been prepared for InterGroup Mining (IGM) and is a review of current kaolin to High Purity Alumina (HPA) technologies, their stages of development and the progress that has been made by the companies and research partners responsible for developing these processing technologies. The purpose of this research was to investigate this sector in attempt to identify how IGM might add value to its potential kaolin opportunity, which is starting to be investigated.

## HIGH PURITY ALUMINA (HPA)

There is a fast-evolving story of the exciting future demand for kaolin as an input into emerging technologies and products that are currently under development which relate to using the mineral as a feedstock for High Purity Alumina (HPA) production. HPA demand is dominated by the LED market for sapphire substrates as well as the use as lithium-ion battery separator coatings for Electric Vehicles (EV) and consumer goods.



**HPA has a myriad of uses.**  
Source: FYI Resources



**HPA is used as an anode electrode separator sheets in the lithium-ion battery**  
Source: Alpha HPA

The electrification of global transportation is happening rapidly with dramatic EV penetration rates which are being driven by government's green regulations led by China and the EU. This is creating a burgeoning demand for battery materials like lithium, graphite, cobalt, nickel and HPA. Ceramic HPA coating is critically important in lithium-ion batteries as it allows for thermal stability whilst still permitting ionic exchange. To meet the perceived demand for lithium-ion batteries, something like seventy mega factories are currently under construction globally.

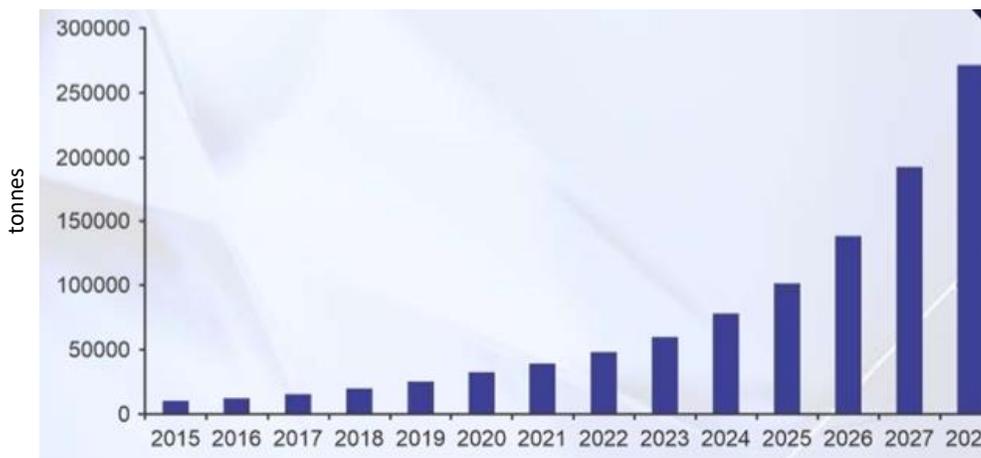
Purity is a critical requirement to prevent battery ageing and so substantially higher prices are being paid for the purest HPA. Purity is measured by the concentration of trace elements like iron, manganese and sodium in the alumina compound. Price and performance of HPA is variable and depends on the density of the product, crystal structure, particle size and the distribution along with the degree of purity. 4N HPA is the largest sector of the HPA market.

Current HPA supply is concentrated in the Asia Pacific Region which is responsible for around 83% with the largest producers being China 58%, Japan 15%, North America 12% and South Korea 10%. Current production is dominated by large diversified chemicals companies like Sumitomo Chemicals (Japan), Hebei Pengda New Material (China), Sasol (South Africa) and Zibo Xinfumeng Chemicals (China). Certainly HPA is seen to be a non-core product for these chemical giants. The HPA market is small at around 45,000tpa (although a variety of figures are published), but high value with HPA 99.99% (4N) having a selling price of approximately US\$15,000-30,000. The market is expected to grow rapidly on the back of continued strong growth in the LED market along with an expected rapid growth in the lithium-ion battery sector.

Quality	Smelter Grade Alumina (SGA)	3N HPA	4N HPA	5N HPA	6N HPA
Purity	99.5%	99.9%	99.99%	99.999%	99.9999%
US\$/tonne	~400	~5,000 – 15,000	~15,000-30,000	30,000-50,000	Small market price by negotiation

**HPA pricing - Alpha HPA presentation October 2019**

There is no doubt that HPA is a critical component in the move to EVs. HPA is a pure form of  $Al_2O_3$  which is being used to manufacture ceramic coated lithium-ion battery separators which provides a key safety and performance element for high-temperature EV batteries.



**Demand for HPA: CRU Global HPA Outlook 2019 via Altech**

Commodities market researcher CRU has forecast a 30% CAGR demand growth for HPA to 272,000tpa by 2028. This represented an upgraded forecast from the CRU which believe that the future LED market will require higher quality HPA. Looking at respectively levels of HPA demand, CRU sees lithium-ion battery separators demand rising to 187,000tpa by 2028 and LEDs demand forecast at 85,000tpa by the same year. The result is that a significant supply deficit is forecast of about 20,000tpa by 2021 and peaking at some 50,000tpa in 2028. Altech Chemicals which had its grand opening ceremony at its processing plant in Malaysia in August 2018 (at the beginning of the plant construction period) reckons that new entrants coming into the market are at best likely to be three or four years behind them.

