Redefining 'scale of economy' for stand-alone specialty alumina production capacities

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Abstract

An overwhelming share of global calcined alumina production is earmarked for aluminium smelting. The remaining 10 % or less goes into the production of a wide range of value-added specialty alumina products. The CAPEX and OPEX of primary alumina producing refineries have been rising rapidly in recent years. This has led to the scale of economy of such production facilities going up in recent years from 100 000 tons per line to multi million tpa (tones per annum) levels. Of late, it is becoming increasingly difficult for primary alumina producers to divert their 'expensive' production capacities from supporting smelter requirements to producing high value low volume customized specialty aluminas. At the same time, the global demand for industrial and consumer durable end use products for various grades of specialty aluminas has been going up. In fact, wider utilization of specialty aluminas and the expansion of their markets is being throttled by the right products not being available at the right time, at the right place and in right volumes. This paper looks at shifting values on criteria that have been traditionally considered for defining 'Scale of Economy' for setting up of Smelter grade Alumina production facilities. It takes a look at the impact it has had on the viability of setting up of standalone merchant and/or captive 'Specialty Alumina' production facilities in the small and medium sector.

Keywords: Specialty Alumina; scale of economy; Capex; Opex; Supply Chain and Product mix management.

1. Introduction

For over a century, Bauxite ore and Bayer process have remained the singular source and production technology for producing smelter grade alumina. The world currently has an annual Alumina refining capacity of 108 Mt and during 2014 this had supported a global primary aluminium production of around 53 Mt. [2, 10]

Of the overall output of global alumina refining capacity, 90-95 % has gone to meet the needs of aluminium smelting. The remaining 6 to 8 million tons were converted into 'Special Grades of Alumina' [2]. During the past couple of decades, eight major specialty grade alumina producers have also come up with a conversion capacity of 2.5 to 3 Mt with feedstock of alumina hydrate and calcined alumina being provided by the primary calcined alumina producers. The balance of supply sources are mostly covered by primary producers themselves and small-scale convertors of low volume high value end product producers. Thus, the cost, pricing and profitability structure of specialty alumina industry remains more tied to that of the primary calcined alumina producers than with its own market technical fundamentals.

In the recent times, few older refineries have had their process and operating systems re-designed to produce Special Grades of Alumina. An exception being, the Mempaw 300 000 tpa Chemical Grade Alumina plant of PTA ANTAM in West Kalimantan, Indonesia which due to commence its commissioning in 2014 [3].

2. Product classification

Specialty Aluminas are broadly classified into two categories.

1. Chemical Grades - Microfine low soda hydrates, Aluminium sulphate, Chlorides, Sodium aluminates, Zeolite, Aluminium fluorides, Fire retardants etc.
2. Calcined grades- Refractory, Abrasive, Ceramic, fused alumina, calcined aluminate cements, Synthetic jewels etc.

In terms of market share by volume, the major application area segment distribution is of the order of

1: Refractories………………………………. 60 – 65 %
2: Ceramics…………………………………... 20 – 25 %
3: Abrasives………………………………….. 10 – 15 %
4: Others……………………………………… 5 – 10 % [7].

The ceramic grades cover a wide range of products, which feed the global Refractory manufacturing industries. The broad categories of refractory input material that Specialty Alumina Industries service are:[10]

1. Tabular Alumina
2. High alpha calcined alumina
3 Reactive alumina
4 Calcined aluminate cements
5. Various grades of spinels
6. Brown sintered alumina
7. Alumina bonding agents

While all metallurgical industries (e.g. iron and steel making, ferrous and non-ferrous foundries, aluminium, copper, zinc and other non-ferrous smelting plants, ferro alloy production and different classes calcinations furnaces etc.) use alumina based refractory and cementing products, it is primarily the global iron and steel industry that has been driving the specialty alumina industries worldwide.

In the advanced steel making nations which are primarily engaged in producing high alloy and special steel, the specific consumption for high alumina refractory varies from 1.3 to 1.6 kg /t [8] of steel. In the technologically lower range of steel making nations like China and India, the specific consumption range of alumina based refractory is of the order of 0.5 to 0.9 kg/t. With Direct Reduction (DR) steel making processes gaining ground along with the secondary metal smelting sectors, (which have higher specific consumption levels of alumina based castables, lining blocks and mortars etc.), the overall average consumption rate could also move northwards at a faster rate in the coming years.

