Significance of increased greenfield alumina refinery design capacity

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1. Greenfield alumina refinery capacity evolution

An alumina refinery consists of a number of unit operations such as grinding, digestion, evaporation, etc. A unit operation generally comprises a string of equipment which together performs the desired process step, for example digestion with tanks, heat exchangers, pumps, vessels, etc. Such a string of equipment is often referred to as a 'train', 'unit' or 'circuit' (e.g. digestion unit, precipitation train, mill circuit). Alumina refinery design generally takes digestion as plant bottleneck.

As Fig. 1 illustrates, the design/initial alumina refinery production capacity of greenfield projects outside China has evolved over time from about 0.5-1.0m tpy alumina 25 to 30 years ago (e.g. Alumar, Worsley) to 1.4-3.3m tpy alumina for more recently constructed and future planned projects (e.g. Lanjigarh, Yarwun, Utkal, GAC).

Note that the actual production capacities of the projects indicated in Fig. 1 have significantly increased as a result of brownfield expansions (not shown in Fig. 1), capacity debottlenecking, and improved process efficiencies and operations performance.

The rationale for the trend in Fig. 1 is the economy of scale: an increased design production capacity is required to improve the economics of greenfield bauxite and alumina projects[1] to meet corporate economic criteria. The question arises what this means with respect to project capital cost[2].

With economics as the driving force, important elements to consider are therefore the development over the same time period of the alumina price (covered in section 2) and operating cost (section 3).

2. Alumina price

The development of the alumina contract price (LME-linked) over this period is shown in Fig. 2 (black line – left axis, in money of the day), which also includes the greenfield projects from Fig. 1 as black diamonds on the price line.

In the early 1980s many greenfield alumina refinery projects were constructed and started up (the four black diamonds in Fig. 2 between 1980 and 1984 in fact represent seven greenfield projects). However, the aluminium (and with it the alumina) market growth did not follow expectations. In addition, these greenfield projects had huge brownfield expansion and debottlenecking potential built into their design: in the 1980s and 1990s refinery capacity increases within ~10 years of start-up ranged from 30-140% (San Cyprian, Puerto Ordaz, Alumar, Wagerup, Worsley, etc). An important aspect in this regard was that the capital cost in US dollar per annual tA installed capacity for brownfield projects was only ~50% of that of greenfield capex[3]. The result was that only limited greenfield capacity was required for a long period of time.

Worldwide aluminium's main end uses include transportation (25-35%), building and construction (20-25%), packaging (12-15%) and engineering (15-20%, including electrical and machinery equipment). In other words the usage of aluminium permeates the global economy, and with it the demand for alumina. To better interpret the fluctuations in the alumina price, Fig. 2 therefore also includes the World GDP/capita growth rate (dashed line – right axis), as criterion for the growth of the global economy, bearing in mind that the number of people worldwide is growing continuously. Comparison of the two lines shows a good correlation: the alumina price has followed the World GDP/capita growth rate, with a time lag of one year or less for at least the last 15 years.

Noticeable in Fig. 2 is the significant and consistent increase in the alumina price in the period from about 2003 until 2008 (when the banking/economic crisis occurred), which does only partly seem to be supported by an equivalent trend in the World GDP/capita growth rate. However, as shown in Fig. 3, this alumina