### HPA PROCESSING TECHNOLOGIES

HPA is traditionally produced industrially by the Bayer Processes which converts bauxite into alumina which is then further processed using the Hall-Heroult Process to create HPA. The Bayer Process is a way of refining bauxite (which contains 30-60% aluminium oxide  $Al_2O_3$ ) which must be purified before it can be refined into aluminium metal. Whilst the Hall-Heroult is a major industrial process for smelting aluminium which involves dissolving  $Al_2O_3$  (usually obtained from bauxite, through the Bayer Process) in molten cryolite (a fluoride of sodium and aluminium which is added as a flux), electrolysing the molten salt bath in a purpose-built cell. This all happens at a temperature of 940-980°C and produces 99.5 – 99.8% pure aluminium, which then need further refining to become HPA.

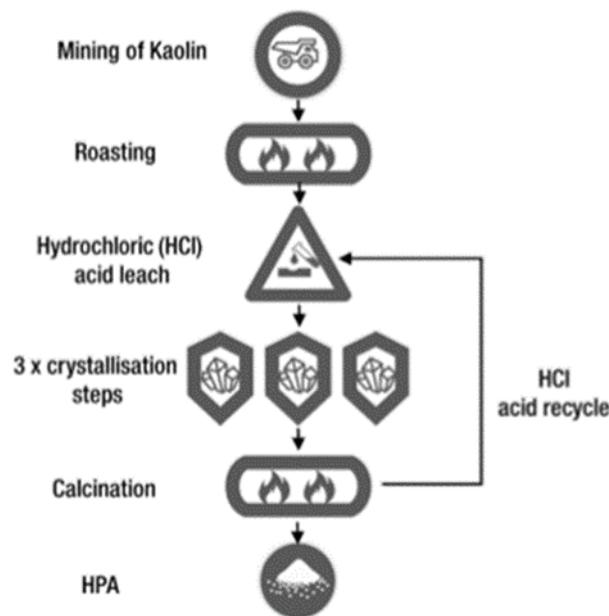
The Bayer and Hall-Heroult Processes are expensive for two main reasons. Firstly, the energy that is required not just to make aluminium but then to all process the Al to become HPA. Secondly, highly processed feedstock material such as aluminium metal must be used in order to produce HPA quality material. In recent times new disruptive technologies have emerged which produce HPA from kaolin which are less expensive, less energy intensive and simpler processes.

Not only are production costs low in the kaolin to HPA processing route but the level of purity seems to be higher. Besides production costs, the big advantage of using low cost low impurity kaolin feedstock materials is that kaolin has already been purified over millions of years by natural weathering. In the right circumstances, this action has served to reduce the level of impurities like iron, titanium, sodium, calcium, potassium and magnesium to low levels in the alumina compound. The main impurity is insoluble silica which can be readily filtered out during the processing. There seems to be three main kaolin to HPA processing technologies: hydrochloric acid leach, solvent extraction and the Griffin Process.

## Hydrochloric Acid Leach

HPA is produced from the hydrochloric acid (HCl) leaching of kaolin clay. This represents the leading processing route that has been adopted by many potential kaolin miners looking to add substantial value by manufacturing and marketing HPA. The technique involves calcining the feedstock material, which is followed by the HCl acid leach, high temperature HCl recovery and HPA refining. Calcination is the process of roasting kaolin to a high temperature in air or oxygen or a limited supply of either to bring about thermal decomposition. The furthest advanced in HCl leaching technology is probably Altech Chemicals where the key to the success of its process (in addition to the high degree of purity of its Meckering kaolin feedstock material) is apparently due to its three stage  $\text{AlCl}_3$  crystallisation/washing circuit which follows the calcining circuit to produce the final 99.99%  $\text{Al}_2\text{O}_3$ . Importantly, the three  $\text{AlCl}_3$  crystallisation/washing steps result in the purity being retained as well as preventing the contaminants being reintroduced into the final product.

Altech points out that its Innovation Patent that has been granted plus 8 patents that are pending are all based on established proven chemistry. Basically, this chemistry was established back in the 1990's by the Swiss and then further developed in the 1980's by the US government and Alcoa as a possible smelter grade alumina (SGA) process. However, at the time this process was not able to successfully compete on a cost basis with the Bayer Process for extracting alumina from bauxite which was all due to the low value of the SGA end product. Plus, it has also got to be pointed out that in those days there was no demand for HPA. So Altech has been applying open chemistry to its Meckering Project which has proven to be very successful and low cost as well as being highly disruptive. It seems to be that the patented/patent pending processes of FYI, Pure Alumina, Orbite and several others are all based on variations of this proven process.