3. Supply chain and input cost security

The smelter grade calcined alumina industry has been facing increasing pressure with the rising cost of inputs and expenses of meeting stiffer regulatory norms. To maintain the economic viability of aluminium smelting and keeping alumina prices to meet the same, the alumina refinery capacities have rapidly moved from 100 000 - 200 000 tpa capacities in the 70’s to multimillion tpa and multi-line single site refineries. By the 1980’s and 1990’s, the ‘scale of economy’ for refineries had overtaken the equivalent captive demand of smelters. This resulted in the increasing availability of higher volumes of hydrates and alumina in the open market. However, this did not necessarily result in any pricing advantage in the supply of these two prime input materials for the specialty alumina industry and consequently for the refractory user industry.

In pricing hydrate and calcined alumina supplies for the non-metallurgical specialty alumina industry, the primary alumina producers had always loaded their own high capital cost contribution disproportionately. The final pricing was generally higher than that of transfer pricing for captive smelter consumption and most of the times, even higher than the open market smelter grade alumina prices.

Despite the higher cost of starting material, the alumina refractory business has continued to look attractive since the low specific consumption rates have maintained a low elasticity to price and demand for the users. However, with the global steel industry experiencing prolonged depression and the demand for higher grades of steel growing, the demand for alumina based refractory is bound to go up in the coming years. This could then also put pressure on the refractory industry to be more cost and price efficient.

The solution for the industry could lie in evolving a favorable Capex independent of that of smelter grade alumina refineries. This could encourage building of stand- alone specialty alumina refineries with bauxite as the starting material and gaining a 'scale of economy' independent of that of the smelting grade calcined alumina industry.

4. Criteria for establishing optimal 'Scale of Economy'

It is a standard economic assumption that the cost advantage in production rises with increasing volumes of production. Economies of scale arise on the basis of the inverse relationship between the quantity produced and per-unit fixed costs; i.e. the greater the quantity of an item produced, the lower the per-unit fixed cost because these costs are shared over a larger number/volume of items [1]. Economies of scale may also reduce with costs per unit going down on account of gaining in operational efficiencies and system synergy. Economies of scale can be classified into two main types: *Internal* – arising from within the company; and *External* – arising from extraneous factors such as industry size [1].

In working out an optimal size of a production plant, the primary contributing factors towards working out optimal scale of economy could fall under two headings, namely:

1. Data from Accounting Records
2. Data from Technical Studies

Under Accounting Factors, the items covered could be related to;

- a. Initial Investment cost
- b. Operating cost
- c. Raw material and inventory carrying cost
- d. Set up cost
- e. Barriers to Capacity utilization
    - i. Limitations on demand
    - ii. Non-homogeneous output
    - iii. Plant / equipment age differentiation and life cycle location
    - iv. Location factors

It may be seen here that all the mentioned factors depend upon the quotations on inputs at the specific plant location. The cost are estimated and verified to some extent through field enquiries. However, the final quotations at given times, render redundant all estimates and elasticity to the financial model of the project.

Data from Technical study:

- a. Civil Construction and infrastructure building cost
- b. Cost of individual units of industrial equipment
- c. Operating cost – Labour + raw material + utilities
- d. System costs – transportation + Regulatory compliances
- e. Product mix

Engineering studies generally provide more reliable estimates as they employ assumptions that are more consistent with those underlying the envelope curve for a location and the class of industry [1] covering a specified product mix. However, engineering factors do tend to err considerably from the time of conception of the project to its implementation and commissioning.

3. Shifting paradigms of global speciality alumina industry

Of the little over 6 - 8 million tonnes of speciality alumina reported [2] to have been produced globally in 2014, the share of chemical and ceramic or sintered alumina is nearly equal.

