CS Ref No: /
May 2006

Northwest Smelter Operating Outlook

A report prepared for Alcoa

CRU | STRATEGIES

CRU Strategies Ltd
PO Box 1269, Langley, WA 98260, USA
PO Box 656, Kennett Square, PA 19348, USA
Website: www.crustrategies.com
Tel: +1 360 321 4707 Fax: +1 360 321 4709
Tel: +1 610 925 1860 Fax: +1 610 925 1861

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Executive Summary

Aluminum is a non-differentiated globally traded commodity. Conditions in the world smelting industry have recently improved, thanks mainly to strong demand growth from China in particular and Asia generally. Moreover, even in the advanced industrial countries the fundamentals of this industry are sound. There is no question that the world will need a great deal more aluminum smelting capacity in the decade 2011-2020. In the next 20 years, CRU expects worldwide consumption to more than double from about 32 million tonnes per year to about 65 million tonnes per year. Thus there is no fundamental demand side reason to permanently abandon any aluminum smelter, including Alcoa's Northwest plants. Every smelter closed will have to be replaced by additional capacity to meet expected worldwide demand, and that replacement capacity will only add to the very extensive construction that will anyway be needed to meet growing demand.

Conditions are also changing in respect of raw materials and energy. The industry is investing heavily in expanding alumina supplies such that CRU believes that the bottleneck in the industry will shift from alumina refineries back to its traditional place at aluminum smelters well before 2010. The rapidly changing energy market environment has also contributed to a structurally higher level of aluminum prices than those to which we have become accustomed over the past two decades. Not only are existing smelters now paying more for power but the number of low cost energy "islands" that are available for the exploitation by the aluminum industry are shrinking in the face of the globalization of the gas market and other cost pressures.

These changes mean that the competitiveness of the Pacific Northwest as a location for aluminum smelting may soon improve. Given the expected prices of cost-based power from the Bonneville Power Administration (BPA), we expect that if BPA decides to provide enough power to allow Alcoa to operate its Ferndale and Wenatchee plants at capacity, those plants will most likely operate for the indefinite future. On the other hand, if BPA decides not to offer any long-term power supply, Alcoa is likely to curtail production at both plants, except for the production that can be sustained using power that is available from Chelan PUD for the Wenatchee plant, and spend its capital to build replacement resources in locations where lower operating costs are available.

There are a number of possibilities that lie between these two extremes. The potential range of outcomes is discussed in more detail within the body of this report.

Chapter 1
Introduction

This report has been prepared by CRU Strategies Ltd (CRU), the management consulting company of the CRU Group. CRU is based in London, England, with branch offices in the United States and China and additional representative offices in Australia and Latin America. CRU provides a wide range of market research, forecasting, and consulting services to the world's metals and mining industry, the major metal consuming industries, financial institutions, key suppliers including electric utilities, and host governments. Further details of the scope of CRU Strategies' activities and those of affiliated companies are available at www.crugroup.com.

The background of this report is an evaluation that is being conducted by the Bonneville Power Administration (BPA) into the consequences of providing up to 560 average MW of electricity to the region's aluminum smelters after 2011. Alcoa currently operates two of these smelters at Ferndale and Wenatchee, both in Washington State. Alcoa has asked CRU to evaluate the probability that it will be economically feasible to operate these plants under various economic and energy market scenarios. The ultimate objective of this research program is to allow BPA to understand the potential aluminum production implications of making power available to aluminum smelters at various prices.

The report is structured as follows. Chapter 2 discusses the industry background that is an essential prerequisite to our analysis. Because the decision to operate an aluminum smelter depends on the prices of primary aluminum and alumina (the raw material) as well as on the price of power, Chapter 3 discusses the outlook for these commodities. Chapter 4 discusses the cost structure of the two Alcoa smelters in a global context, identifies the issues that are specific to their operation and develops conclusions regarding the likely operation of these plants under different scenarios.

Although this report has been prepared at the request of Alcoa and specifically concerns the Ferndale and Wenatchee smelters, a similar methodology can be used to reach equivalent conclusions regarding other Pacific Northwest smelters. While this report has been reviewed by Alcoa, all of the data in it is drawn from the ongoing aluminum industry research program of CRU Analysis, which is the CRU Group company involved in regular market forecasting and production cost surveys of all of the major commodity sectors including aluminum. As such, this report does not contain commercial data that is confidential to Alcoa and is, therefore, available for public discussion as appropriate to the BPA decision-making process.