***Simplified processing route for HPA from kaolin using HCL leach.***

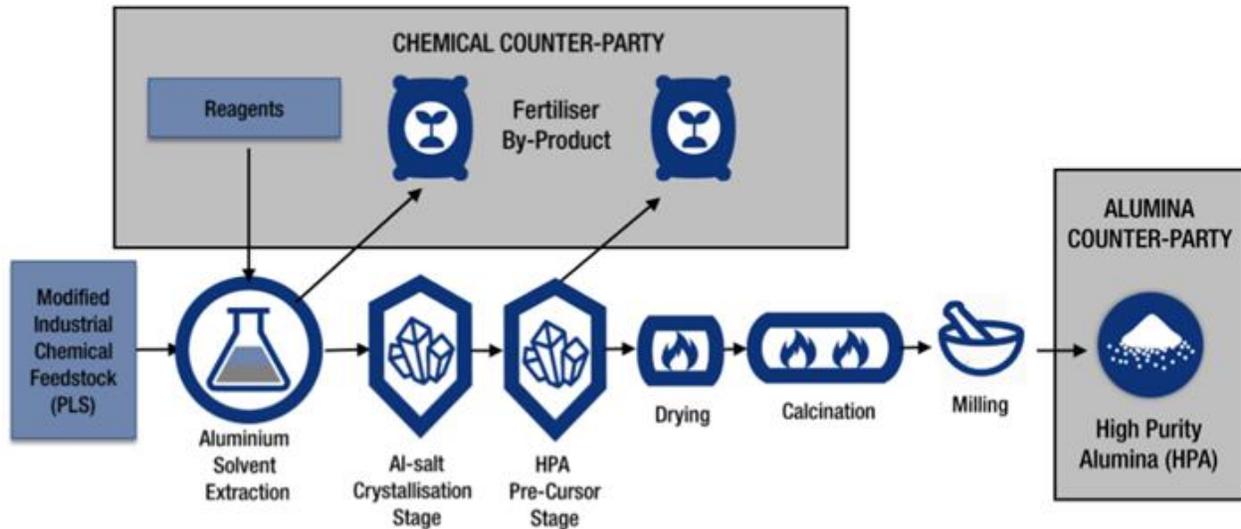
***Source: Alpha HPA***

Process optimisation by Pure Alumina showed that leaching of Al was completed within 30 minutes with a sub 63-micron kaolin concentrate requiring lower acid concentrations without any significant impact on alumina recovery. Kaolin concentrate was also found to react strongly with acid at low temperatures of 80°C, suggesting lower energy consumption. This does point to the potential for smaller plants, low temperature process and probably less exotic metals being needed in the construction of the processing plant which would serve to reduce operating and capital costs at Pure's Yendon Kaolin Project. Potentially other kaolin to HPA projects which are planning on going the HCl leach processing route could also benefit from such lower opex and capex.

## Solvent Extraction

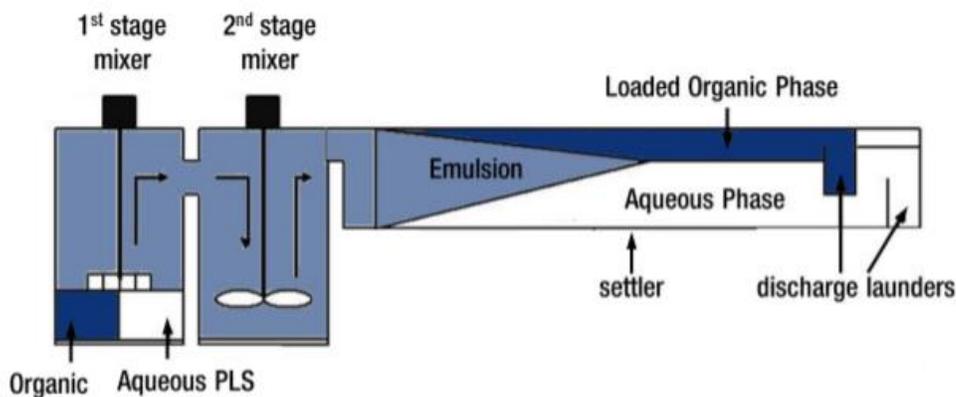
Alpha HPA's proprietary HPA First process is based on the established Solvent Extraction (SX) process. Basically, solvent extraction is used to purify and upgrade a pregnant leach solution which has been produced by the leaching operation to generate an electrolyte. Certainly, it's a crucial step in producing high purity electrolyte copper from leached ores and worldwide some 25% of global copper production uses SX.

Alpha HPA sees this as a highly selective process that delivers HPA purity. It is a wet chemical process and so no high-pressure vessels are required. Alpha HPA uses the HPA First process to make HPA from a blend of readily available industrial chemicals rather than a mine generated feedstock, although the company started off with a more normal model of mining its own feedstock material.



**HPA First process based on an established SX process. Source: Alpha HPA**

Alpha HPA (formerly Collierina Cobalt) is utilising its proprietary licensed SX and refining process to make a 4N (99.99%) HPA. The proprietary process HPA First was adopted in July 2018 and marked a major advance on the previous process flowsheet, which was used a feedstock generated from the acid leaching of laterite mineralisation from the company's Collierina Ni-Co-Sc Project in central NSW.



**HPA First process is an atmospheric wet chemical process**



**SX pilot plant in operation**

## **Griffin Process**

The Griffin Process was developed by Halcyon Resources, which was recently acquired by Accelerate Resources. On acquisition, Halcyon owned a 100% interest in the Tambellup Kaolin Project, WA and the intellectual property (IP) for this innovative production method to process Tambellup kaolin to HPA.

The Griffin Process produces high grade aluminas and silica by chemical digestion and crystallisation; with aluminas produced by this method reported to be high grade with optimal particle characteristics. Silica produced is reported to be a fine powder with high purity for immediate use (a co-product with applications in ceramics, paint and rubber). Key inputs are kaolin, sulphuric acid and ammonium sulphate, which are all readily available. The process is thought to have cost advantages over existing HPA production methods although to date no numbers seem to have been published.



***Tambellup Kaolin Project and samples of HPA produced using the Griffin Process.  
Source Quantum Resources announcement 08-06-17***

## COST COMPARISONS

Below we have compared the results from published feasibility studies of projects using the HCl leach and solvent extraction processing technologies. Although HPA has been produced by the Griffin Process, as yet there does not seem to be any results available from any feasibility studies to be used for comparison purposes. We would have also liked to have include Polar Sapphire in this table but as a private company its feasibility studies are not publicly available.