For the **chemical grades,** the market differentiation in terms of physical and chemical specification and areas of application is very widely distributed. It covers both the categories of hydrate and alumina based products. Applications wise, hydrate based speciality alumina products vary widely from the basic range of fire retardants and paint filler pigments to those in their purest form for pharmacy and cosmetic inputs. In the calcined special chemical grade category, it ranges from usage for basic pharmacy formulations and catalytic carries in activated form to highly sophisticated nano products. Within the same application area, the specifications could vary considerably to meet user industry’s processing technology. The pricing spectrum is also very wide. Under the conditions, there is no distinct market driving segment in the chemical grade section. The industries engaged in chemical grade speciality alumina are found to function mostly as standalone industries concentrating on production of a cluster of products targeted at specific customers or market segments. For feed stock, these industries depend entirely on the Smelter grade alumina producers and normally choose locations closer to the primary alumina plants or special alumina based industrial cluster zones. The pricing of their products are mostly based on the procurement cost of feed material from the ‘mother’ alumina refineries. The market however remains highly fragmented and difficult to quantify in terms of both value and volume.

In the **ceramic and sintered category**, the product spread is classified under a limited range of 7-8 sub-categories. On the application side, over 90 % of the material goes to the refractory industries. Under the refractory category too, the application market segmentation is skewed towards the global Iron & Steel industry. The projected market segmentation is [2]:

- Iron and Steel Industry & Foundry – 85 - 90 %
- Cement and Lime calcining industry – 10 - 15 %
- Non-ferrous Metal Industry – 2 - 3 %
- Glass, Ceramic and Chemicals – 1 - 3 %

The emerging dynamics of the global iron and steel industry in the coming years will therefore decide the direction of the growth of ceramic and sintered speciality alumina industry.

4. Global iron and steel industry

In 2014, the rated capacity of the global iron and steel industry was 1 662 million tonnes, with over 850 million tonnes coming from China alone [4]. While the global steel industry has been going through a lean phase since 2009-2010 and the capacity utilisation factor in recent years has been at a low of 75 %, the distribution in the sickness factor of the industry is rather heterogeneous.

A summary of the movements in the global iron and steel industry over 2003 - 2004 to 2013 - 2014 is given in Table 1 (Source: World Steel Committee Economic Statistics 2014) [4]:

Table 1. Evolution of iron and steel industry over time.

S.No.	Item	Unit	For 2004	For 2013	% Change
1	World Crude Steel Production	Mtpa	1063	1649	+586 Mtpa - +55 %
1a	-do- North America	-do-	134	118	- 12%
1b	Europe	-do-	203	116	-42%
1c	CIS	-do-	113	108	-4.5%
1d	Latin America	-do-	45.5	45.8	-------
1e	Asia	-do-	503	1123	+123%
1e1	China	-do-	272	822	+202%
1e2	India	-do-	33	82	+148%
1e3	Middle East	-do-	14	26	+86%
Iron Making					
2.0	Steel production through Electric arc F/c route	-do-	355	452	+27%
3.0	Blast F/C route	-do-	1035	1168	+12%
4.0	Direct Reduction (DRI) route	-do-	45	75	+67%
Steel Making					
5.0	Open Heart F/C route	-do-	33	8.7	-74%
6.0	Oxygen Blown Converter	-do-	675	1186	+75%
7.0	Steel production through Electric arc F/c route	-do-	355	452	+27%

This table gives an idea of how the steel industry has moved over last ten years globally and also as per the processes utilised for iron and steel making.

The global raw steel production went up by 55 % between 2004 and 2013 from 1 063 Mtpa to 1 649 Mtpa and all the traditional and pioneer steel producing regions, namely, Europe, Americas, Commonwealth of Independent States (CIS), Japan, Korea and Australasia regions saw declines in raw steel production. During the same period, China, India and the Middle East emerged as prime iron producing regions. With a total production of 930 Mtpa, the three put together covered more than 67 % of total global output. Even if China does is not adding new capacity at the same rate at which it did during the last decade, India is emerging as an ambitious player targeting more than 200 Mtpa capacity by 2020 - 2025. The Middle East region with its distinct energy advantage is targeting closer to 100 Mtpa capacity during the same period. Therefore, the region to watch out for the global refractory producers and marketers in the coming decades will be the Asia and Middle East.

In terms of technology, the dominance of the blast furnace (BF) route continued in the last decade. It still has a share of over 70 % of crude steel production [6], the growth in direct reduction (DR) and electric furnace routes have shown a much faster rate of capacity build up (67 % and 27 % respectively) [5] as compared to the BF route (12 %). This is good news for high alumina refractory producers as the non- BF processes tend to consume 10 - 15 % higher high alumina refractory per ton of steel.