Chapter 2
Industry background

1. General introduction

Aluminum is the second most important material used in the world economy after steel. In 2005 the value of world primary aluminum production was approximately $61 bn compared with $304 bn for steel[1] and $54 bn for copper. Aluminum is used mainly in the transportation equipment, construction, and packaging industries, which account for 75% of total world use. Additional sectors that consume aluminum include consumer durables, capital equipment, and electrical conductors. Aluminum is subject to competitive pressures from steel and plastics in all of its major markets as well as from wood and other construction materials and from copper in heat exchanger and conductor applications.

Aluminum is the second most common element in the earth's crust after silicon. The vast majority of today's supplies are obtained from bauxite ores, which occur widely in the tropical regions, and are low cost to mine. Typical bauxite mining costs are only $5-10/t. Compared with other forms of mining, bauxite extraction is relatively simple. Most operations incorporate progressive land rehabilitation and re-vegetation programs in order to minimize environmental impact. There is no likelihood of bauxite resource depletion in the foreseeable future.

Bauxite's low value to weight ratio means that freight costs tend to be the decisive component in the overall cost of supply to the next processing step – the alumina refinery. Over the last 25 years, almost all new alumina refineries have been located close to mining areas.

Alumina refining involves dissolving bauxite in a hot caustic soda solution followed by solid/liquid separation and the subsequent recovery of pure alumina by precipitation from the liquid fraction. Alumina refineries are essentially chemical plants. Typical alumina production costs, including the costs associated with bauxite mining and delivery, range from about $120/t at low cost integrated facilities in Australia, Brazil and India, to about $200/t or more at refineries in the United States and Europe that depend on imported bauxite and whose cost structures therefore reflects significantly higher transportation expenses. Between two and three tonnes of bauxite are

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[1] This figure is measured at the slab and billet stage of steel processing, which is broadly equivalent to aluminum ingot.

required to produce each tonne of alumina. Alumina generates a solid waste known as red mud, which must be held in retention ponds and managed on a long-term basis.

Alumina is a fungible commodity that is extensively traded around the world. The United States, Western Europe, Russia and the Far East – particularly China – are the major importers, while Australia, Brazil, the Caribbean and India are the major exporters. With few exceptions alumina quality is standardized, and smelters are largely indifferent as to the precise source of this material. Although alumina is not traded on any commodity exchange, there is reasonable price transparency as a result of the activities of specialized research organizations, including CRU Analysis, which conducts industry surveys and reports a consensus assessment of the prices prevailing in this sector on a monthly basis. Approximately 10% of the world's alumina is sold on a spot price basis, but by far the most common arrangement is for alumina to be sold at a percentage of the price of metal on a multi-year contract basis.

Primary aluminum smelters convert alumina into pure metal by electrolysis. Power is supplied via a carbon anode that is suspended over a pot containing alumina and various bath materials. As liquid aluminum is produced, the carbon anode is consumed in the following basic reaction:

$$2AL_2O_3 + 3C \rightarrow 2AL_2 + 3CO_2$$

In practice, approximately 1.92 tonnes of alumina and 0.4-0.45 tonnes of carbon are required to produce each tonne of aluminum.

The above process is extremely electricity intensive. In the 1960s approximately 18 MWH were required to produce each tonne of aluminum. Over the years energy efficiency has greatly improved such that modern, state-of-the-art smelters require around 13.2 Mwh per tonne in the pot rooms and around 14 Mwh in the overall operation, which includes supporting activities like the manufacture of the carbon anodes and the casting of the liquid metal. CRU estimates that the energy requirement at Ferndale is 15.2 Mwh/t and at Wenatchee is 16.5 Mwh/t. Ferndale is, in energy efficiency terms, an average plant in the spectrum of the world industry, while Wenatchee, a significantly older plant, is somewhat less efficient than the average.