Processing technology	HCL Leach			Solvent Extraction
	Altech Chemicals	FYI	Pure Alumina	Alpha HPA
Company	FIDS	PFS	PFS	PFS upgrade
Study	FIDS	PFS	PFS	PFS upgrade
Date	October 2017	March 2020	June 2018	March 2019
Project	Meckering, WA	Cadoux, WA	Yendon, NSW	Buys in feedstock
HPA plant location	Johor Malaysia	Kwinana Western Australia	Melbourne Victoria	Gladstone Queensland
Resource Mt	12.7	11.3	3.7	n/a <sup>1</sup>
Grade % Al <sub>2</sub> O <sub>3</sub>	29.4%	24.8%	34.7% <sup>2</sup>	n/a
Aluminium feedstock processed t/yr	-	-	-	20,400
COSTS US\$m				
Project capital costs	297.6	189	271	149 <sup>3</sup>
Revenue pa	120.3	188	202	310 <sup>4</sup>
Operating costs pa	44.6	50	69	107.5
Annual free cash flow	-	-	-	199
EBITDA pa	75.7	133	133	200
NPV	505.6	543	692	n/a
Discount rate	7.5%	10%	10%	n/a
Payback period	4.5years <sup>5</sup>	3.6 years <sup>5</sup>	4.1 years	n/a
IRR	21.9%	46%	34%	n/a
NPV/Capex ratio	1.70	2.87	2.55	n/a
Project life	30 years	25 years	39 years	n/a
Annual HPA production	4,500tpa	8,000tpa	8,000tpa	10,200tpa
HPA production costs/t	US\$8,550	US\$6,217	US\$7,668	US\$5,123 <sup>6</sup>
Production grade Al <sub>2</sub> O <sub>3</sub>	>99.99%	>99.99%	>99.99%	>99.99%
Capital intensity/t	US\$66,133	US\$23,575	US\$33,875	US\$14,608
Long term HPA sale price (average)/t	US\$26,900	US\$24,000	US\$25,200	US\$25,000
Gross margin on sales	68%	74%	68%	79%

<sup>1</sup> As the HPA First project is not constrained by mine life, there is no fixed project life, and therefore the company did not perform a discounted cash flow analysis, but instead the financial analysis was presented on an EBITDA basis.

<sup>2</sup>kaolin resource of 3.7Mt ore, equivalent to 1.6Mt of 34.7% kaolin concentrate

<sup>3</sup>pre-production

<sup>4</sup>including by-products

<sup>5</sup> including ramp-up

<sup>6</sup> after accounting for by-product credits

### **Feasibility study results compared. Source: Altech Chemicals. FYI, Pure Alumina and Alpha HPA**

Feasibility studies for both HCl leach and SX kaolin to HPA projects show highly compelling economics and returns based on long term HPA (4N) prices in the range of US\$24,000 – 26,900, which looks reasonably conservative given the growth in the demand that is forecast and the impending significant supply deficit over the next five years. The last seen estimate of the current price of HPA(4N) which is approximately US\$15,000 – 30,000.

Cost comparisons have been investigated between four companies at various later stages of their development headed by Altech with its project which is currently being constructed, which at 4,500tpa is substantially smaller (though more recently increasing the production level to 6,000tpa has been mentioned) than those of its competitors (8,000 – 10,200tpa) but has a higher capex and a capital intensity which is double the highest figure for the three others in the select peer group being compared above. However, the lowest capital cost of all seems to be Polar Sapphire whose patent HCl leaching process which has an operating cost of US\$6,750/t lies at the bottom of the range. Polar also has a low capital cost of US\$12 million per 1,000tpa of installed capacity (i.e. capital intensity of US\$12,000/t) which is the lowest of the range suggested by the results in the above table.

## CONCLUSIONS

Our analysis suggests that there is no outright winning type of kaolin to HPA processing technology between HCl leach and solvent extraction. As always, each company reckons that its process lies in the lowest quartile for production costs. The solvent extraction method being pioneered by Alpha HPA does report substantially lower capital intensity and lower capital cost (resulting from analysis carried out in late-2017), which looks to result from the company producing HPA from a blend of readily available industrial chemicals rather than mining its own feedstock kaolin.

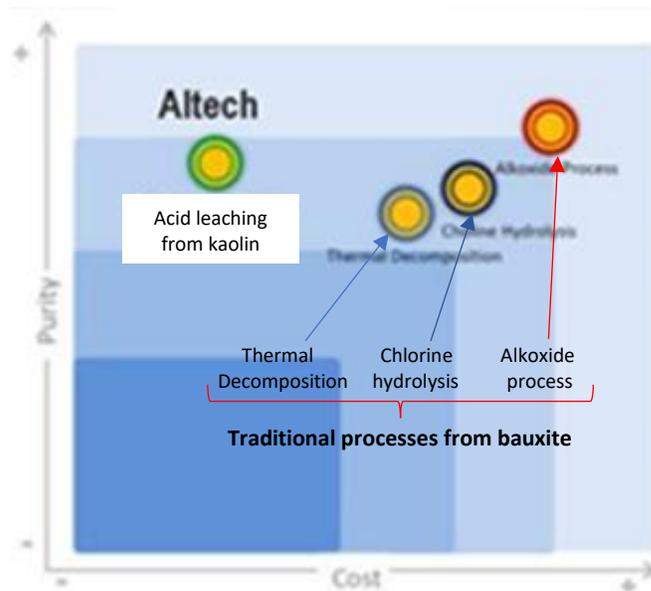
Looking at the feasibility studies of the others in the peer group does show that mining and beneficiating at the mine site to improve the economic value of the ore by removing gangue minerals is responsible for only a small percentage of the overall capex and opex. In its PFS, FYI suggests that mining at a rate of 50,000tpa (dry) and beneficiation at Cadoux would represent something like 15% of the total operating costs/tonne with refining costs at Kwinana representing the remaining 85% of opex. Looking at capital costs, the mining operation at Cadoux is responsible for 7% of capex with 93% represented by the costs associated with building and start-up of the refinery at Kwinana, WA.