In steel making processes, the oxygen blown convertor technologies have emerged as distinct leaders with over 75 % growth rates and now covering more than 70 % of global steel making production capacity. This too is good news for high alumina refractory producers.

Even though the overall volume of raw iron and finished steel production volumes have come down in Europe, America and other developed countries, these regions continue to maintain a higher specific rate of alumina refractory consumption at 1.3 to 1.4 kg/t. This compared to the Chinese and Indian steel producers who are working with a specific consumption rate of 0.5 to 0.9 kg/t [2]. However, as these new dominating iron and steel producing regions keep moving towards producing higher performance steel and greater proportion of DR and electric arc steel production, the specific consumption of refractory in general and those in the high alumina category should also go up. It is estimated that with every 1 % improvement in refractory rate, the Chinese iron and steel industry alone would add over 82 000 tpa of additional demand for alumina refractory products [7].

This therefore, more or less, defines the pattern and direction in which the alumina based refractory market will move and the global location which would be best suited for additional brown and green field production capacities.

5. Changing paradigm of project accounting factors

5.1. Cost of construction and infrastructure building

In the developing world, it is not uncommon to expect lower cost of labour. Limited availability of skilled work force has been a negative factor for setting up manufacturing industries in these parts of the world. However, with the availability of higher level of mechanisation and automation, the impact of labour quality and productivity on over all operational cost is no longer as pronounced.

5.2. Limitations on demand

Being a typical industrial commodity, special grades of alumina would be required to be produced for specific consuming industries who in turn would be designing their operations to suit the quality and volumes demanded by the user- buyer industries.

In developing economies, which are, in general overburdened with the task of supporting larger population, Governments permit the use of their national resources only if it benefits their population in terms of job creation, revenue for the exchequer’s accounts and does not adversely impact their otherwise perennially endangered ecology. In addition, industries in heavily populated developed countries cannot be started and stopped, temporarily or permanently merely on commercial considerations. Larger capacity production facilities are not always the best and most profitable option under such conditions. Setting and continue operating up high capacity plants with expensive public funding only to meet socio - political obligations, may not, always be a commercially or economically prudent decision. The traditional consideration of profitability being directly proportional to size of operation may not always prove to be the right option where the cost of carrying unutilised capacities can easily destroy most ‘break even’ capacity calculations.

5.3. Operating cost

In addition to the processing cost, the other significant contributors to final cost of production are stores inventory and ware housing costs. It is generally accepted that smaller plants have a higher contributing cost input from relatively higher specific consumptions. However, the same could be more than neutralised by effective management and economising on Supply- chain operational cost. Smaller plants can more easily choose to be ancillaries to captive buyers and consumers. With more and more processing and manufacturing plants adopting just in time (JIT) procurement plans, smaller plants would offer greater economy and flexibility in production planning to the downstream processors.

5.4. Raw material cost

Aluminium bearing clays are the largest occurring minerals on the earth crust. Bauxite is not necessarily the predominant of them since all clays on the earth’s crust carry some amount of aluminium. The technological developments in Bayer process over the years have been lowering the cut off levels of alumina silica and other impurities in bauxite. Since the physical and quality norms of the users of speciality alumina are different from that of the aluminium smelting industries, and the processing industry itself adopts varying technologies to cater to its product mix, it would not be illogical to expect that bauxites of a different grade could be specified on both technological and economic considerations as starting material.

The ever-expanding scale of economy of alumina refineries called for large scale mechanised Bauxite mining operations. This required access to large and continuous deposits that could accommodate mechanised and uninterrupted mining. Alumina refineries are being increasingly planned with assured supply from an proven deposit for a minimum of 30 years to cover the estimated economic life of an alumina refinery. Over the years, sourcing of Bauxite has become a limiting factor in setting up alumina refineries. This has more or less pushed out of consideration smaller deposits of 10 - 30 million tons available for pocket mining operations. Larger mining operations have also been challenged by deforestation, overburden disposal, environment degradation and the issues involved in rehabilitation of displaced ethnic populations etc. Over the years, environment regulations have also become more stringent and securing prospecting and mining concessions are becoming more difficult to come by for the industry.

