CAPITAL COST: TO BE OR NOT TO BE

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ABSTRACT

The capital cost of a bauxite and alumina project is a key parameter in meeting corporate threshold economic criteria and in many cases may "make or break" a project. Although capital costs of projects tend to be quoted and compared, a consistent basis is often lacking and "apples" are compared with "pears".

This paper addresses elements of capital cost estimates of bauxite and alumina projects.

I. INTRODUCTION

Similar to operating cost.[1]), the capital cost of a bauxite and alumina project is not a stand-alone item but forms an integral characteristic of a project. It is influenced by the bauxite resource quality, country infrastructure, logistics of raw materials import and alumina export, the alumina production capacity and the choice of technology and design.

Capital cost plays a key role in the economics of a bauxite and alumina project due to its capital intensity:

- Greenfield projects: typically 930-1100 $ per annual ton alumina production capacity ($/AnntA);
- Brownfield projects: typically 450-750 $/AnntA.

Actual numbers depend on project scope, location, size of expansion, level of "maturity" of the existing plant for brownfield expansions (i.e. how much of the brownfield capacity potential has already been used), inclusion of items like owner's costs, etc.

Understanding the capital cost of a project and its build-up is therefore essential, especially if comparisons between projects are made, and to assess opportunities to lower a project's capital cost.

II. PROJECT SCOPE

The scope of a bauxite and alumina project may include some or all of the following elements.

MINE

Following are the main mine scope items for greenfield bauxite and alumina projects (brownfield alumina refinery expansions may not include "Mine" related scope items if the bauxite feed is purchased from a third party).

- Mine Infrastructure.
- Crusher / Beneficiation Plant.
- Bauxite Storage.
- Bauxite Transport System (e.g. conveyor).
- Mining Equipment.

REFINERY

Brownfield bauxite/alumina projects are in economic terms much more attractive than greenfield projects (e.g.[2]). One of the reasons is that conventional plant layouts include (significant) provisions for future expansions that are not (yet) generating a return. Several of the projects constructed in the early eighties were thus able to accommodate additional digestion and/or precipitation production units on the original plant layout (e.g. Wagerup, Worsley, Alumar, Alunorte).

Other aspects are that plants have typically been over designed due to conservatism by the project owner, technology supplier, engineering contractor, and equipment manufacturers and that plant operators, once they have familiarized themselves with their specific ore characteristics, find ways to increase plant production capacity. Greenfield plants should therefore aim right from day one at achieving maximum production level.

This situation resulted in projects with significant (low cost) de-bottlenecking / brownfield potential as illustrated by their steadily increasing production capacities over the past 20 years. In other words the economic potential of these projects was underutilised for a significant period of time.

Following are the main refinery scope items.

- Process Facilities: bauxite grinding, pre-desilication, digestion, clarification, etc. This item may be split out differently (see below).
- Utilities: steam and power generation, air compressors, etc.
- General facilities: cooling pond, mobile equipment, residue disposal area, communications, etc.
- Materials Handling: bauxite stacking & reclaiming, alumina storage and handling, caustic storage & handling, etc.

Table 1 provides an indicative breakdown of refinery capital expenditure (capex) in main plant elements.

Element	% of Refinery Capex
Bayer Loop*	38-49%
Utilities	20-26%
General facilities	14-19%
Calcination	7-10%
Materials Handling	5-8%
Disposal of Residues	3-5%

* Incl. bx grinding, desilication, digestion, clarification, security filtration, HID, precipitation, hydrate classification, oxalate control, evaporation

[1] Refer "Operating Cost – Issues and Opportunities", paper by P.J.C. ter Weer, Light Metals 2006, San Antonio, pp 109-114

[2] Refer "Greenfield Dilemma - Innovation Challenges", paper by P.J.C. ter Weer, Light Metals 2005, San Francisco, pp 17-22

Table 1 – Plant Overall Capex Breakdown (indicative)

Table 1 illustrates that the Bayer loop represents the largest part of refinery capex. About 20% of total refinery capex is precipitation yield related.

INFRASTRUCTURE

A second important reason for the difference in economics between greenfield and brownfield bauxite / alumina projects is the requirement for greenfield projects to construct infrastructure, both "external" (e.g. port, alumina transport) and "internal" (e.g. piperacks, power distribution, water supply, buildings). Examples of infrastructural requirements and related capex ranges are shown in Table 2.

