Alumina project economics sensitivity (What-if) analysis

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Sensitivity (What-if) analysis – Objective and tools

A sensitivity analysis is generally conducted as element of a project's economic evaluation to assess which parameters have the greatest impact on its economics, i.e. on Net Present Value (NPV) (e.g. in million USD), Internal Rate of Return (IRR) (in %), and Value over Investment / Capital Efficiency Ratio (VIR/CER), etc. Refer Appendix 1 for a description of NPV, IRR and VIR/CER. A project's payback period (period for the cumulative cash flow to become zero from a defined point in time), another economic parameter, is not discussed here (note however that IRR and payback period are correlated).

A sensitivity analysis provides an indication of the impact on the base case economics of a project if one of its parameters would vary from its projected value. Key parameters that may be considered for a sensitivity analysis of a (bauxite and) alumina project include:

- Product (bauxite / alumina) sales price
- Total project operating cost (opex) or elements thereof such as:
  - Consumption rates (e.g. bauxite, coal, fuel oil, caustic soda)
  - Consumables prices (e.g. fuel oil, caustic soda, coal)
- Total project capital cost (capex) or elements thereof such as:
  - Mine
  - Alumina refinery
  - Infrastructure (e.g. port facilities, railway, personnel housing, roads)
- Production capacity increase / decrease
- Currency exchange rate
- Other variables (e.g. NPV discount rate, loan interest rate, tax holiday, etc.).

Reference project and economics

A reference project is used in this article, based on the assumptions shown in Table 1 (the base case). The bauxite quality assumed for the reference project can be found in Appendix 2, Table 2.

Table 2 shows the economics of the reference project based on a discounted cash flow (DCF) evaluation.

Sensitivities – examples and results

This article explores the sensitivity of the reference project to variations of the first four parameters mentioned above, i.e. alumina price, total cash opex (excludes sustaining capital cost), total capex, and plant capacity of the first two operating years, with changes of 5% points over a range of ±15%.

The results are presented in Table 3 (numbers in red between brackets are negative).

Fig. 1 is a graphic image of the sensitivity of the project's NPV (%) for the four parameters (results of the top half of the table). Note that the x-axis is expressed as percentage change of the parameters shown in the figure relative to the reference case / base case defined in Table 1. In other words, for
the reference project used here this means that e.g. a 10% parameter variation represents a change:
- of the alumina price of -USD38.5/tA
- of total capex of -USD224m
- of total cash opex of -USD20/tA and
- of plant capacity of the first two years: 63% (yr1)/85.5% (yr2) for a reduction of 10%, i.e. a total production decrease of -264 kt over these two years; and 77% (yr1)/100% (yr2) at an increase of 10%, i.e. a total production increase of -192 kt over these two years – the reason for the difference between these two (+192 vs -264 kt) for a change of ±10% being that the maximum plant capacity has been limited to design capacity.

Note that the relationship between NPV (8%) on the one hand and alumina price, total cash opex and total capex on the other is linear as a result of the way the NPV is calculated (refer formula (1) in Appendix 1). The only exception is the plant capacity of years 1 and 2: this displays also a linear relationship with NPV (8%) until the point where the capacity limitation to design capacity comes into effect (for year 2 roughly beyond a relative increase of 5%, not relevant to year 1 for the parameter range covered by Fig. 1).

Fig. 2 provides a graphic representation of the sensitivity of the reference project IRR for the same four parameters (the results of the bottom half of Table 3). For the parameter range considered in the figure (±15%), the relationship between IRR and the four parameters displays a fit with second order polynomial trends. Note however that these relationships require reconsideration outside the parameter range of Fig. 2.

Observations and discussion

Fig. 1 (sensitivity of NPV (8%)) illustrates the following main points:
- The reference project in this article is very sensitive to relative alumina price fluctuations: a drop by only -2% (-USD8/tA) or more results in a negative NPV (8%).

In most if not all (bauxite and) alumina projects, a realistic assumption of the alumina price used for its economic evaluation is a key parameter. This is complicated since these evaluations often cover 30 years or more. Admittedly the period of time with the highest impact on a project’s economic outcome is its payback period, typically around ten years for a (bauxite and) alumina project. The alumina price has proven however to fluctuate significantly over the long as well as the short term as illustrated in Fig. 3 for the period 1980 to 2016 (solid line – left axis) and in Fig. 4 for the period January 2017 to May 2018. The latter period highlights the recent massive alumina price fluctuations (February to May 2018) resulting from capacity cutbacks at the Brazilian Alunorte refinery and US sanctions imposed on Rusal.

- The reference project is quite sensitive, albeit to a lesser extent (the line is not as steep), to relative total cash opex fluctuations: an increase by just over ~3.5% (-USD7/tA) results in a negative NPV (8%).

Total cash operating cost is the result of a
It is well known in the alumina industry that the development and construction of several (bauxite and) alumina projects, sometimes even brownfield expansions of existing plants, ended up over budget, in some cases with cost increases significantly higher than 4% (e.g. Aughinish, Alumina, Worsley, Gove).

- The reference project appears again even less sensitive to relative changes of the capacities of years 1 and 2, assumed in the base case at 70% (year 1) and 95% (year 2). However a drop of these capacities by -7.5% or more, equivalent to a total of only ~200 kt over these two years, results in a negative NPV (8%).

A recognized challenge of the bauxite resource in the widest sense (including aspects of mining, processing, existing country infrastructure, logistics, environment, societal, legal, etc.) when converting it to smelter grade alumina with the selected technology, at the desired quality, is in a responsible way with respect to safety and environment.