Governments world over are, in general, more careful in granting exploration and mining rights of large deposits sought by large scale miners for merchant and/or captive mining. However, smaller and isolated deposits which can easily support smaller size speciality alumina projects over their economic life of, say 30 - 35 years generally do not attract as stringent scrutiny and qualifying norms for the grant of concessions as is required for larger deposits. This offers a perfect opportunity for the speciality alumina industry to build ‘stand-alone’ projects in bauxite bearing areas to ensure valuable raw material supply security for their projects. Captive mining also offer the freedom to source Bauxite of quality fitting to the requirements of the process for production of a chosen product mix of special grades of alumina.

5.5. Set up cost

In building plants in heavily populated developing countries like China, India, Indonesia and Vietnam the acquisition of land is increasingly becoming a difficult task. Therefore, the challenge now is to design plants with smaller foot-print A smaller plant not only has an advantage in carrying lower initial licensing and linkage tie up cost but also saves on building of captive social and non-plant infrastructure.

5.6. Barriers to capacity utilization

Apart from market conditions, many local labour and regulatory conditions can also limit optimum capacity utilisation of production plants. Smaller size plants, in general, have greater flexibility in meeting such unforeseen conditions due to lower set up time and cost. Some of the other features of industrial climate, not always encountered in developed economies, could be:

5.6.1. Limitations on demand

Overall market demand for industrial products covers the sum total of present and future demands of existing users and also that of new entrants to the market. The availability of market share for exploitation would depend on the operational strength of the existing players and new ‘me too’ players entering the market. Smaller producers are generally more vulnerable to losing their business to larger and technologically superior competitors and latest market entrants. They however, have greater flexibility in moving their market positioning and altering or divesting their product mix.

5.6.2. Non-homogeneous output

Unlike the primary alumina industry, speciality alumina production plants are, in general, multi product set ups. Apart from a limited range of standard products, the quality norms and product specification are dictated by the buyer/user. With their lower set up costs, the advantage to move with market movements and changing customer demands rests with smaller plants.

5.6.3. Plant age differentiation and life cycle location

An increase or decrease in capacity need not draw upon proportionate cost or capacity of equipment, labour deployment and specific consumption rates. Therefore, to assume that a smaller plant would show arithmetic regression in equipment cost may not always be true. This is a disadvantage of smaller plants which can be met with modular configurations of units with proper engineering of plant layout and equipment specification building.

5.6.4. Location

Production plants choose a location at either resource or market head. For the larger smelter grade alumina plants, the site selection options are restricted by land availability, localised and national environmental regulatory norms.

6. Changing paradigm of data from technical study for plant sizing

Technical data utilised for deciding on plant sizing, could broadly be covered under the following headings:

- Pricing of key equipment and relative factors
- Supply conditions
- Product homogeneity
- Location factors

At the time of deciding on the budgetary allocation for the project, the costs more often than not tend to be higher than the initial estimates. Smaller plants which do most of their project procurements locally tend to be more accurate in budgeting and actual expenditure.

6.1. Cost of individual units of industrial equipment

Smaller plants have an advantage in this context as the project implementation periods are lower and the suppliers tend to quote prices to meet lower lead time and monetary turn over cycle. This defies the general perception that smaller equipment tend to cost higher on per unit output basis.

6.2. Operating cost – Labour + raw material + utilities

Larger plants are expected to generate higher labour productivity. However, with increasing automation, the elasticity to labour productivity to man-hours needed for unit production is coming down rapidly. In smaller plants which are more tuned to closer and personalised supervision compared to larger plants, the learning curve of work force is found to take a steeper curve.

6.3. Raw material cost

Raw material cost gains a distinct advantage in smaller plants on account of lower inventory carrying costs. Larger plants do have the advantage of better bargaining power on procurement prices of raw material and consumables on volumes. However, captive sourcing and effective supply chain management can considerably reduce the cost of this relative disadvantage of volumes for the smaller plants.

6.4. Support System costs – transportation and regulatory compliance

While transport costs in bulk procurement and movement may be an advantage in operation for larger plants, they are also subject to more stringent regulatory checks on compliance to labour law legislations, pollution control and corporate governance etc. Smaller plants, especially when they operate within industrial clusters and as subsidiary or ancillary of a mother plant, tend to have the major cost of regulatory compliances taken care of by the mother units.