Item	Capex Range (M$) *
Port Facilities	$50 – 150^{+}$
Aa & Raw Materials Transport	$50 – 100^{+}$
Water Supply	$20 – 50^{+}$
Housing Facilities	$30 – 150^{+}$

* Indicative only, actual numbers may deviate significantly

Table 2 – Typical Infrastructure Requirements

This means that the capex for a greenfield project is penalised, even for greenfield projects with limited infrastructural requirements, as may be illustrated by table 3 below, which shows some indicative capex numbers for a 1.5 Mt/yr Aa greenfield project with limited infrastructure requirements.

Element	Capex (M$)	Capex ($/AnntA)
Mine	120	80
Refinery	1,050	700
Infrastructure	225	150
Total	1,395	930

* Indicative only, actual numbers may deviate significantly

Table 3 – Indicative capex of a 1.5 Mt/yr Aa greenfield project with limited infrastructure requirements

III. INVESTMENT COST BUILD-UP

The total investment cost of a project may be broken down as shown in Table 4 (indicative numbers).

Investment Cost Item	$/AnntA
Direct Costs	600
Indirect Costs	220
Project Contingency	100
Engineering Contractor's Fee	30
Total Installed Cost*	950
Escalation	90
Financing Costs	5
Owners Costs	35
Working Capital	35
Total Investment Cost	1115

* Often referred to as "Capex"

Table 4 – Investment Cost Build-up

Total installed cost is often referred to as "capex".

Tax conditions, which are location specific, should be taken into consideration before deciding on the final (optimum) split of the capital costs between the indicated categories.

DIRECT COSTS

The Direct Costs (sometimes referred to as Direct Field Costs) of the mine, refinery and infrastructure may be split up as shown in Table 5. Contractor's mobilisation and demobilisation costs are assumed to be included with the direct costs.

Investment Cost Item	
Direct Costs	
Equipment	
Bulk Materials	
Concrete	
Structural steel	
Mechanical	
Piping	
Electrical	
Instruments	
Insulation	
Paving	
Roads	
Fencing	
Buildings	
Construction Labour Costs	
DCS/Control Systems	
Information Systems	
Direct Costs Contingency	

Table 5 – Typical Direct Costs Build-up

Equipment

This covers tanks, process vessels, pumps, agitators, heat exchangers, filters, thickeners, mills, calciners, etc.

Bulk Materials

Bulk Materials include items such as piping, concrete, structural steel, electrical, instrumentation and insulation.

INDIRECT COSTS

In this paper contractor's cost items such as support and non-productive labour, mobile equipment, craneage (incl. major craneage for heavy lifts), spare parts, logistics, scaffolding, utilities during construction, etc. are considered either part of indirect costs or owner's costs. Others may include these items with the direct costs, either explicitly, or in the rates. The Indirect Costs may be split up as shown in Table 6.

Engineering, Procurement and Construction Management

Engineering, Procurement and Construction Management (EPCM) costs may amount to somewhere between 5 - 20% of the total investment cost, depending upon the nature of the project and the engineering/contracting strategy.

Temporary Construction Facilities

These include removal and rehabilitation.

Freight

Freight costs include handling charges.

Construction Equipment

Construction equipment covers items like heavy cranes and trucks and scaffolding.

Indirect Costs	
Engineering, Procurement and Construction Management (EPCM)	
Temporary Construction Facilities	
Freight	
Construction Equipment / Scaffolding	
Vendor Representatives	
Spare Parts	
Mobile Equipment	
Utilities during Construction	
Commissioning / Start-Up Assistance	
Start-up / Commissioning Modifications	
Outside Consultancy Fees	
Insurances, Bonds and Guarantees	
NDT & Geotechnical Testing	
Indirect Costs Contingency	

Table 6 – Typical Indirect Costs Build-up

Mobile equipment

This includes items like forklift trucks, pick-up trucks, cranes, trailers, fire engine, front end loaders, etc.

Utilities during construction

Utilities cover gas, water, electricity and air.

Insurances, bonds and guarantees

This item covers the engineering, construction and warranty maintenance period.

Indirect Costs are sometimes expressed as percentage of the Direct Costs and may range indicatively from 25-50%, depending on the project scope, location, etc.

IV. CONTINGENCY AND ESCALATION

ALLOWANCES & CONTINGENCY

A cost estimate is made with a degree of certainty based on what is known (design criteria, process description, PFD's, P&ID's, equipment lists, general arrangements, etc).