The electricity intensive nature of this industry means that aluminum smelters have traditionally been established in regions where low cost electricity, often from hydroelectric facilities, is available. Besides the Pacific Northwest, traditional smelting areas using hydroelectricity include Quebec and British Columbia in Canada, Norway and Iceland in Europe, Brazil and Venezuela in Latin America, and Siberia. Low cost coal has also become the basis for smelter developments in parts of the U.S. Midwest, Australia and South Africa, while in more recent years low cost gas associated with oil production has become the basis for aluminum smelter development in areas like the Middle East and Trinidad.

Electricity costs are the most important single differentiator of the competitive structure of the aluminum industry. Some smelters are still in the position to acquire power for less that $10/Mwh, while others now pay as much as $40/Mwh. Given an average consumption rate of 15.5 Mwh/t, the difference between these figures represents a cost differential of $465/t in the context of a commodity whose long-term price is generally thought to be in the range of $1,500-1,750/t.

Aluminum is also a non-differentiated and standardized commodity where most consumers are indifferent to the identity of the supplier and base their purchasing decisions strictly on price. Daily trading on the London Metal Exchange (LME) sets the reference price of primary aluminum. This terminal commodity market also trades futures and options in order to offer facilities for managing metal price risk to producers, consumers and traders in the industry. Aluminum may be traded for delivery up to five years out (63 months). The actual price received by the Ferndale and Wenatchee smelters will not be the same as the LME price because of the product mix and locations involved. However, changes in the LME price will always translate directly into similar order of magnitude changes in their prices.

To summarize: primary aluminum smelting is a commodity conversion business in which one non-differentiated internationally traded commodity, alumina, is transformed into another non-differentiated internationally traded commodity, primary aluminum, mainly by the application of electricity. Even very large producing companies such as Alcoa have no control over these prices. Thus, in order to operate an aluminum smelter, the conversion margin – that is, the difference between the aluminum price and the alumina price – must exceed the smelter's production costs, of which by far the most important and uncertain component is the price of electricity.

2. Technical issues related to smelter operations

It is not sufficient simply for the margin that can be earned by the smelter to exceed the operating costs, including power. In addition, management must have the expectation that this will continue to be the case for at least a three-to five-year period. The reason is that there are significant one-time costs involved in stopping and starting pot lines and also maintaining pot lines in a standby condition during the periods in which they are not operating. In addition, smelters require significant sustaining capital investment in such things as bake furnace relining, crane overhauls and environmental control upgrades on a five- to twenty-year cycle. In other words, management has to be confident that the smelter will be able to run profitably for a sufficiently extended period of time such that all these costs can be recovered. In the absence of this, it will not be worthwhile to restart the smelter, and it may have to be abandoned altogether.

The nature of aluminum smelting technology is such that these plants need to run on a continuous basis. If power supply is interrupted for more than 3 hours, there is a risk that the molten metal will freeze in the pots. If this happens, the reconstruction of many of the pots in the line will be required which is a very expensive proposition. On the other hand, an orderly, planned shut down of the smelter involves tapping all of the liquid metal from the pots, a process that takes no more than 5 days. Even this is not risk-free. As the pots cool to room temperature, the thermal stresses involved can damage the cathode linings and result in reduced life. However, given an orderly shut down, major reconstruction is often averted, and the plant can then be restarted over a 60- to 90-day period.

Given these technical limitations, it is clear that seasonal operation of an aluminum smelter is not likely to be an attractive strategy. Indeed, CRU knows of no cases where this has even been attempted. However, aluminum smelters do have some flexibility in their use of power that may have value to BPA under certain circumstances.

Firstly, it is possible to temporarily reduce (but not eliminate entirely) consumption for 4-6 hours at a time in order to free up generating capacity to meet peak loads. This is possible because the temperature of aluminum electrolysis is significantly higher than the freezing point of aluminum. Thus, pots can be allowed to cool down for a short period of time without freezing. The quantum of demand modulation that is possible and the associated cost varies from one smelter to another. However, as a generalization, a 20% reduction for 4-6 hours per day about three times per week should be feasible.

