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GREENFIELD DILEMMA – INNOVATION CHALLENGES

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ABSTRACT

After a long period without greenfield projects, the Aluminium industry is currently considering several greenfield Bauxite / Alumina opportunities worldwide. However many of these potential projects have difficulty to meet threshold criteria used by the industry for their economic evaluation.

This paper provides an insight in aspects of this issue and compares the economics of brownfield with greenfield Bauxite / Alumina projects. It concludes with suggested directions that could be explored to improve greenfield project economics.

EVALUATION CRITERIA

Project proposals in most industries are economically evaluated applying several criteria to ascertain if they meet company threshold levels and for ranking purposes in case a choice of projects exists.

These criteria include:

- Net Present Value (NPV), the sum of a project's annual cash flows at a chosen interest / discount percentage per year. The selected discount rate depends on the industry sector and often includes the cost of capital and a country risk element. In the bauxite / alumina industry the discount rate may range from about 6-16%. In this paper 10% has been used (indicated as NPV(10%)). NPV measures how much value is added or lost and is often used as prime criterion to assess the attractiveness of an investment.

- Internal Rate of Return (IRR), the discount percentage at which NPV equals zero. IRR may be considered a measure of the "quality" of an investment.

- Value over Investment (VIR) or capital efficiency ratio, the ratio of NPV at the chosen discount rate and the investment (may be expressed in various ways). Another investment quality indicator.

- Payback period. The period for the cumulative cash flow to become zero from a defined point in time. The cash flow may be expressed in different ways.

Of course many other criteria are also taken into consideration when a project is evaluated, such as availability of resources, strategic reasons, country view, marketing and financing aspects, robustness with respect to position on the cash cost curve, risks, etc. However these fall outside the scope of this paper.

The economic criteria mentioned above are also used in the Bauxite and Alumina industry and are applied to projects of all sizes. The focus of this paper is on brownfield and greenfield capacity expansion projects.

Although greenfield capacity expansion projects are self explanatory (i.e. on a greenfield – undeveloped – site), the difference between de-bottlenecking and brownfield capacity expansion projects is sometimes less well defined. However refinery capacity expansion projects of 500,000 ton/yr alumina and above are generally considered brownfield expansions as they often require additional trains to be added to some of the major plant facilities (e.g. digestion, precipitation).

For the purposes of this paper a refinery capacity expansion project of 1.5 Mt/yr alumina has been used to compare economics.

Before considering the economics of greenfield and brownfield bauxite / alumina projects, we will first review some effects of changes in alumina price, project operating costs ("opex"), capital costs ("capex") and tax holiday on NPV and IRR.

For simplicity's sake, the following has been assumed:

Evaluation period: construction time + 25 yrs
Construction time: 3 yrs (capex spread equally)
Project construction starting next year
Tax depreciation period on capex: 20 yrs
Corporate tax rate: 35%
Full production from operating year 1 onwards
Numbers in "real terms" (inflation removed)
Cost of studies etc not considered

Table 1 – Project Assumptions

NPV, IRR and VIR have been calculated using an Excel spreadsheet.

ALUMINA PRICE

The alumina price, although being outside the control of a project, plays an important role in Bauxite / Alumina project economics.

Figure 1 on the next page illustrates the relationship between NPV(10%) and Alumina Price for a brownfield type capacity expansion project (70 \$/tA opex, 450 \$/Annual tA capex, no tax holiday).

A linear relationship exists. The angle of this line is the same for different sets of values for opex and capex, however the intercept with the y-axis changes. This relationship is a result of the way the NPV is calculated:

$$NPV(i)=\sum aj*(1+i/100)^{-j} \qquad (1), \text{ with}$$

i	= discount rate;
∑	= summation from j=0 to n (project duration);
aj	= annual cash flow (after tax) at time j;

a =(Price-Opex-Tax-Capex)*Production Rate;
Price, Opex, Tax and Capex expressed per tA.