However there is always a gap between what is known and the expected cost based on previously completed work. Therefore often allowances are included on quantities, and growth allowances for quotes and expected contractual awards.

A quantity allowance on bulk materials may vary between 3-10%, while a growth allowance on bulk materials may vary between 3-5%, both depending on the level of engineering.

Contingencies are included to cover unforeseen (unknown) items of work which will have to be performed, or elements of cost which will be incurred within the defined scope of work of the estimate but that cannot be explicitly foreseen or described at the time the estimate is being prepared because of lack of information. For example the impact of technology risk, risk of contractor insolvency, divergent weather patterns, industrial relations effects, etc. The contingency allowance is thus an integral part of the estimate.

In other words the contingency is developed by considering all of the factors that could affect the expected final cost of the project, but which have not been able to be quantified as part of the basic estimate.

Contingency evaluation is often carried out in combination with project risk analysis and consideration of the high and low range of the estimate. This analysis is generally carried out at two levels.

Firstly a pass is made through the direct and indirect content of the estimate. It is necessary to consider the nature of the scope of each package and the degree of technology risk and design development of each scope item assessed against a range of contingency factors that have been collected from experience in a broad sample of projects. This will generate a package contingency for the project.

The other factors to be considered in the second pass through the contingency analysis are project wide risks that may influence the expected cost outcome of the project. This project wide component of contingency is sometimes termed project contingency to distinguish it from package contingency.

A contingency is not to be considered as a compensating factor for estimating inaccuracy. Nor is it intended to cover items like potential changes in project scope, acts of god, labour disruptions beyond the control of the project manager, currency fluctuations or cost escalation beyond the estimated rates.

Depending on the stage of development of the cost estimate contingencies may indicatively range from 5-10% (at project execution phase) to 30-40% (at concept phase), refer Table 7.

ESCALATION

Escalation is the combined effect of general inflation and market conditions specific to the project (e.g. other planned major projects in the region, the demand for contractor's labour, equipment, materials, etc.). The total impact of inflation on a project depends on the phasing of expenditure during the project. Or putting it differently, the capex estimate is based on a certain date, while actual expenditures will be made in the future. To get an indication of the actual final expenditure, escalation is added to the capex estimate.

Overall escalation numbers may vary depending on projected timing and inflation projections. Escalation may typically be between 10-15% of total capex.

V. CONTRACT TYPES

Different contract types are being used for the implementation of bauxite and alumina projects. The cost of each of these contracts may differ significantly. However the cost of the engineering contractor should not be considered in isolation, but in combination with owner's costs and financing costs.

Following are some of the more common ones.

EPCM

Under EPCM the contractor manages the project on behalf of the project owner. The project risk will therefore largely be borne by the owner, resulting in more efficient project pricing than for EPC.

However, as the risk is largely borne by the owner, the latter will have to secure financial reserves to meet project risk and contingencies.

EPC

Under an EPC contract the contractor is to deliver a complete facility, for a guaranteed price, by a guaranteed date and one that performs to a specific level. If the contractor does not perform, he will face monetary liabilities. In other words if a problem occurs, the project company will focus on the contractor to fix the problem and provide compensation. The EPC contract provides a single point of responsibility.

In an EPC contract the project company is guaranteed among others a fixed completion date, a fixed completion price, no or limited technology risk, guaranteed output, security from the contractor, which protects the project company if the contractor does not comply with its obligations and restrictions on the ability of the contractor to claim extensions of time and additional costs.

The above factors make it attractive to the project company as it provides a level of certainty for the project owner and its bankers. Plus the construction risk is borne substantially by the contractor.

A drawback is that it allocates most of the construction risk to the contractor, who is then forced to build contingencies into the contract price for unforeseeable events. This leads to higher contract prices than the ones applied for some of the other contractual structures. Another drawback is that the project company has limited ability to intervene when problems occur during construction.

LUMP SUM TURNKEY

This contract shifts more risk to the contractor: the contractor is paid a predetermined sum for completing a particular stage or the whole contract works. It's a fixed contract price. In case of a change, the sum is not adjusted. The contractor therefore carries the risk of correctly estimating, at the time of contracting, the extent of work required to be carried out. The contractor is selected by competitive bidding. Basic and detailed design of the project is the contractor's responsibility.