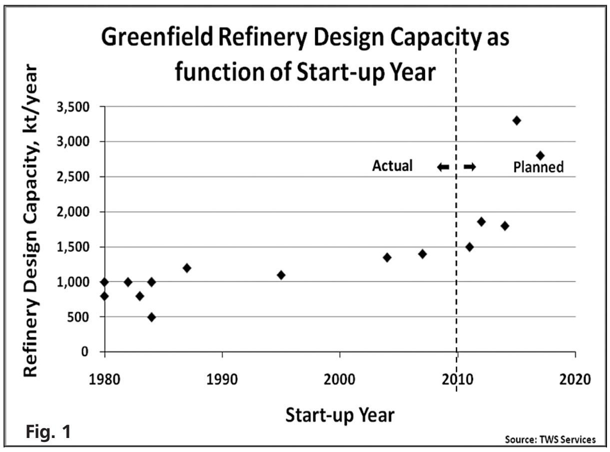

Fig. 1

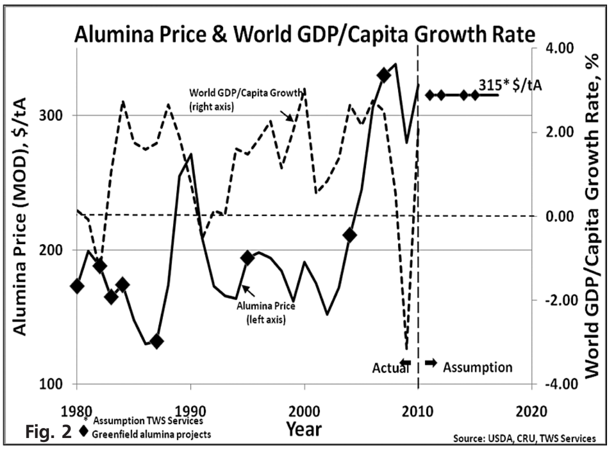

Fig. 2

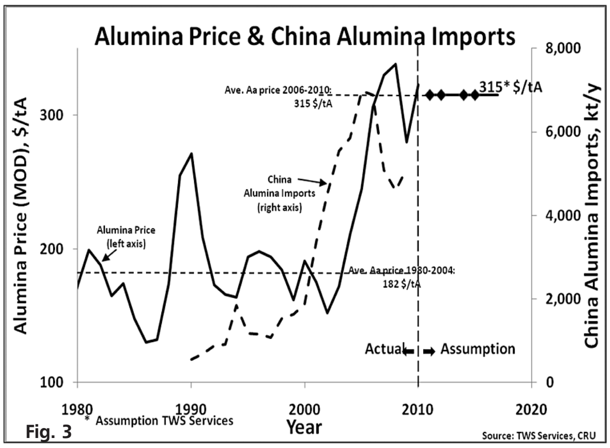

Fig. 3

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[1] *Reference [1] provides an overview of bauxite and alumina project economics*

[2] *Reference [2] provides an overview of capital cost*

[3] *See reference 1*

price increase seems to correspond with China's significantly increasing alumina imports over part of that period (dashed line – right axis).

Fig. 3 also illustrates the average alumina prices between 1980 and 2004 (~182 USD/tA), when the Chinese alumina imports reached a level of close to 6 million tonnes and kept increasing, and between 2006 and 2010 (~315 USD/tA). For project evaluation purposes beyond 2010 an alumina price of 315 USD/tA has been assumed in this paper. Although not shown here, the alumina (LME-linked contract) price as expected closely followed changes in the aluminium 3-month LME price, with a time lag of typically a year in the period before.

3. Operating cost[4] and margin

A next key element is operating cost (opex). In the context of this paper opex refers to the total cash cost in USD/tA. The total cash opex differs for each individual greenfield project; however, in almost all cases the total cash opex of a greenfield project ends up in the first quarter of the industry cash operating cost curve of the year in which it starts operations. For the purpose of the current analysis the average of the first quarter of the annual alumina industry's cash cost curve has been used as greenfield cash operating cost. Fig. 4 compares alumina price with cash opex. This figure indicates a good correlation between cash opex (dashed line – right axis) and alumina price (black line – left axis), with the alumina price following opex changes with a time lag of about a year.

In summary the following correlations have emerged from the above for the period 1980 to 2010:

- The 3-month LME aluminium price has followed changes in the global economy as expressed by the World GDP/Capita growth rate with a time lag of a year or less
- The (LME-linked contract) alumina price has closely followed changes in the aluminium price for the last 16 years or so, with a time lag of typically a year in the period before
- The significant increase in China's alumina imports in the period 2000 to 2010 was followed by an increase in the alumina price resulting in an average alumina price in the period 2006 to 2010 which was about 130 USD/tA above the average alumina price in the period 1980 to 2004.
- The alumina price has followed opex changes with a time lag of about a year.