Although we are not comparing like with like due to differing production capacities etc, adjusting the numbers for Alpha HPA by these amounts to reflect mining of kaolin would suggest an adjusted capex cost US\$160 million (US\$15,860/t adjusted capital intensity) and an adjusted operating cost of US\$5,500 per tonne (which includes by-product credits) which shows that the opex and capex figures begin to move closer towards numbers that FYI has determined its recently published DFS (March 2020). So, we see the range of operating costs forecasts from these companies in the range of US\$5,000/t (adjusted) to US\$8,550/t.

On capex, the lowest capital intensity is Polar Sapphire which has a patented HCl leach process that is reported to be US\$12,000/t HPA. The most expensive process on a capital expenditure basis is Altech Chemicals with a capital intensity of US\$66,133/t, though the three other companies have values ranging between US\$15,860/t (Alpha HPA – adjusted to include a mining stage) and US\$33,875/t.

Certainly, the estimated cost advantage of HCL leaching and SX of kaolin to produce HPA is substantially cheaper than the traditional methods of producing HPA using a bauxite feedstock. Persistence Market Research in its outlook for the HPA market outlined the cost advantage that Altech's acid leaching process of kaolin had over the traditional methods like alkoxide process, chlorine hydrolysis and thermal decomposition. Now in Altech's Final Investment Decision Study (FIDS), the estimated HPA production costs were US\$9,900/t which were higher than its competitors that ranged from US\$5,500 (adjusted) to US\$7,668 showing that they possess even greater cost advantages.

On a purity basis, Altech and the three other projects highlighted in the cost comparison table seem to be matching or beating results being achieved by traditional HPA production methods using bauxite. These disruptive technologies have been proved to produce >99.99% HPA (4N), which is important in the biggest potential growth market of the future (EV batteries) as purity is the critical requirement to prevent battery ageing.



**HPA market - Global Industry Analysis and Forecast 2016-24.**

**Source: Persistence Market Research**

HCl leaching methods are based on open chemistry which makes such a processing route probably more available to juniors to develop a bespoke derivative method or through a licensing deal. Polar Sapphire's simple cheap HCl leach process provides the hope of a short lead time of just twelve months to commercial production and cashflow with a low scale up risk; in addition to reduced capex by having fewer processing stages.

Last year Pure Alumina planned to acquire Polar Sapphire for C\$25.7 million (US\$18.6m) and it's not hard to see the obvious attractions of integrating Pure's flagship Yendon HPA Project with Polar's low cost technology. This acquisition deal was to be funded by C\$13.75 million in Pure shares and C\$12 million in cash but fell through as the Pure was unable to raise the \$30 million to fund the acquisition along with project integration and development costs.

Work on the ground at the IGM's Brumby Project in North Queensland has led to approximately 100 million tons of kaolin being identified. This material results from the weathering of granite and an initial sample has been sent for analysis to ascertain its purity and brightness in order to assess whether a potentially saleable product can be mined.

A deposit of this scale would equate to a sizeable resource in the kaolin world for projects looking to produce HPA and substantial value could be added in driving the project up the valuation curve. HCl leach Enterprise Valuations are led by Altech Chemicals (pilot plant stage - 12.7Mt resource) and Andromeda Metals (Scoping Study stage - 26.0Mt resource) which trade on US\$22.7 million and US\$26.0 million respectively, following recent stock market weakness. Certainly, IGM's kaolin potential could easily open the doors to a whole raft of opportunities stemming from the Company's proprietary production with value-adding processes, off-take agreements and deals with leading channel distributors.