On the other hand, because the design criteria are given by the owner, problems most frequently arise when the owner's design criteria are open-ended or subject to varying interpretations. Then the question is, who is responsible for the cost and time impact associated with the change.

COST REIMBURSABLE

Two ways of arranging a contract are by competitive bidding or negotiation. In competitive bidding, contractors bid for the right to execute the project. Instead of competitive bidding the owner may choose to award construction contracts to one specific contractor (e.g. based on its reputation, expertise, etc).

In a competitive bidding context, lump sum and unit price compensation are mostly used, while cost reimbursement is usually followed in the context of a negotiated contract. In the latter case the contractor is paid his costs including overheads and preliminaries together with a fee which may be either a percentage fee or fixed. This payment mechanism is appropriate when an early start is required but the project lacks sufficient definition to allow the other two payment mechanisms to be adopted. Usually the owner perceives that he has the necessary construction expertise to make the major decisions relating to method of construction and only requires the contractor's resourcing skills.

By choosing a cost reimbursable contract, the owner is facing two major issues:

- Difficulty in determining how much the project will cost;
- A lack of incentives for a builder to keep costs down.

A solution is to create a legal relationship which requires the contractor to notify the owner of a possible cost overrun. In the US, the law expects each party to exercise good faith and fair dealing.

Another approach is to share the risk of cost over run between the owner and the contactor. This is achieved by using target cost contracts or contracts with a maximum guaranteed price.

The target cost contract specifies a penalty or a reward to a contractor depending on whether the actual cost is greater or lower than the contractor's estimated direct cost.

A maximum guaranteed price arrangement imposes a penalty on a contractor for cost overruns and failure to complete the project on time. Amounts below the maximum are shared between the owner and the contractor. The contractor is responsible for costs above the maximum.

UNIT PRICE OR RE-MEASUREMENT CONTRACTS

This type of contract is used when the design responsibility lies with the owner and the design is to be completed during construction. The advantages for the owner are that by adopting overlapping phases of design and construction, construction can start early.

The overlap of design and construction means that variations to the original outline scheme are likely, but the unit price mechanism provides a ready means of pricing the variations.

A drawback is that the contractor is paid a price or rate for each unit element of work carried out and identified at the time of contracting. Usually it is done on a monthly basis, based on a monthly valuation. So the unit price payment mechanism thus places the risk with the owner, for estimating the extent of the works at the time of tender.

VI. FINANCING STRUCTURE AND COSTS

Historically industrial projects such as bauxite and alumina projects have been promoted by large industrial corporations and financed through the traditional corporate finance scheme: equity allocation along with corporate debt, issued with securities over existing and cash-generating assets.

Several factors result in modifications to the existing scheme and point to a different financial approach: Project Financing. Some confusion exists on its definition as it is sometimes thought to be a kind of corporate financing applied to large industrial undertakings. However, project finance, also referred to as non-recourse or limited-recourse finance, can be defined as the raising of debt aimed at financing an asset with security on the asset and its cash-generating capacity rather than on the sponsor of the project. This means that the lenders will have no or very little recourse against the project owner and thus have to ensure through a due diligence that the project provides satisfactory and low-risk future revenues.

The four main characteristics of project finance over corporate finance are 1. Risk reduction for the owner (risk being borne by the lenders will be significantly higher, which is reflected in an increased interest rate); 2. Increased leverage (measure of the amount of debt raised to finance a firm's asset, traditionally to a debt-to-total capitalization of 50%; project finance enables greater leverage, on average around 70%, greatly increasing the expected return on capital investment, but also increasing the equity risk, and therefore the interest rate); 3. Legal separation (project finance involves the creation of a legally independent entity – the Project Company – that will finance, develop, construct, own and operate the project.; this is mainly aimed at facilitating the securitisation of the project assets), and 4. Contracting structure. Figure 1 provides the standard contracting framework for a project-financed deal.

