CHEMICAL ECONOMICS - MINERAL PROCESSING

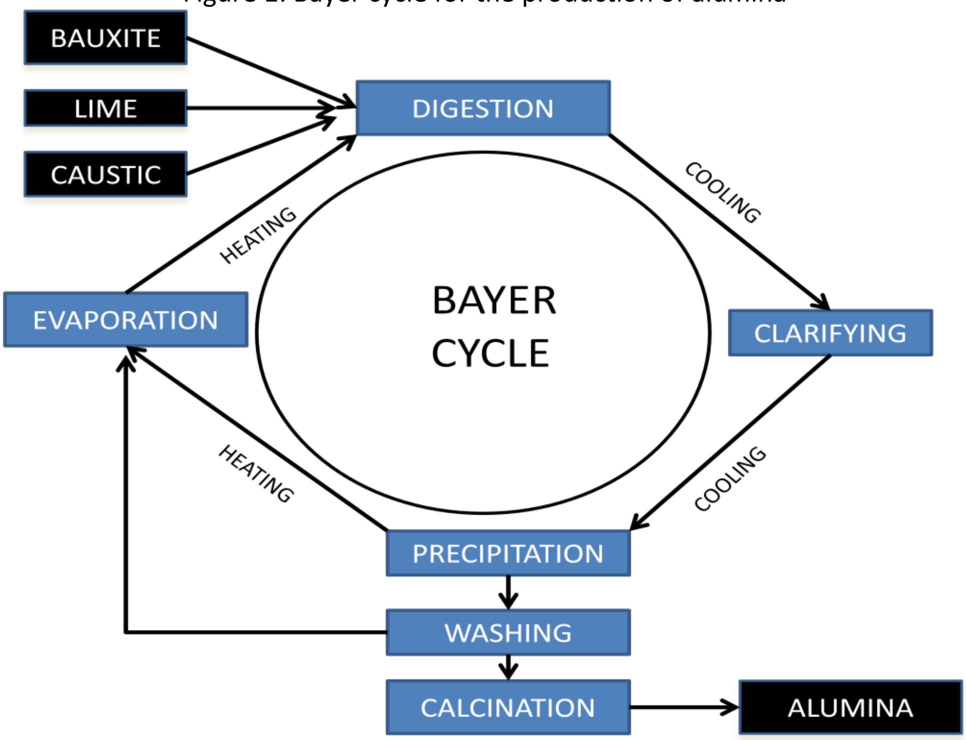
For over a century Australia has had a major competitive advantage in the production of raw materials. Over this period there have been many industries adding value to the basic minerals, perhaps the best known was the establishment by BHP of the Newcastle steelworks in 1912 using iron ore from South Australia and Hunter Valley coal. Most mineral ores are processed in some way using a broad cross section of chemical processes. This may range from using chemically doped water for froth floatation to extraction of metals, for example cyanide extraction of gold ores.

For some added value industries extensive chemical processes are used in the beneficiation of ores, production of refined intermediates and production and refining of metals. Of pertinent interest is the production of aluminium from bauxite ore via alumina intermediate. This series of processes involves value addition from US$40/t for bauxite to US$2000/t for aluminium metal.

Although not unique, Australia has some of the largest and richest bauxite deposits in the world. This hydrated alumina occurs in vast beds around the Gulf of Carpentaria and also significant deposits south of Perth. Exports of the bauxite deposits based around Weipa on the Gulf of Carpentaria help set the world price, typically in the range US$35 to US$50/t FOB (free-on-board).

The first stage in the aluminium production process is the purification of the bauxite to produce a refined alumina using the Bayer process, Figure 1. In this process, the raw bauxite ore is dissolved in sodium hydroxide (caustic soda) at high temperature forming a supersaturated sodium aluminate solution. This separates the impurities which contain a high proportion of iron, known as red mud.

Figure 1: Bayer cycle for the production of alumina



The sodium aluminate is then cooled and alumina seed crystals added to precipitate the alumina from the supersaturated solution. The excess caustic is concentrated and recirculated.