## APPENDIX: KAOLIN TO HPA PEER GROUP

Company	Share price	Mcap US\$m	EV US\$m	Sales US\$	Comments
<b>PILOT PLANT</b>					
<b>Alpha HPA Limited (ASX:A4N)</b>	A\$0.14	56.8	56.1	n/a	<p>Location: Sydney</p> <p>Processing technology: HPA First - proprietary licensed SX and refining process to make a 4N (99.99%).</p> <p>Project: Solvent Extraction, the HPA First Project.</p> <p>Resources/Reserves: Makes HPA from a blend of readily available industrial chemicals rather than using a mine generated feedstock.</p> <p>Feasibility studies: Updated Pre-Feasibility Study (March 2019), with original PFS (November 2018) for delivering 10,200tpa of 4N (99.99% purity) HPA into the burgeoning HPA market. Updated PFS (March 2019) assumed an HPA price of US\$25,000/t. Unit cash cost accounting for by-products of US\$5,123/t, annual free cash flow of US\$199m and annual EBITDA of US\$200m. Pre-production capital cost was estimated at US\$149m and a capital intensity of US\$14,563/t with a payback period of less than 2 years. Aluminium feedstock processed at a rate of 20,400tpa.</p> <p>Met test results: First HPA production using HPA First process produced 99.994% HPA</p> <p>Latest news: HPA First pilot plant commenced in July 2019. MOU signed with chemical counterparty (February 2020). Also owns Collerina HPA-Nickel-Cobalt project in NSW.</p>
<b>Altech Chemicals (ASX:ATC)</b>	A\$0.059	28.0	22.7	67K	<p>Location: Meckering, WA</p> <p>Processing technology: HCL leach process originally developed by Altech in conjunction with TSW Analytical Pty Ltd and Simulus Engineering Pty Ltd. Chemistry established in 1990s by Swiss and further developed by US government and Alcoa in 1980's, Altech applied open chemistry to Meckering – very successful and lowest cost with main reactant HCl re-used.</p> <p>Project: Meckering Kaolin Deposit</p> <p>Resources/Reserves: 12.7Mt JORC Mineral Resources (Measured 1.5Mt@ 30% Al<sub>2</sub>O<sub>3</sub>, indicated 3.3Mt @ 30% Al<sub>2</sub>O<sub>3</sub> &amp; Inferred 7.9Mt @ 29.1% Al<sub>2</sub>O<sub>3</sub>). Very low iron due to weathering.</p> <p>Feasibility studies: Final Investment Decision Study (FIDS October 2017) for the HPA project with a 4.5ktpa HPA operation (although since the management has talked about the potential to increase plant capacity to 6,000tpa HPA) with a 30-year life and capex US\$297.6 and an average operating cost of US\$8.55/kg (US\$8,550/t). Robust project economics also included: Pre-tax NPV(7.5%) US\$505m, IRR 22%, payback 4.5 years (including ramp-up), EBITDA US\$75.7m pa, and gross margin 63% at a lifetime sale price US\$26.9/kg (US\$26,900/t).</p> <p>Met test results: HPA 99.99% (4N) purity or greater.</p> <p>Latest news: 4,500tpa HPA plant is being constructed at Johor, Malaysia at a cost of US\$280m with off-take agreement with Mitsubishi that covers the first 10 year of sales. Construction ahead of schedule (March 2020).</p>
<b>Polar Sapphire (private)</b>	-	-	18.6 <sup>1</sup>	n/a	<p>Location: Toronto, Canada</p> <p>Processing technology: Patent HCl leaching process.</p> <p>Project: Cleantech company manufacturing HPA using various feedstocks including aluminium metal.</p> <p>Resources/Reserves: n/a</p> <p>Met test results: Producing 3N to 6N HPA. Polar Sapphire manufactures and sells HPA 3N-6N powders for various applications. Apparently, a simple cheap process that reduces capex by having fewer processing stages coupled with a short lead time of just twelve months to commercial production and cashflow with a low scale up risk.</p>

					Latest news: Producing 900tpa from what is essentially a pilot and demonstration plant but has plans to increase that capacity in 2020 by another 1,000tpa (December 2019). Pure Alumina's proposed acquisition of Polar Sapphire was terminated in mid/late 2019 as the necessary capital could not be raised. Pure Alumina had planned to purchase Polar for C\$25.7m (US\$18.6m <sup>1</sup> - funded C\$13.75m in Pure shares and C\$12m in cash) with Pure seeking to raise \$30m to integrate its existing process with Polar's low cost technology. Polar's process has a low capital cost of US\$12m per 1,000tpa of installed capacity and forecast operating cost of US\$6,750/t.
<b>FYI Resources (ASX:FYI)</b>	A\$0.048	7.72	7.19	9k	Location: WA Processing technology: HCl leach Project: Cadoux Kaolin Project Resources/Reserves: JORC Resource 11.3Mt with 3.2Mt Proven and Probable ore reserves at 24.8% Al <sub>2</sub> O <sub>3</sub> – resources support 50 years of production at 8,000tpa but the DCF analysis in DFS was only undertaken for the first 25 years. Feasibility studies: Definitive Feasibility Study (March 2020) forecast after-tax results of NPV (@10%) of US\$543m, IRR 46% and project payback of 3.6 years. Total operating cash cost of US\$6,217/t HPA produced, project capex of US\$189m and capital intensity of US\$23,575/t. PFS was dated September 2018. Met test results: Outstanding purity and consistencies achieved during commissioning trials. Latest news: DFS announced with news that the company had secured A\$80m strategic project development equity (March 2020). Construction and commissioning of pilot plant completed, which will allow FYI to determine project success and economies as the HPA strategy moves towards commercialisation (October 2019). FYI is also targeting potash projects in Thailand and Laos
<b>PRE-FEASIBILITY STUDY</b>					
<b>Pure Alumina (ASX:PUA)</b>	A\$0.011	1.57	0.70	119k	Location: Ballarat, Victoria, NSW Processing technology: HCl leach Project: flagship Yendon HPA Project Resources: Kaolin resource of 3.7Mt ore, equivalent to 1.6Mt of 34.7% kaolin concentrate sufficient for 39 years of 8,000tpa HPA production. Feasibility studies: Yendon HPA Pre-Feasibility Study (July 2018) annual HPA production 8,000 tonnes +99.99% Al <sub>2</sub> O <sub>3</sub> (4N). Project Capex US\$271m (including US\$50.2m in contingencies) and capital intensity of US\$33,875/t. Average cash cost of production US\$7,668/t with a forecast sale price US\$25,200/t. Average EBITDA US\$133m, project NPV(10) US\$692m and IRR 34%. Met test results: Kaolin resource is highly responsive to acid leaching which showed that most of the leaching of Al is completed within 30 minutes, and little further improvement by the 2-hour mark. Latest news: Recently called off acquisition of Polar Sapphire as it could not raise the necessary equity - now looking at alternatives to generate shareholder value.
<b>SCOPING STUDY</b>					
<b>Andromeda Metals (ASX:AND)</b>	A\$0.031	27.0	26.0	12k	Location: South Australia Processing technology: Direct Shipping Ore (DSO) to toll metallurgical refineries in China/Japan with plans to produce long term HPA feedstocks through partnership opportunities. Project: Carey's Well halloysite-kaolin deposit at the Poochera Halloysite-Kaolin Project in South Australia. Andromeda is earning up to a 75% interest this project from Minotaur Exploration to become a producer of high-quality halloysite-kaolin and high purity alumina material.