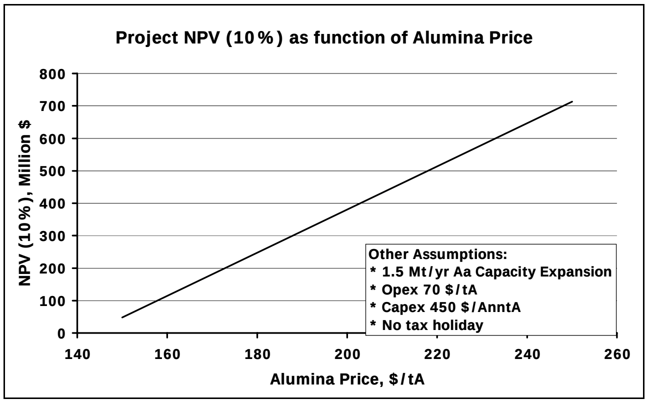

Figure 1 – NPV(10%) as function of Alumina Price

Figure 2 below illustrates the relationship between IRR and Alumina Price for the same project.

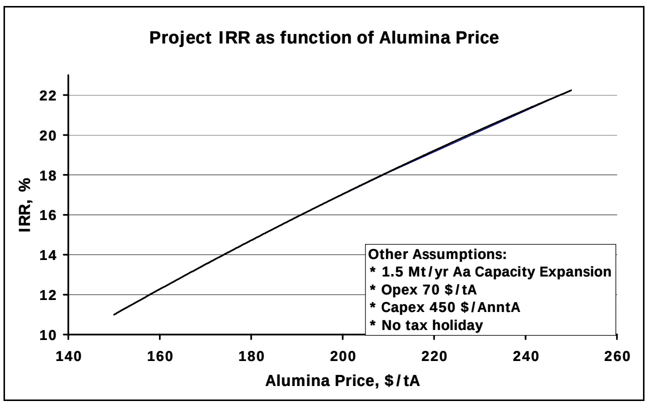

Figure 2 – IRR as function of Alumina Price

Figure 2 shows a good fit for a polynomial relationship of the second order. At different sets of values for opex and capex, polynomials of the second order remain showing a good fit, however the coefficients differ. This is caused by the shape of the curve describing NPV as function of discount percentage (see Figure 3 below).

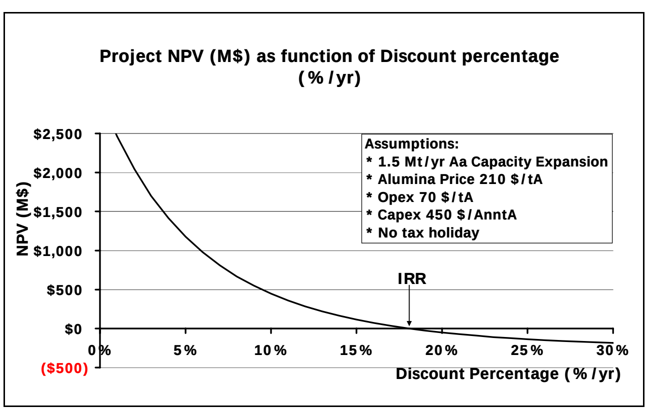

Figure 3 – Project NPV as function of Discount %

Figures 1 and 2 above illustrate the effect of alumina price in the range 150-250 $/tA. During an economic cycle, prices may range from 90 to 400 $/tA (cycle average price is around 200 $/tA). As can be seen from these figures, the timing of a capacity expansion project in the economic cycle may have a big impact on its economics.

OPEX & CAPEX

Both Opex and Capex of a project influence project economics. To illustrate their effect the alumina price has been kept constant at 210 $/tA in the examples below.

Figure 4 below provides an example of the relationship between NPV(10%) and Opex for a brownfield type capacity expansion project (210 $/tA price, 450 $/Annual tA capex, no tax holiday).