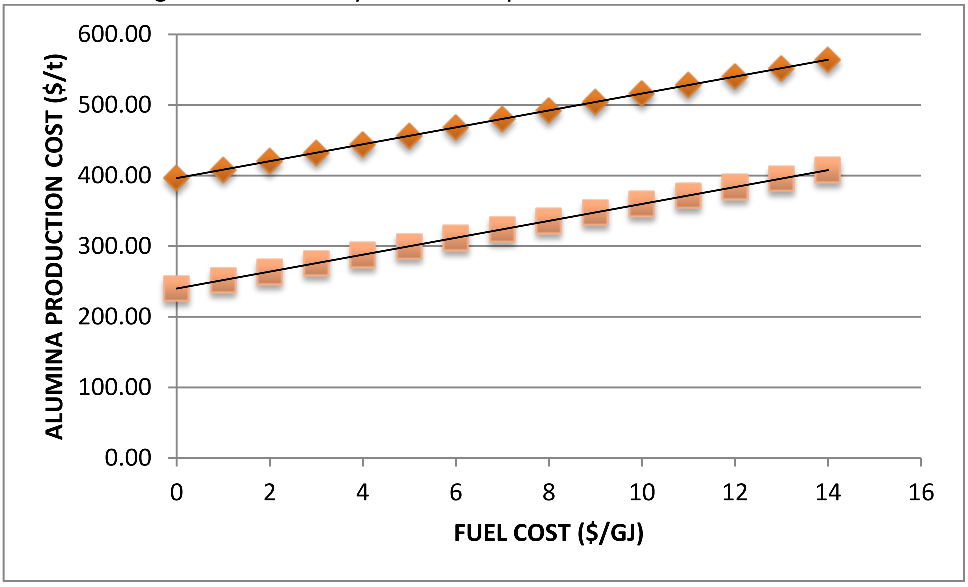
The alumina is then calcined to produce the refined alumina for metal production. Apart from bauxite the main inputs are caustic soda and energy; some smaller inputs in some refineries are lime for assisting the handling of silica and starch for clarifying the liquors. Typical statistics are shown in Table 1.

Table 1: Statistics for alumina production ($US 2013)

	unit	unit/t Al_2O_3	$/unit	$/t
bauxite	t	2.37	34	80.58
caustic	t	0.1	400	40.00
lime	t	0.05	120	6.00
starch	t	0.01	300	3.00
power	GJ	1.25		
	MWh	0.347	50	17.36
Fuel	GJ	11.7	8	71.20
				240.54
Capital Cost	$/t	1071.4		
Return on Capital (20y life; 3y construction)		156.4		156.45
Working capital	$	0.083	350	
Return on WC (10%)				2.917
Operating cost as percent of capital cost	10%	107.14		107.14
ALUMINA PRODUCTION COST				**507.05**

This estimate is for a basic alumina refinery. Most refineries seek to reduce the fuel demand by extensive heat integration of the various operations and many refineries have co-generation facilities providing both power and heat (steam). Apart from bauxite and caustic the only other major input is fuel (as gas or fuel oil). The sensitivity of the alumina production cost to the prevailing price of fuel is shown as the top line in Figure 2.

Figure 2: Sensitivity of alumina production cost to fuel cost



At the present time the typical selling price for alumina is $350/t. The graph indicates that this price cannot be achieved on the above statistics and this production cost can only be achieved by writing-off the capital investment (lower line). This marginal production cost curve indicates that alumina refineries require fuel prices below about $9/GJ to achieve the international export price.

For refineries using fuel oil (the Gove refinery in NT) fuel costs are typically $9/GJ or more making these facilities non viable. For refineries using gas (Kwinana (WA) and Gladstone (Qld)) on-going viability is dependent on securing gas contracts at below parity LNG export prices, currently higher than $8/GJ. Recent falls in crude oil price hay assist the viability but this is unlikely to spur investment in new refineries.

Aluminium metal is produced by electrolysis of alumina (dissolved in molten cryolite) using a carbon anode which is oxidised in the process. The reaction stoichiometry being:

$$2Al_2O_3 + 3C = 2Al + 3CO_2$$

Aluminium metal production requires an enormous input of electricity up to 15MWh/t of aluminium and aluminium production statistics usually go hand-in-hand with a major power investment. Often the aluminium smelter becomes the foundation customer, receiving power at the marginal price (sometimes lower) from the utility which makes up its costs from other customers. To help cap such a subsidy, return on capital is aligned to the utility investment which is generally over a longer period and with a lower capital return than typical commercial costs (30y project, 7.5% discounted cash flow (DCF) compared to a more typical 20y project with 10% DCF). Typical statistics for a 200,000t/y smelter is shown in Table 2.