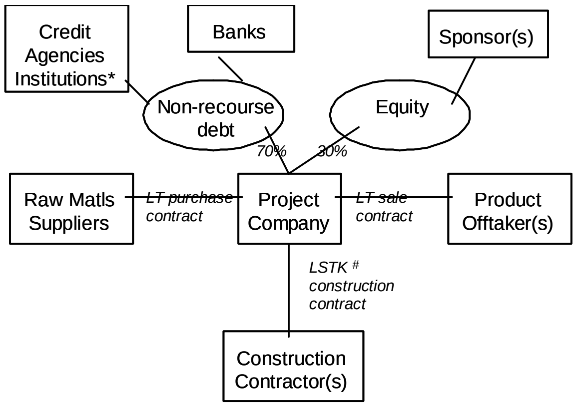

Figure 1 – Project Finance deal structure (example)
(LT=Long Term; LSTK=Lump Sum Turn Key)

Although project financing has been applied for more than a century, this approach has recently been gaining broad popularity. Total project-financed investment has increased from $10 billion per year in the late 80s to more than $220 billion in 2001. Project finance has a wide range of applications, e.g. power plants, industrial plants, refineries, pipelines, infrastructure, etc.

The reason for this success in many industrial areas is the possibility to develop massive projects with limited capital resources and minimum risk for the sponsor. Besides, project companies, like joint ventures, enable the participation of many industrial and financing partners. Finally, the possibility for complex financing schemes involving several institutions allows the funding of large sums. Commonly found financiers in the project finance sector are commercial banks and agencies in which more than two nations participate (multi-lateral agencies such as the World Bank and regional Banks for Reconstruction and Development).

Financing costs such as interest during construction, costs incurred in contracting loans, taxes, etc are not included in the scope of this paper. As outlined above, they will depend on the project financing construction, the country involved, etc.

VII. OWNER'S COSTS

Owner's costs are not part of a project's capital cost because they don't get capitalized. However they are costs made by a project owner in the context of project development and should therefore be included in the economic evaluation of a project.

These costs comprise those activities which are the responsibility of the project owner when implementing a project from the beginning of the study phase to the production of the first product. From then on project costs become the responsibility of operations. They may be categorised in pre and post investment decision as follows.

- Pre investment decision: costs made before the project proposal has been approved. In other words these costs are sunk costs by the time the investment is approved (e.g. costs of studies and sampling and testing costs). Although they represent part of the costs to a company to develop a project they are normally not included in the economic evaluation.
- Post investment decision: these costs are part of the investment to be approved and should be included in the economic evaluation of the project.

Owner's costs cover a wide scope. The following provides an outline of components of owner's costs.

- **Staff**. This item includes project staff (management, technical support – incl. engineering consultants – and administration and support services), and staff involved with pre-commissioning, commissioning and start-up (operations and maintenance).
- **Pre-Operational Expenses.** This item covers recruitment costs, operations training, salaries before commissioning is started, start-up team, first precipitation charge with purchased seed hydrate and excess raw material consumption during initial operation.
- **Indirect staff costs.** Items like travel, accommodation, expenses, training, etc.
- **Office costs.** Includes project office, site office, vehicles, equipment.
- **Insurances.** Examples of insurances: public liability, material and construction, professional indemnity, vehicles.
- **Fees.** Examples of fees: technology, council, state, federal.
- **Bonds and licences.** E.g. for construction, start-up, reclamation, temporary facilities.
- **Legal.** Legal costs made in the context of putting together construction agreements, agreements for land access and land acquisition, operating agreements, etc.
- **Overheads.** Items like advertising, community relations, auditing, soil and geotechnical tests, temporary power usage, marine and land surveys, exchange rate variation allowance, taxes & duties, corporate charges, etc.
- **Land and rights of way.** Cost of land acquisition is sometimes included in owner's costs, while in other cases it is included as part of capital cost.
- **Geology, Mining, Process.** This item covers activities like drilling, exploration, (bulk) sampling, laboratory testwork, trials and licenses.

VIII. WORKING CAPITAL

Working capital includes alumina and hydrate, both in process and in product, raw materials (caustic soda in solution and in stock, heavy fuel oil in stock, bauxite on stockpiles, lime, other), warehouse inventories (incl. capital/insurance spares, process and operating supplies), accounts payable/receivable and cash.

IX. PROJECT DEVELOPMENT STAGES

Development of a greenfield bauxite/alumina investment opportunity from initiation to an actual operation takes the project through a number of development stages.

Table 7 provides an overview of typical project development stages, their objectives, duration and study cost. These project development stages require appropriate capital cost estimates as shown in Table 7, the key distinction between these estimates being the reliability of the information used to prepare the estimate to the targeted accuracy. Cost estimates are therefore classified, each with its accuracy, and are related to the stage of development of a project. Indicative percentages of total engineering completed at each stage and contingency ranges are also included in Table 7.