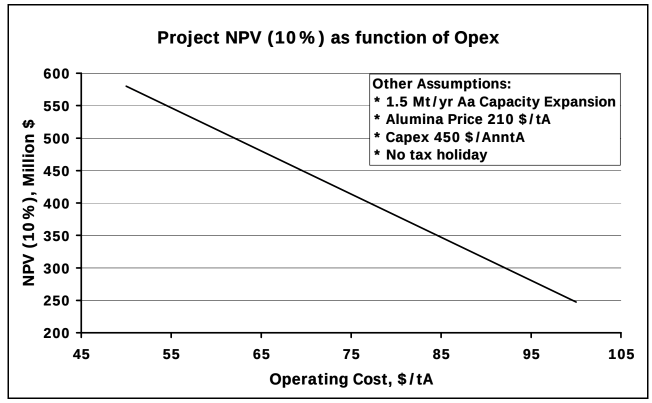

Figure 4 – NPV(10%) as function of Opex

The relationship is again linear, with a negative angle (refer equation (1)). As above for the NPV-Price relationship, the angle of this line is the same for different sets of values for price and capex, however the intercept with the y-axis changes.

We should keep in mind that opex for brownfield projects may vary from typically 50-90 $/tA and for greenfield projects from 80-130 $/tA.

The relationship between NPV and Capex is also linear, with the same characteristics as those between NPV and Opex above.

Figures 5 and 6 below illustrate the relationship between IRR and Opex, respectively IRR and Capex (assuming 210 $/tA price, 450 $/Annual tA capex, respectively 70 $/tA opex and no tax holiday).

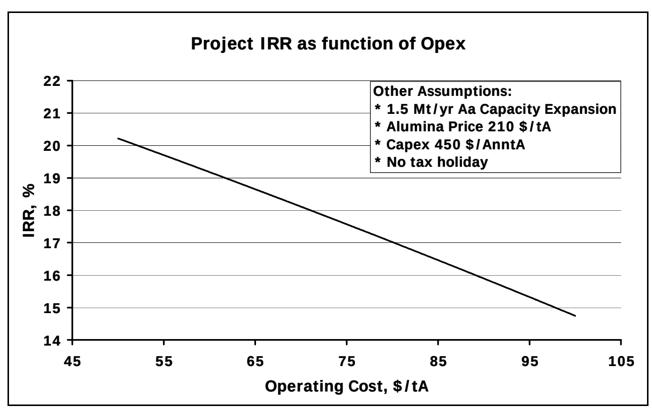

Figure 5 – IRR as function of Opex

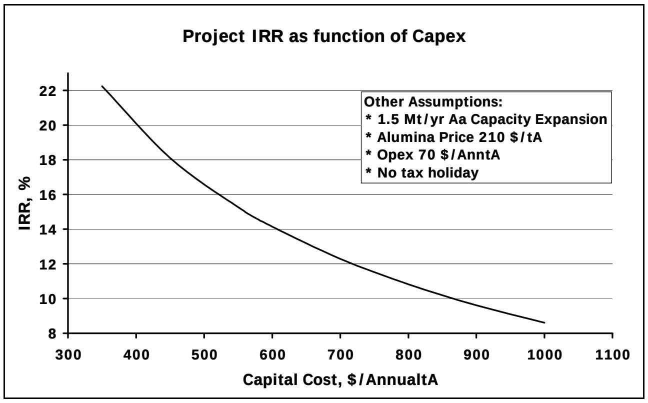

Figure 6 – IRR as function of Capex

Polynomials of the second order show a good fit, similar as above between IRR and Price, however with different coefficients.

The capex range for brownfield projects may range from typically 350-550 $/Annual tA and for greenfield projects from 700-1100 $/AnntA.

EFFECT OF TAX HOLIDAY

The reason to illustrate the effect of a tax holiday on project economics is because it may be significant.

A tax holiday may be granted by governments to provide an incentive for the implementation of a project in that country. It is therefore often (but not only) granted to greenfield projects, as such projects represent sometimes the first or a very significant investment of a company in that country.

It depends on project scale and country and other agreements between a government and a company, but a 10 year tax holiday on a greenfield project is not uncommon.