6.5. Product mix management

Ultimately, scale of economy depends significantly on the positioning of the breakeven cost point – benefit representation curve. The business and operational model of Speciality alumina plants are distinctly different from smelter grade alumina plants. While the former have the option, which they in general follow, of producing and marketing of a wide range of products with a very wide range of applications, the smelter grade alumina plants are single product catering to an oligopolistic market scenario. The contribution factor in both cases follow different routes.

In case of smelter grade alumina the contribution model would be:

$$M_s = \frac{S_1 - C_1}{C_1} \tag{1}$$

M_s	Contribution from sale/transfer of smelter grade alumina
S_1	Sale/transfer Price
C_1	Cost of production .

In the overall revenue plan of a primary alumina producer, the contribution of earning from sale of hydrates and calcined alumina to downstream special alumina industry is, in general, rather insignificant. Therefore, both in terms of volume and value, this downstream market is rarely treated by the primary alumina producers as an important and independent ‘business and independent profit centre’.

In case of multi product speciality alumina production system, the contribution would be the arithmetic sum total of the contribution from each class of the market product.

$$M_{sp} = \sum \frac{S_a - C_a}{C_a} + \frac{S_b - C_b}{C_b} \tag{2}$$

M_{sp}	Sum total of contributions from each product in the product mix
S_a, S_b, S_c	Sales price
C_a, C_b, C_c	Ex works cost of production.

The single product smelter grade alumina producing plants are in general captive entities of a smelter. They mostly venture into the open markets to sell their surplus alumina, generated on account of a ‘scale of economy’ followed and which by design would be higher than the captive needs of the smelter. There are not many stand-alone alumina refineries in the world which produce exclusively for the open markets.

7. Conclusions

The dynamics of the special grades alumina industry, especially its ceramic and refractory component, is closely linked to that of the global metallurgical industry. Since over three decades, the world has been witnessing a tectonic shift in global primary metal production capacities in both ferrous and non-ferrous sectors. The Asia pacific and Middle East regions are currently contributing around 70 % of overall global production of iron and steel, aluminium and other major and minor non-ferrous and strategic metals. Similar developments have been witnessed in the cement; foundry and metal forming industries, all of which use alumina based refractory material in different forms.

The special alumina producing industries, world over, have been depending on the primary smelter grade alumina producers for sourcing their basic input raw material of hydrate and calcined alumina. In turn, technically and in terms of economics, the growth, pricing, and profitability of the industry has remained closely linked to the worldwide smelter grade calcined alumina producing industry.

Traditionally, for sizing of a production industry, the factors considered for evaluation have covered the elements of project financial accounting and its technical detailing. These factors have always been closely linked to the socio-economic and socio-political indices prevailing at the sites under consideration and the one finally selected for setting up of the production facility.

The iron and steel industry consumes over 90 % of the ceramic and refractory grade alumina based material produced in the world and continues to be the prime mover of the overall growth of special grade alumina industry. With the shift in the global metallurgical industry production base to Asia-pacific and Middle East region, there has also been a paradigm shift in evaluation of criteria for defining ‘scale of economy’ for special alumina projects. This calls for investors to take a serious look at the Asia Pacific Bauxite rich areas for setting up green field projects with captive bauxite sourcing.

It would be logical for investors to take a serious look in to the region keeping in mind the
Of late, opportunities have come up in Asia and other developing Bauxite rich regions where large number of smaller deposits are more easily available compared to the large concessions needed for setting up mega scale mechanised mining projects. Such smaller 10 - 30 Mt deposits are no longer attractive for the bauxite mining industry supplying large primary alumina refineries. The emerging business scenario in these regions seem to favour setting up of smaller capacity value added speciality alumina production facilities with bauxite from such smaller deposits as the raw material as against sourcing of hydrates and alumina from primary producers. Raw material security in terms of pricing, quality management and process compatibility favours lowering of the ‘scale of economy’ for future green field speciality alumina projects in the Asia-Pacific, Middle East and other Bauxite rich developing parts of the globe. It opens up opportunities for smaller and medium level industry investors to enter the industry as both standalone merchant and captive producers. This could not only result in better growth rate for the industry but also improve its costing and profitability, in the years to come.

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