The cost of a capital estimate is related to its targeted accuracy and may be expressed as percentage of the total project cost as shown in Figure 2. Note that this graph is indicative only, and that actual estimate costs may vary considerably based on the specifics of a project.

	Project Development Stage (typical)	
	Conceptual	**Pre-Feasibility**
Objectives	Order-of-magnitude evaluation of investment opportunity	Review alternatives, select preferred option, economic evaluation
Duration, months	6-10+	8-16+
Study Cost*, M$	1-2+	4-6+
Capital Cost Estimate	Order of Magnitude	Preliminary
Estimate accuracy (before contingency)	±30-40%	±20-25%
Overall Engineering		5-15+% complete
Contingency, %	25-30	20-25

* Indicative for a 1.5 Mt/yr Bauxite/Alumina greenfield project

Table 7A – Project Development Stages

	Project Development Stage (typical)	
	Feasibility	**Execution**
Objectives	Project optimisation, economic evaluation for approval to proceed	Project execution, including commissioning and start-up
Duration, months	10-18+	36-40+
Study Cost*, M$	10-25+	
Capital Cost Estimate	Budget	Definitive
Estimate accuracy (before contingency)	±10-15%	±5% to ±10%*
Overall Engineering	20-30+% complete	65+% complete
Contingency, %	15-20	5-10

* Indicative for a 1.5 Mt/yr Bauxite/Alumina greenfield project

Table 7B – Project Development Stages (cont.)

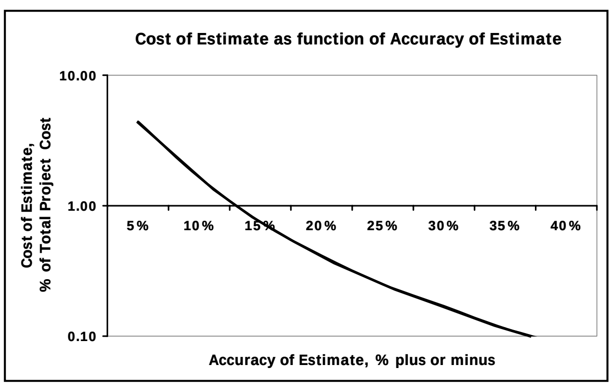

Figure 2 – Cost of Estimate as function of Accuracy

X. CONCLUSIONS

- Bauxite and alumina projects are capital intensive.
- When comparing capital costs of different bauxite and alumina projects it is important to identify which cost items are and which are not included in the quoted numbers to ensure that "apples" are compared with "apples".
- Infrastructure capex, being location dependent, may have a significant impact on overall project capex and thus on economics. This also means that a project based on a smaller plant capacity is seriously penalised if significant infrastructure investment is required.
- The cost of the contract type applied (EPCM, EPC, etc) for project implementation should be considered in combination with owner's and financing costs.
- Cost estimates are related to the stage of development of a project and to its targeted accuracy.

XI. OPPORTUNITIES

As discussed elsewhere ([3]), bauxite resource quality in its widest sense has a more profound effect on capex than technology. In other words for a greenfield project the emphasis should be on identifying the "right" bauxite resource.

In order to enhance the economic success of a project, technology and innovation should be focused on supporting that objective. Following are some potential opportunities to improve the investment costs of a greenfield bauxite / alumina project (see also [4]).

- Minimise infrastructure in the design, both "external" (port, rail, town, etc) and internal (piperacks, buildings, structural steel, etc).
- Do not build provisions for future expansions in the design, but focus on maximising the advantage of building a dedicated plant.
- Do not over design e.g. with respect to plant operating factor, design allowances and sparing philosophy.
- Do not re-invent the wheel. If others can do something better than you, or if specialist equipment is available, make use of that route rather than developing it yourself.
- Investigate other methods of plant construction as applied in other industries (e.g. modular approach).
- Investigate simplifications of the Bayer process, e.g. deleting the green liquor filtration facility by further developing flocculation technologies.

[3] Refer "Operating Cost – Issues and Opportunities", paper by P.J.C. ter Weer, Light Metals 2006, San Antonio, pp 109-114

[4] Refer "Greenfield Dilemma - Innovation Challenges", paper by P.J.C. ter Weer, Light Metals 2005, San Francisco, pp 17-22