Figure 7 below provides an example of the effect of a 10 year tax holiday on the NPV of a greenfield type project (assuming 210 $/tA price, 800 $/Annual tA capex).

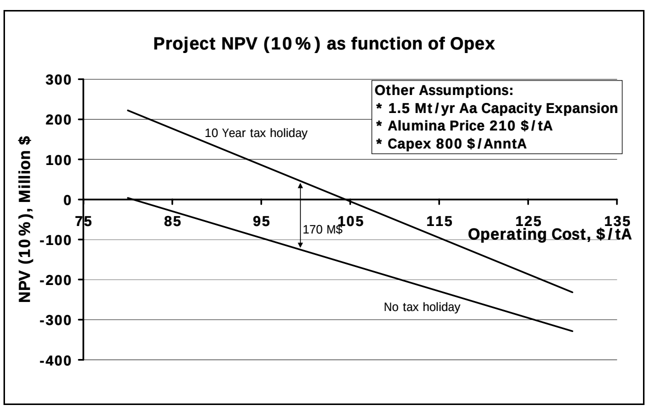

Figure 7 – NPV(10%) as function of Opex & Tax Holiday

Figure 7 illustrates that a tax holiday of 10 years could mean the difference between go and no-go for a project.

Figure 8 below illustrates the effect on the IRR of the same project and confirms the outcome of Figure 7.

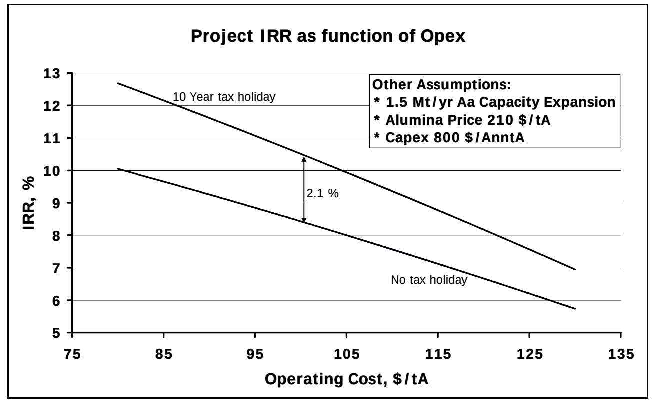

Figure 8 – IRR as function of Opex & Tax Holiday

The following tables 2 and 3 summarise the effects of alumina price, opex, capex and tax holiday on NPV and IRR for typical brownfield and greenfield projects. Both the change in absolute value and as percentage compared to the base case is indicated.

Capacity Expansion: 1.5 Mt/yr Alumina Price: 210 $/tA		BROWNFIELD 450 $/AnntA Capex; 70 $/tA Opex	
		NPV(10%)	IRR
Base Case	No tax holiday	447 M$	18.1%
Alumina Price	+20 $/tA	+ 133 M$	+2.1%
Opex	- 10 $/tA	+ 66 M$	+1.1%
Capex	- 40 $/AnntA	+ 43 M$	+1.5%
Alumina Price	+10%	+ 30%	+12%
Opex	- 14%	+ 15%	+6%
Capex	- 9%	+ 10%	+8%

Table 2 – Effect of price, opex and capex changes on economics of a Brownfield project

Capacity Expansion: 1.5 Mt/yr Alumina Price: 210 $/tA		GREENFIELD 800 $/AnntA Capex; 100 $/tA Opex	
		NPV(10%)	IRR
Base Case	No tax holiday	-129 M$	8.4%
Alumina Price	+20 $/tA	+ 133 M$	1.7%
Opex	- 10 $/tA	+ 66 M$	0.9%
Capex	- 80 $/AnntA	+ 86 M$	1.0%
Tax Holiday	10 year	+ 170 M$	2.1%
Alumina Price	+10%	+ 103%	+ 20%
Opex	- 10%	+ 51%	+ 11%
Capex	- 10%	+ 67%	+ 12%
Tax Holiday		+132%	+ 25%

Table 3 – Effect of price, opex and capex changes on economics of a Greenfield project

Note that the numbers in these tables do not represent specific projects. However they are illustrative of the effects of the changes in price, opex and capex on NPV and IRR.