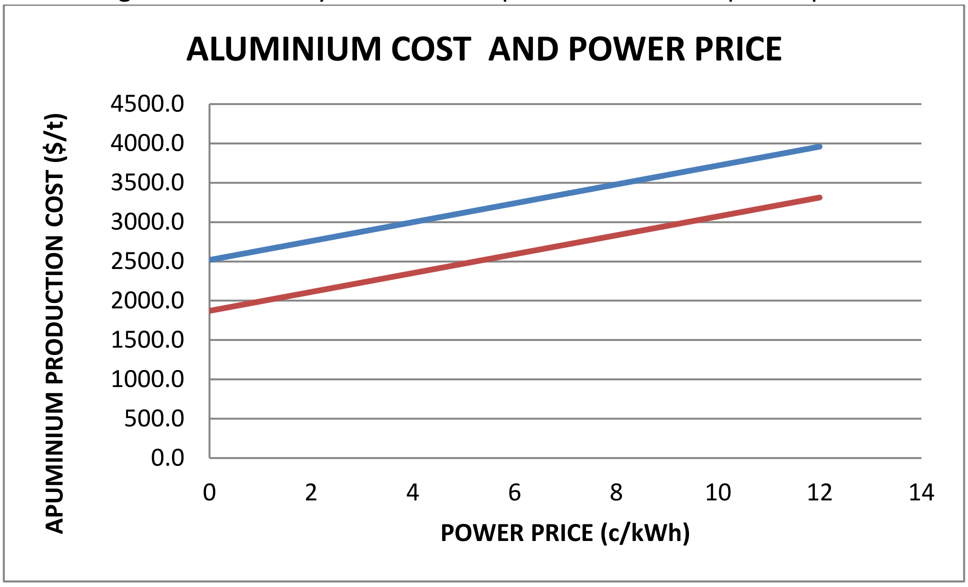
Table 2: Statistics for aluminium metal production ($US 2013)

			$/t
nominal capacity	kt/a	200	
Construction period	y	3	
Required return (DCF)	%	7.5%	
Operating period	y	30	
Capital recovery	%	10.03%	
Capital cost	$M	1289.17	6445.84
Capital Charges	$M/a	129.32	646.58
Working Capital (30 day stock)	$M	31.76	
Return of Working Capital (10%)	$M/a	3.18	
Total capital charges	$M/a	132.49	662.46
Operating costs(a)	$M/a	358.24	1791.22
Power demand	MW	273.97	
Power price	c/kWh	2	
Power Costs	$M/a	48.00	240.00
TOTAL COSTS	$M/a	538.74	2693.68

(a) Operating costs include alumina, anode carbon plus other on feedstock operating cost (labour, maintenance, chemicals etc.)

With a power cost of 2c/kWh the unit production cost of aluminium is about $2600/t. Unfortunately this is well above the current world traded price for the metal at about $2000/t. The impact on the cost of production against the power price is shown in Figure 3 (upper line). Again we see these prices achieved by writing-down the capital investment to near zero (lower line).

Figure 3: Sensitivity of aluminium production cost to power price



As noted by the stoichiometry, aluminium smelters are large emitters of carbon dioxide even without the consideration of emissions from fossil fuel power plants. With addition of carbon emission taxes this further marginalises Australian operations relative to other operations on the Pacific Rim. With power prices typical of the Australian wholesale price of about 5c/kWh the production cost well exceeds the international price of the metal even if the capital cost is fully written-off.

Over the past decade China has invested heavily in alumina and aluminium production and Australian producers have to match the Chinese export price of typically $2000/t.

The poor standing of the economics of the aluminium value chain have other implications for processing of advanced metals, such as titanium and magnesium, often touted as a potential major growth areas for Australia. The production of light metals is energy intensive and until the present trend of increasing energy prices in Australia can be reversed then there will be little likelihood of attracting the required investment.

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