As both alumina price and operating cost have now been assessed, the margin between the two can now be calculated. The result is shown in Fig. 5, which also illustrates the average margins in the periods 1986 to 2004 (~80 USD/tA) and 2006 to 2010 (~174 USD/tA). In other words, the average cash margin between these periods has more than doubled. With the results from sections 2 and 3 we now return to the original question what the significance is for project capital cost of the increased greenfield alumina design capacity noted for the period 1980 to 2015.

4. Economics and capital cost

To assess the effect of the developments discussed above on the capital cost of greenfield alumina projects, it has been assumed in the current analysis that a greenfield project should deliver an IRR[5] of 8%, a target typically used in the alumina industry as economic criterion. An Excel spreadsheet has been used to calculate project economics. Other evaluation assumptions include the following:

- Project evaluation period: construction time +30 years
- Greenfield / brownfield construction time: 3 / 2 years (capital cost spread equally)
- Tax depreciation period on capex: 20 years
- Corporate tax rate: 32%
- Full production from operating year 1 onwards
- Numbers in 'real terms' (i. e. inflation not included).

Historical greenfield project: To illustrate a typical historical greenfield alumina project the following assumptions have been used:

- First operating year: 1985
- Greenfield (initial / design) production capacity (refer Fig. 1): 1m tpy
- Brownfield expansion capacity (refer section 2): 1m tpy, coming on line in operating year 10
- Brownfield expansion capital cost (refer section 2): 50% of greenfield capex
- Alumina price (refer Fig. 3): 1985 to 2004: 182 USD/tA; 2005: 245 USD /tA; 2006 to 2014: 315 USD /tA
- Operating cost (refer Fig. 5): 1985 to 2004: 102 USD /tA; 2005: 130 USD /tA; 2006 to 2014: 141 USD /tA.

Applying the above assumptions, the capital cost found to arrive at an IRR of 8% for a 1m tpy greenfield alumina project is about 1,000 USD per annual tA. With a brownfield expansion capacity of the same size, the final capex of the expanded project ends up at 750 USD per annual tA.

[4] Reference [3] provides an overview of operating cost

[5] Internal Rate of Return: the discount percentage at which NPV equals zero. NPV: Net Present Value: the sum of a project's annual cash flows at a chosen interest / discount percentage per year, which often includes the cost of capital and a country risk element.

Note that the numbers quoted here are averages and that actuals will vary for an individual project (the target IRR of 8% may also differ per project). It is estimated that a capital cost range applies of about 800 to 1,200 USD per annual tA for greenfield projects in this period.

Future greenfield project (outside China): For a future greenfield alumina project, two sub-options have been considered (refer Fig. 1):

- 1.5m tpy refinery capacity, increased by a brownfield expansion to 3m tpy in the 6th operating year (current greenfield projects include a faster implementation of a brownfield expansion)
- 3m tpy refinery capacity from the 1st operating year onwards.

Other assumptions:

- First operating year: 2011
- Brownfield expansion capital cost: 60% of greenfield capex
- Alumina price (refer Fig. 3): 315 USD/tA
- Operating cost (refer Fig. 4 and 5): 141 USD/tA.

Applying the above assumptions, the capital cost found to arrive at an IRR of 8% for a 1.5, respectively 3m tpy greenfield alumina project is about 1,940, respectively 1,440 USD per annual tA. With a brownfield expansion capacity of the same size for the first sub-option, the final capex of the expanded project (which by that time will also be at 3m tpy) ends up at 1,550 USD per annual tA, i.e. about 100 USD per annual tA higher than the 3m tpy greenfield project.

At the UBS Australian Resources Conference, held in Sydney on 3 June 2010, Alumina Ltd gave a paper which included an estimate of capital costs of greenfield alumina projects. The range quoted for projects outside China was 1,230 to 1,890 USD per annual tA, consistent with the numbers found in the current analysis. The increase in capital cost from an average of 1,000 to 1,600 to 1,700 USD per annual tA between the early 1980s and 2010 is in line with the increase in the Chemical Engineering Plant Cost Index (CEPCI) over the same period (from about 317 in 1983 to 535 in 2010).