The numbers in these tables show how significant price changes and a 10 year tax holiday are on project economics. It is also clear that opex and capex changes can be significant, however the opex and capex reductions used in the tables are quite challenging (-10 $/tA, respectively -40 and -80 $/Annual tA).

In the examples above the NPV numbers were calculated at a discount rate of 10%. As mentioned on page 1, this discount percentage may be different for different projects. That would change the absolute NPV numbers (not IRR), but wouldn't change the trends covered above.

Let us now turn to the subject matter of this paper.

ECONOMICS OF GREENFIELD & BROWNFIELD PROJECTS

A number of new greenfield projects were built in the early 80's, e.g. Aughinish, Alumar, Worsley, Wagerup, Nikolaev, San Cyprian, Ciudad Guayana.

However aluminium (and thus alumina) market growth didn't follow expectations.

In addition these greenfield projects had a huge de-bottlenecking and brownfield expansion potential built into their design.

The result has been that only limited greenfield capacity has been built since then, e.g. Damanjodi, Alunorte (actual design also early 80's), Pingguo.

Some of these projects may have ended up not generating the projected economic returns based on which they were approved. However it was (and in most cases still is) economically (much) more attractive to construct brownfield than greenfield capacity. The following may illustrate the issue.

Let's assume a required expansion capacity of 1.5 Mt/yr as above, an alumina price of 210 $/tA (i.e. close to cycle average) and otherwise the same assumptions as in Table 1.

As mentioned earlier the typical capex range for brownfield projects is about 350-550 $/AnntA and for greenfield projects about 700-1100 $/AnntA. The opex range may vary typically from 50-90 $/tA for brownfield projects to 80-130 $/tA for greenfield projects.

In view of arguments outlined earlier, a 10 year tax holiday is assumed for the greenfield project and no tax holiday for the brownfield project.

Combining the two opex ranges and using the two capex ranges for brownfield and greenfield projects, the following picture emerges for NPV(10%) and IRR (Figures 9 and 10).

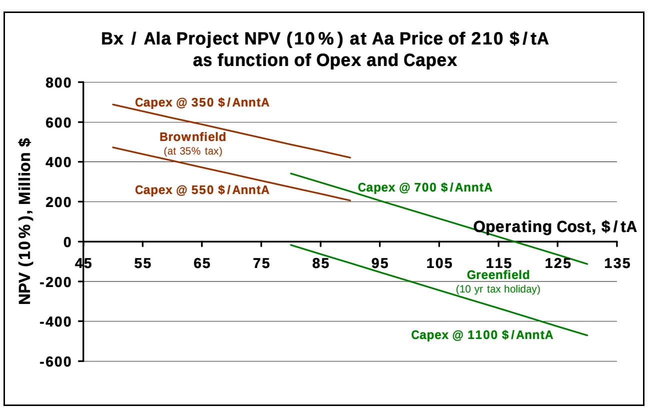

Figure 9 – NPV(10%) for Brownfield and Greenfield projects as function of typical Opex & Capex ranges

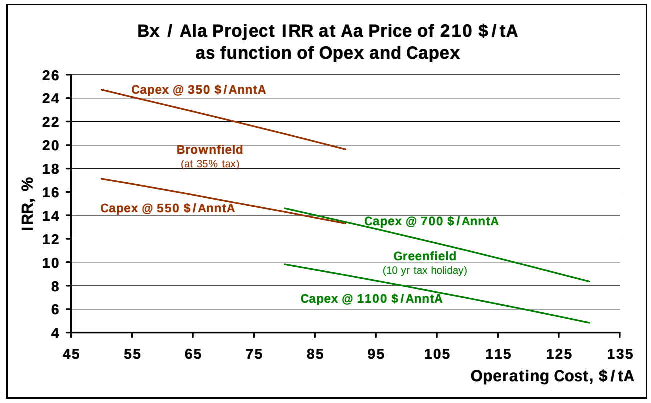

Figure 10 – IRR for Brownfield and Greenfield projects as function of typical Opex & Capex ranges