					<p>Resources/Reserves: Updated resources statement showed that the overall "bright white" kaolinised granite Mineral Resource has increased by over 28% to 26.0Mt and the in-situ "bright white" kaolinised granite will yield 10.6Mt of minus 45-micron quality kaolin product.</p> <p>Feasibility studies: Scoping Study showed All In Sustaining Cost (AISC) averages A\$396/tonne of fully refined kaolin with an anticipated selling price of A\$700/tonne, project cashflow is approximately A\$800m, pre-tax NPV (8%) A\$413m and IRR 174%. Pre-production capital cost is estimated at A\$9m with a maximum cash requirement of A\$25m prior to initial revenues being received. Expanded Scoping Study/Pre-Feasibility Study is scheduled for completion early in the June quarter 2020.</p> <p>Met test results: Global Innovative Center for Advanced Nanomaterials (GICAN), University of Newcastle, NSW, is currently producing some exciting research results using Carey's Well halloysite in battery technology development, water purification, carbon capture and hydrogen storage (December 2019).</p> <p>Metallurgical tests have shown that Carey's Well halloysite-kaolin has achieved 4N (99.99%) purity with only a single purification stage.</p> <p>Latest news: Drilling programme from Halloysite showed concentrations of up to 91% have been taken from drill holes containing up to 20 metres of high whiteness kaolinised granite. A selection of 9 holes drilled at Carey's Well, Tomney and Condooringie recorded an average of 59% halloysite in the minus 2-micron fraction (December 2019).</p>
<b>Minotaur Exploration (ASX:MEP)</b>	A\$0.028	6.37	6.40	153k	<p>See comment above for Andromeda Metals which holds a 51% stake and has the right to earn a 75% interest. Minotaur is actively exploring IOCG style targets in Australia.</p>
<b>Metalsearch (ASX:MSE)</b>	A\$0.005	2.18	1.04	n/a	<p>Location: Queensland</p> <p>Processing technology: Own bespoke HPA technology – few details mentioned on the announcement that the patent application had been lodged (December 2019).</p> <p>Project: Abercorn Kaolin Project which was acquired by Metalsearch along with the IP in August 2019.</p> <p>Resources/Reserves: 24 holes drilled in 2007 showed potential for the extraction of marketable volumes of higher-grade Al<sub>2</sub>O<sub>3</sub> feedstock.</p> <p>Feasibility studies: one of the requirements on acquisition was the completion of a Scoping Study (not published on website).</p> <p>Met test results: Has produced 99.99% Al<sub>2</sub>O<sub>3</sub> (4N HPA) from mined material.</p> <p>Latest news: In December 2019, the company lodged a patent application for HPA production which comes after an R&amp;D agreement with the University of Queensland (UQ). Over the past year, the School of Chemical Engineering at UQ has collaborated with Abercorn Kaolin to develop an HPA production approach and have successfully produced Al<sub>2</sub>O<sub>3</sub> at a grade of 99.99%.</p> <p>Also owns Kraaipan Gold-Nickel-Copper-PGM Project in Botswana</p>
<b>METALLURGICAL TESTING</b>					
<b>Alchemy Resources (ASX:ALY)</b>	A\$0.01	3.55	3.21	9k	<p>Location: NSW</p> <p>Processing technology: HCl leach</p> <p>Project: West Lynn/Summervale Project (NSW) are highly prospective nickel-cobalt-alumina tenements covering 381km<sup>2</sup> within world-class Nickel-Cobalt endowed ultramafic belt.</p> <p>Resources/Reserves: HPA overlies Ni-Co. West Lynn Project maiden Inferred JORC 2012 resource; 21.3Mt @ 0.84% Ni, 0.05% Co, 2.4% Al, 20.0% Fe, 12.9% MgO. Summervale Prospect maiden Inferred JORC 2012 resource; 6.6Mt @ 20.8% Al<sub>2</sub>O<sub>3</sub>, 2.8% Fe, 1.15% TiO. Good potential for Ni-Co and alumina resource expansion.</p>