Secondly, it is possible for a smelter to offer any power supplier an element of "dry year risk insurance." Given the precipitation pattern prevailing in the Pacific Northwest, BPA will normally have a high level of confidence regarding hydroelectric generation over the coming water year by 31 March. If the snow pack is inadequate, smelter load could potentially be shed by 30 June at the completion of the spring runoff. Technically, the smelter could, of course, be shut down sooner – as quickly as 10-15 days. However, from a commercial perspective, a 3-month or longer notice period is more practical since it would allow the aluminum company to adjust its supply chain, consume existing inventories of alumina and carbon, and develop plans to minimize the adverse impact on customers and the workforce.

Interrupting a smelter's power supply in the two ways described above does involves additional costs. However, these costs may be less than those involved in providing the equivalent standby power generation capacity.

3. Market risk issues related to smelting operations

In practice, the existence of a futures market for primary aluminum makes it possible to manage gross smelter margins. Metal can be traded forward on the LME for 63 months. This, combined with the alumina industry's practice of negotiating 3- to 5-year contracts at fixed percentages of the metal price, means that gross margins can be "locked in" at any given point in time.

To illustrate this, in April 2006 a smelter considering a start up, which would take about three months to fully implement, would have been faced with the following schedule of forward prices:

July 2006 (3 months)	$2,643
July 2007 (15 months)	$2,520
July 2008 (27 months)	$2,384
July 2011 (63 months)	$2,152

In practice, forward prices can be obtained from market makers and financial institutions for each intervening month as well. In the same period, April 2006, CRU Analysis reported that medium-term alumina contract terms were running at 18% of the metal price. Since we need 1.92 tonnes of alumina to make every tonne of aluminum, this means that the gross smelting margins would have been as follows:

July 2006 (3 months)	$1,730
July 2007 (15 months)	$1,649
July 2008 (27 months)	$1,580
July 2011 (63 months)	$1,409

If BPA agrees to supply power to aluminum smelters at fixed prices over a reasonable multi-year periods of, say, 5 years, then it becomes possible for companies to determine with a fair degree of predictability whether the gross margins that can potentially be locked in through hedging are, or are not, adequate to cover operating and sustaining capital costs and the other one-time costs associated with the restart.

If the quantity of power that BPA contemplates offering to aluminum smelters at a reasonably predictable cost of service based price is less than the actual requirements to operate these plants at full capacity, the smelters also need a forward market in electricity in order to determine whether or not to operate the balance of their capacity.

This market should have price transparency and reasonable liquidity over a future 3- to 5-year period similar to that offered by the LME in the case of metals. While the region's power market is slowly evolving in this direction, more progress is required to develop a truly robust market. As long as there is inadequate liquidity in the forward power market, the costs associated with hedging, particularly the spread between buy and sell prices, will be higher than necessary – and quoted prices are likely to be more volatile – higher at times of shortage and lower at times of surplus – than would be the case in a fully liquid market. Hedging costs are real expenses and have to be deducted from the margins quoted above. One alternative to a liquid forward market is to rely on over the counter transactions with other power industry participants. Unfortunately this involves performance and credit risk, which ultimately translates into a real business cost as well.

These power market issues are relevant because the ability of a smelter to operate all of its capacity has a bearing on the likelihood that it will purchase power from the BPA. As explained in more detail in Chapter 4, there are significant economies of scale involved in a full capacity operation at Alcoa's two smelters as compared with partial operation. These economies of scale could materially influence the long-term viability of these plants.

Finally, if short-term interruptible power or dry year risk insurance is an element of any transaction between BPA and an aluminum smelter, the smelter can also use the forward pricing facilities of the LME to decide whether or not to purchase replacement power on the open market for the period of any such interruptions.

Chapter 3

The outlook for the aluminum market

As discussed in the previous chapter, primary aluminum is a non-differentiated globally traded commodity. In fact, most of the aluminum produced in the Pacific Northwest will probably be exported to the Far East markets rather than being shipped to consumers in the U.S. Midwest. Consequently, this discussion of the aluminum market focuses on the global industry outlook.

1. Aluminum demand

The following table summarizes the pattern of world aluminum consumption in 2005 and the growth of global demand experienced over the past 45 years.