Observations from Figures 9 and 10:

- Even with a 10 year tax holiday applied to greenfield projects, brownfield economics are significantly more attractive than those of greenfield projects.
- Absolute values of the economics of a brownfield type project can be very attractive.
- Absolute values of the economics of a greenfield type project are not very attractive.
- The economics of a brownfield project are more "robust" than those of a greenfield project, i.e. a higher than planned opex or capex will not "kill" the economics of a brownfield project but may very well result in unacceptable economics for a greenfield project.

The last two points are also illustrated by Figure 11 below, which shows the VIR ratio (NPV(10%)/Discounted Capex) for the two ranges used above.

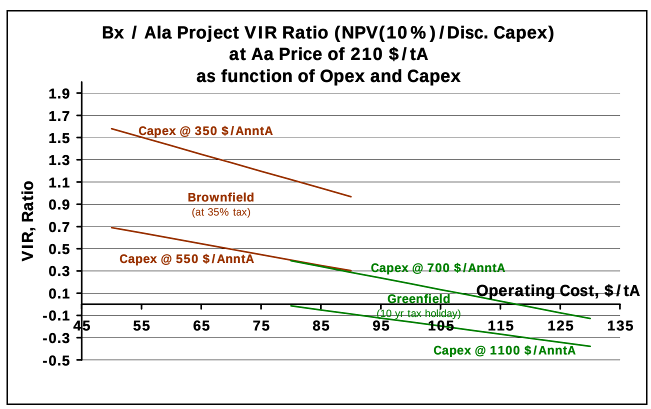

Figure 11 – VIR for Brownfield and Greenfield projects as function of typical Opex & Capex ranges

This ratio, as mentioned on page 1, may be used as indicator of the "quality" of an investment. VIR ratios above about 0.7 are typically considered attractive for brownfield projects, 0.3 for greenfield projects.

Final NPV and IRR values for a project will obviously depend on actual alumina price, capex, opex, tax rate etc as discussed earlier.

In addition NPV and VIR values also vary with the selected discount percentage.

However the four observations mentioned above do not significantly change. Only high alumina price levels, such as the industry has been experiencing over the last 1-2 years or so, would affect the third conclusion.

This is the dilemma facing companies that are in the process of deciding on bauxite / alumina capacity expansion projects: a greenfield project is often difficult to justify purely based on economics. And if a brownfield alternative is available it is nearly always (significantly) more attractive. Of course not all companies would have a brownfield alternative to choose from.

As brownfield expansion capacity is being exhausted the economics of the remaining brownfield expansion capacity and those of current greenfield projects may get closer to each other. That doesn't however improve the economics of greenfield projects, it means deteriorating economics for brownfield projects.

Let us therefore now consider the causes of the above and an approach to potential solutions.

TECHNOLOGY AND INNOVATION CHALLENGES

Important reasons for the big difference in economics between greenfield and brownfield bauxite / alumina projects are:

- The requirement to construct *infrastructure*, both "external" (e.g. port, alumina transport) and "internal" (e.g. piperacks, power distribution, water supply, buildings).

  Examples of infrastructural requirements:

Item	Capex Range (M$) *
Port Facilities	50 – 100
Aa & Raw Matls Transport	50 – 100
Water Supply	20 – 50
Housing Facilities	30 – 100

* Indicative only, actual numbers may deviate significantly

Table 4 – Infrastructure Requirements

  This means that project capex is penalised, even for greenfield projects with limited infrastructural requirements, as illustrated by table 5 below.

Element	Capex (M$)	Capex $/AnntA
Mine	120	80
Refinery	1000	670
Infrastructure	150	100
Total	1270	850

* Indicative only, actual numbers may deviate significantly

Table 5 – Indicative capex of a 1.5 Mt/yr Aa greenfield project with limited infrastructure requirements

  Refer to Table 3 above for the effect of capex increase on the economics of a greenfield project.