					<p>Feasibility studies: n/a</p> <p>Met test results: Good initial metallurgical recoveries reported using nitric acid leach (patented DNI Process™) for Ni-Co and standard HCl leach for alumina. 99.95% HPA produced on first met sample without process optimisation.</p> <p>Potential for calcination of aluminium hydroxide by-product to produce HPA.</p> <p>Latest news: Further resource drilling and metallurgical work planned. (February 2020).</p> <p>The company's leading projects seem to be those focused on gold and base metal potential which includes the Karonie Gold Project (WA).</p>
<b>Orbite Technologies Inc (private)</b>	-	-	-	-	<p>Location: Halifax, Nova Scotia, Canada</p> <p>Processing technology: Orbite process (HCl leach). Four step process: aluminium ore preparation, leaching, extraction of alumina, extraction of iron and calcination, where acid leaching then occurs at very high temperature using hydrochloric acid.</p> <p>Project: Grande-Vallee deposit</p> <p>Resources/Reserves: n/a</p> <p>Feasibility studies: n/a</p> <p>Met test results: The Orbite process is an industrial means to refine aluminium ores (such as bauxite) to produce alumina (aluminium oxide) patented by Orbite Alumnae using acid rather than sodium hydroxide in a similar way to the Bayer Process.</p> <p>Latest news: A shortage of recent news as this clean tech company was declared bankrupt in 2017. At which time it seems that Orbite was in the midst of the process of finalising its first commercial HPA production plant in Cap-Chat, Québec and had completed the basic engineering for a proposed smelter-grade alumina (SGA) production plant.</p>
<b>Lava Blue (private)</b>	-	-	-	n/q	<p>Location: North Queensland</p> <p>Processing technology: n/a</p> <p>Project: Lava Plains Gemfield</p> <p>Resources: Extensive resources</p> <p>Feasibility studies: n/a</p> <p>Met test results: Achieved 4N purity on kaolin and developed two process pathways in the laboratory to produce &gt;4N HPA in a joint project with two other Australian institutions, Queensland University of Technology (QUT) and the Innovative Manufacturing Cooperative Research Centre (IMCRC) in 2018.</p> <p>Latest news: Building a pilot plant and conducting feasibility into the construction of a 1ktpa commercial facility with plans to increase capacity to 5ktpa in the future (October 2019)</p>
<b>DRILLING</b>					
<b>Accelerate Resources (ASX:AX8)</b>	A\$0.026	1.02	0.57	n/a	<p>Location: WA</p> <p>Processing technology: Griffin Process – innovative production using sulphuric acid and ammonium sulphate.</p> <p>Project: Tambellup - Kaolin Accelerate acquired Tambellup Kaolin Project and processing IP in November 2019.</p> <p>Resources: Two kaolin prospects have been identified by previous drilling within the tenement.</p> <p>Feasibility studies: n/a</p> <p>Met test results: n/a</p> <p>Latest news: Company completed Aircore drill programme (52 holes for 769m) which confirmed that kaolin is near surface with continuity and consistency. Drilling provides the material for initial metallurgical test work (February 2020)</p> <p>Also has Mount Monger Gold, Comet Gold and Mt Read Cobalt project (Tasmania).</p>

**EARLY STAGE**

<p><b>Canyon Resources (ASZ:CAY)</b></p>	<p>A\$0.08</p>	<p>23.6</p>	<p>22.1</p>	<p>38k</p>	<p>Location: Cameroon, North Western region            Processing technology: n/a            Project: Mayouom kaolin deposit            Resources: An initial exploration program completed in June 2018 identified a large kaolin deposit within the permit area. Results from initial sampling programme were very positive and show that the deposit had clear potential for HPA production. The sampling program confirmed that there is high-grade Al<sub>2</sub>O<sub>3</sub> with continuity both vertically and horizontally with very low impurities (April 2018).            Feasibility studies: n/a            Met test results: n/a            Latest news: Intends to complete a drilling programme in the company's current year ending 30-06-20.            The company's flagship project is the Minim Martap Bauxite Project which is a global tier one bauxite asset.</p>
<p><b>Archer Materials (ASX:AXE)</b></p>	<p>A\$0.175</p>	<p>24.7</p>	<p>23.0</p>	<p>38k</p>	<p>Location: Kimba, NSW            Processing technology: n/a            Project: Franklyn Halloysite-Kaolin Project/Eyre Peninsula High Purity Alumina Project.            Resources/Reserves: Kaolin Exploration Target for the Franklyn Project is reported as a range 45Mt – 90Mt at a grade of 30– 36% Al<sub>2</sub>O<sub>3</sub> (at -45µm) in November 2019 with permit to start drilling asap.            Feasibility studies: n/a            Met test results: n/a            Latest news: The company has access to world-class facilities to build prototype chips based on qubit processor. (November 2019).            Minerals technology company with an R&amp;D arm as well as mineral exploration.</p>

## **ABOUT THE AUTHOR**

Dr Michael Green is an independent analyst who specialises in growth companies and resources companies. He gained a BSc Honours degree in Mining Engineering from Nottingham University, UK and PhD for a thesis that looked at the economic analysis of mining projects.

Having been involved in consultancy work, Michael began working in the City in the 1980s as a Mining Analyst with stockbrokers Buckmaster & Moore and then HSBC-owned Greenwell Montagu Securities. Subsequently, he was involved in analysing a wide range of growth companies and became Head of Research at stockbroker Everett Financial which specialised in the small cap market.

Since, 2006 Michael has been an independent analyst. He has specialised in analysing companies in the resources sector providing research for mining companies, stock brokers, corporate finance houses, advisers and independent research firms. Between 2008 – 2011, he was a Non-Executive Director of Ascot Mining PLC, a quoted Central American gold mining company. In addition he has worked closely with resources companies assisting in Investor Relations.

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