In this context, a sensitivity analysis of a particular project could for example indicate that modifying its process plant at the expense of a capex increase would result in structurally lower cash opex, with as end result improved overall economics (both opex and capex represent negative cash flows i.e. a form of exchangeability exists between the two with respect to their impact for instance on NPV and thus on project economics [2]). Or as another example, outsourcing of specific activities would improve overall project economics as a consequence of a drop of required capex despite an increase in opex.

**Conclusion**

A sensitivity analysis of a (bauxite and) alumina project is a useful tool to assess the impact of potential variations of major project parameters on its economics. It may also be used to evaluate opportunities to improve or alternatively mitigate threats to achieve projected economics.

**Appendix 1 – NPV, IRR, and VIR/CER**

**Net Present Value (NPV (x %))**

The Net Present Value (NPV) represents the sum of a project's annual cash flows at a chosen annual interest / discount percentage (net meaning that both the costs and benefits of an investment are included). The NPV is generally used as the primary economic evaluation criterion of a project, calculated as follows:

\[ \text{NPV} = \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \]

where:
- \( i \) is discount rate, %;
- \( \Sigma \) is summation from 0 to \( n \) (project duration, no. of years);
- \( C_t \) is annual cashflow (after tax) at time \( t \) (yr).

**Key inputs of the annual cash flows:**
- On the revenue side: the amount of product generated and its sales price.
- On the cost side: capital cost, operating cost, sustaining capital, tax payable and depreciation.

The selected discount rate, \( i \) in formula (1) above, is generally the appropriate weighted average cost of capital (WACC), reflecting two elements: a risk-free rate and a risk premium which depends on the industry sector and the specifics of a project. Risks in this context

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*Graph showing alumina price and price reaction to supply disruptions.*

*Fig. 4. Price reaction to supply disruptions and potential trade restrictions highlight the tight market balance.*

*Graph showing alumina price and potential trade restrictions.*

*Source: Article 28 May 2018 by G. Djukanovic [1]*
**Fig. 5** Project NPV (M$) as function of Discount Percentage (%/yr)

Table 4: Assumed bauxite quality of the reference project

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical (w/w, dry basis - except moisture)</td>
<td>43.0</td>
</tr>
<tr>
<td>Total alumina (Al₂O₃)</td>
<td>39.2</td>
</tr>
<tr>
<td>Boehmite alumina</td>
<td>1.2</td>
</tr>
<tr>
<td>Total silica (SiO₂)</td>
<td>2.85</td>
</tr>
<tr>
<td>Reactive silica (SiO₂)</td>
<td>1.85</td>
</tr>
<tr>
<td>Iron oxide (Fe₂O₃)</td>
<td>28.3</td>
</tr>
<tr>
<td>Total organic carbon (as C)</td>
<td>0.1</td>
</tr>
<tr>
<td>Total inorganic carbon (as C)</td>
<td>0.2</td>
</tr>
<tr>
<td>Impurities (TiO₂, P₂O₅, Cr₂O₃, ZnO, etc.)</td>
<td>2.6</td>
</tr>
<tr>
<td>Moisture</td>
<td>11.0</td>
</tr>
</tbody>
</table>

(1) At digestion conditions

In the bauxite/alumina industry, the discount rate may typically range between 5-15%. In this article, a discount rate of 8% per year has been used as base case, indicated as NPV (8%). NPV measures how much value is added or lost by a project and is often used as prime economic criterion to assess the attractiveness of an investment. It is a central tool in the Discounted Cash Flow (DCF) analysis and is a standard method for using the time value of money to appraise long-term projects. The NPV of a project may be expressed in any currency (USD, Euro, GBP, CNY, etc.) or unit (USD, 1000USD, mUSD).

**Internal Rate of Return (IRR)**

The IRR signifies the discount percentage at which the NPV equals zero and is illustrated in Fig. 6 for the reference project of Table 1.

**Appendix 2 – bauxite quality used for the reference project**

In summary, the assumed bauxite quality consists of Gibbsite (major) and Boehmite (minor) as alumina minerals, enabling low temperature digestion and co-generation of steam and power, and of iron minerals (Hematite, Goethite, etc.; major), Kaolinite (medium) and Quartz (minor).

**References**

1. https://aluminiuminsider.com/alumina-costs-are-hurting-aluminium-smelters

**Author**


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**Fives awarded contracts by Alba and Hydro**

**Emission monitoring system for Alba**

In March 2018, Fives was awarded a contract by Aluminium Bahrain (Alba) for the supply of the Continuous Emission Monitoring System (CEMS) of Potlines 4 and 5. The CEMS will monitor the emissions (hydrogen fluoride and dusts) inside the potroom and at GTC inlet/ outlet.

The scope of supply includes general engineering, equipment delivery as well as installation and commissioning of the system. This contract confirms both Fives’ expertise and know-how in process and system integration, and Fives’ capabilities to execute turnkey service contracts.

**Anode paste preparation for Hydro Aluminium**

As part of the revamping of its Sunndal Aluminium smelter in Norway, Hydro Aluminium has awarded a contract to Fives for a new anode paste preparation line. This will be integrated into the existing green anode plant, commissioned by Fives back in 1967, a testimony of the company’s equipment lifetime.

Hydro’s aim is to overcome the current equipment obsolescence to anticipate a future pot amperage increase and to produce better quality anodes for the optimal performance of the electrolysis pots. Fives will supply its proprietary equipment and will integrate other equipment to deliver a fully operational production line.

One of the challenges will be for Fives to incorporate the new line into the existing plant, keeping the current equipment in operation until the commissioning of the new one.

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