  In the context of opex something similar applies: an organisational infrastructure needs to be put in place for a greenfield project (e.g. operational, maintenance, purchasing).

- Historical layouts with (significant) *provisions for future expansions* that are not (yet) generating a return.

  Several of the projects mentioned earlier were able to accommodate additional "trains" (lines, units), such as digestion or precipitation, on the original plant site.

- Plants have typically been *over designed* due to conservatism by the project owner or technology supplier. Additional factors were applied in the design and engineering phases, e.g. to meet production guarantees. And often the same applies to equipment manufacturers.

  This situation resulted in projects with significant (low cost) de-bottlenecking / brownfield potential as their steadily increasing production capacities over the past 20 years have illustrated. Turning it around, one could say that the "earning power" potential of these projects was underutilised for a significant period of time. Or putting it differently brownfield projects have been so attractive at the expense of the original greenfield projects.

- *Process and technological developments* such as yield improvements and process control / automation projects have provided opportunities to extract more capacity from existing facilities.

  Several of the projects mentioned earlier were designed in a period that precipitation yield was typically 50-55 g/l. Due to improved operational procedures and better control facilities yield has increased by maybe 10-15 g/l.

In other words historical greenfield projects had huge brownfield expansion capacity inherently built in. In addition many of these projects were built in the same period. The end result has been that for a long period of time little incentive existed to develop greenfield projects and to actively pursue significant improvements in project design and layout. This situation may be reflected also by the limited resources that the industry has been dedicating to research and development efforts in innovations and technological improvements.

Although the global alumina consumption may not yet have fully caught up with the remaining brownfield capacity expansion potential, several companies seem interested to expand their alumina production capacity, including companies that do not have the option of brownfield expansions.

In other words, the timing seems right for finding solutions to the dilemma sketched out above.

Alumina prices through economic cycles have shown not to stay at a high level forever. In fact long term cycle average prices were declining consistently until about 2 years ago. The most robust long term solution therefore appears not to assume alumina prices staying at a certain level, but to define a structural approach to innovation and R&D. Such an approach falls outside the scope of this paper.

However the reasons outlined above for the big difference in economics between greenfield and brownfield bauxite / alumina projects provide some clues how this issue could be tackled.

- "Design a project requiring no infrastructure". This shouldn't necessarily be interpreted literally, but innovative thinking could assist in coming some way, e.g. using skids (platforms, modules). Another approach might be not to "take the plant to the bauxite", but taking bauxite to a site with existing infrastructure (refer CVRD's plans to take Paragominas bauxite by slurry pipeline to Alunorte plant).

  In the context of opex this could mean designing a plant requiring "no organisation", e.g. by applying automation and "maintenance-less" equipment (as much as possible), and using a simple straight forward plant design. Outsourcing of activities may be considered in general terms, but doesn't by itself address the issue of the necessity of organisational infrastructure.

- "Don't build costly provisions for future expansions into a project / plant design". Again this statement shouldn't necessarily be taken literally. However if that were the mindset, plant design may look different, as the focus would be on maximising the advantage of building a dedicated plant. A next production unit would have to be justified based on its own (economic) merits. This also opens up the aspect what would be the optimum capacity for such a plant.

- "Do not over design a project / plant". One angle could be to critically review factors ("fat") built into a design (e.g. with respect to plant operating factor, design allowances and sparing philosophy). Another could be to make a conscious dedicated effort to "achieve maximum production capacity" right from start-up.

- "Look over the fence" (e.g. of other industries) to assess / review if technologies / practices / ideas that are "proven technology" elsewhere could be applicable and economically attractive to bauxite / alumina projects. This may apply both to process related as to project related aspects.

- Stimulate technology development and R&D efforts. As mentioned earlier such efforts should fit within a larger corporate and industry context.

The above may illustrate that the big difference in economics between greenfield and brownfield bauxite / alumina projects is not necessarily a law of nature. Many technology and innovation challenges are left which, once addressed, could significantly narrow the gap.