5. Conclusions and consequences

Despite a significant increase of the average margin (delta between alumina price and operating cost) from about 80 USD per annual tA between the first half 1980s and 2004, to 174 USD per annual tA since about 2006, greenfield alumina project economics have not structurally improved. This is caused by an increase of the average capital cost for a greenfield alumina project in this period from about 1,000 to 1,700 USD per annual tA capacity, and occurred despite a large increase in the scale of greenfield alumina refinery projects outside China from about 0.5-1.0m tpy alumina in the early 1980s to 1.4-3.3m tpy alumina in 2010.

The increase in the design/initial capacity of greenfield (bauxite mine and) alumina refinery projects outside China over the past decades has had major consequences:

- Project complexity amplified, especially in terms of project planning and management. Significant infrastructural works are often required, involving extensive government involvement, further adding to project complexity.
- Project capital cost has grown to several billion USD, and owners reduce risk through project financing and the formation of multi-party joint ventures. Although perfectly reasonable, this complicates project implementation (e.g. with respect to decision making processes).
- Due to the financial commitments involved, globally only a limited number of (very) large companies have the financial and human resources to develop greenfield projects.
- For the same reasons (project scope, complexity), only a limited number of engineering firms have the required skills and experience to successfully implement these projects.
- Typically a project life of 30+ years is (implicitly) applied to justify the significant investment of a greenfield bauxite and alumina project. The reason: an alumina refinery can operate effectively for decades. For greenfield projects with a captive refinery this means that the bauxite deposit on which they are based should be able to sustain refining operations for such a period of time. Therefore only (very) large bauxite deposits are developed, indicatively 200 to 300 Mt and more.

Solving the dilemma that a large (disproportionate) increase in project scale is required to achieve acceptable economics, requires a concerted effort by the industry players (alumina companies, equipment manufacturers, engineering firms, R&D, etc.) to find improvements and innovations in areas such as project development, technologies, etc. Steps in this direction have been made, see reference [4] and [5], but have not yet resulted in a significant improvement.

6. References

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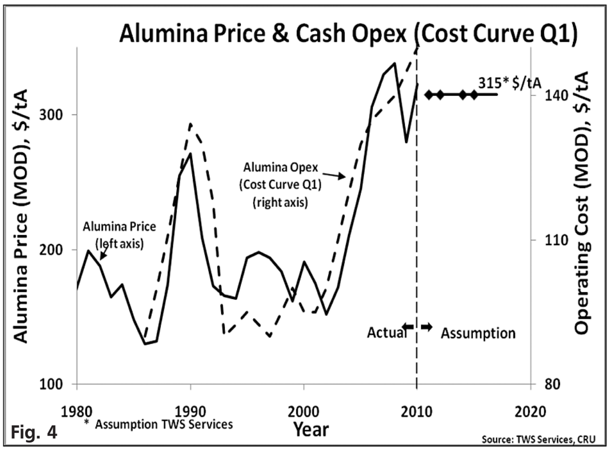

Fig. 4

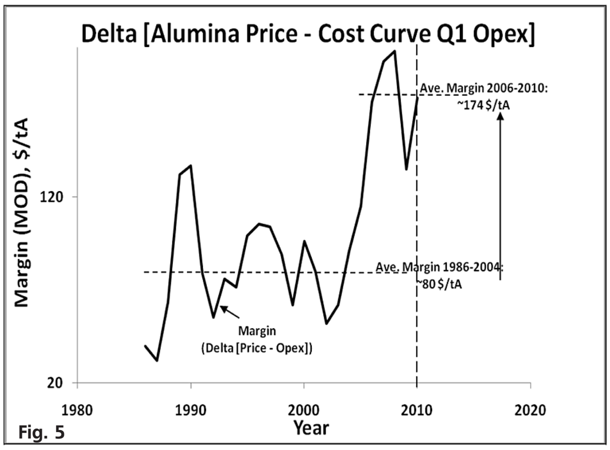

Fig. 5