Table 3.1: Primary aluminum consumption – historical trends

	2005		Annual Average % Growth			
	000 t	Share	60-74	74-79	79-89	89-05
EU/EEA	7,248	22.7%	7.4%	2.2%	1.7%	2.2%
Other Europe	766	2.4%	13.4%	4.1%	2.0%	2.8%
CIS	840	2.6%	6.6%	3.8%	3.8%	-6.9%
North America	7,085	22.2%	9.0%	-0.5%	-1.0%	2.5%
Latin America	1,363	4.3%	13.9%	6.8%	3.6%	3.6%
Middle East/Africa	1,090	3.4%	19.7%	2.9%	8.8%	5.1%
China	7,161	22.4%	11.5%	8.2%	4.8%	13.4%
India	940	2.9%	12.2%	11.2%	7.5%	5.1%
Japan	2,408	7.5%	16.7%	6.7%	2.1%	0.7%
South & East Asia	2,652	8.3%	14.6%	18.3%	8.3%	8.0%
Oceania	392	1.2%	12.4%	10.9%	0.4%	0.7%
Total World	31,945	100.0%	9.0%	2.7%	1.8%	3.3%
excl CIS, China	23,943	75.0%	9.2%	2.3%	1.4%	2.8%
exc CIS only	31,105	97.4%	9.4%	2.6%	1.5%	4.1%

Sources: Metallgesellschaft, CRU Analysis

As a consequence of the growth of the Chinese economy in recent years, this country now consumes as much aluminum as North America and Western Europe. These three areas, plus Japan, account for some 75% of world consumption.

Historically, aluminum consumption has evolved in four distinct phases bracketed by important macroeconomic and socio-political events:

i) from 1960 to 1974 demand grew at 9% per annum, or more than double the rate of growth of world GDP; this was the period when many new market applications for aluminum were developed by the industry, including the beverage can; this process was associated with sharply falling real aluminum prices and was brought to an end by the first oil crisis;

ii) from 1974 to 1979 growth fell to less than 3%, slightly below the rate of growth of global GDP; the main feature of this period was the stagnation of North American and, to a lesser extent, West European markets in the face of a serious oil price induced business cycle; however, during this time Latin America and the Asian economies, including, significantly, the Japanese, continued to expand their use of aluminum at rates well in excess of GDP; this period was brought to an end by a second oil crisis;

iii) 1979 to 1989 was a period in which the growth of aluminum demand declined further to under 2% per annum, or around 60% of the growth of world GDP; there was a further deterioration in growth rates in North America and Western Europe along with much slower growth in Japan and Latin America; in the case of the developed industrial countries, this period featured vigorous efforts by governments to deal with the inflationary crisis of the late-1970s using restrictive monetary policies that resulted in high interest rates; this hurt aluminum consumption via its impact on interest sensitive sectors such as autos, consumer durables and construction; in Latin America the problem was compounded by a prolonged financial crisis related to the region's debt load; and

iv) 1989 to 2005; aluminum growth sharply recovered to 3.3%, around the same rate of growth as world GDP; the trigger for this was the fall of the Berlin Wall and the collapse of communism; while this produced a sharp fall in consumption in the CIS, which led to a temporary aluminum surplus and very low prices by 1993, the U.S. economy also staged a major sustained recovery while Europe improved more moderately; the key development, however, during this period was the tremendous growth that took place first in Southeast Asia and later, and to an even greater extent, in China as these regions benefited particularly from the growth of international trade and other aspects of the globalization phenomenon; Japan, by contrast, suffered a prolonged recession.

Looking to the future, CRU considers that the fundamental drivers of aluminum demand remain favorable, at least for the next 5-10 years.

From a geographic perspective, the key factor is China. This country has been growing its use of aluminum at double-digit rates since about 1990. In 2005 we believe China overtook North America, and in 2006 we predict they will overtake Western Europe in terms of aluminum consumption. At the heart of this is China's urban construction boom. We sense it has a long way to go since there are still more people in interior China, who have benefited only marginally from the country's recent success, than in the coastal regions. Either development will spread to the interior or there will be continuous, potentially accelerating, migration to the coastal regions. Either way, there should be ongoing strong demand for residential and commercial structures and urban infrastructure. The current major expansion of the power grid is also boosting aluminum demand. In addition, China's domestic demand for automobiles and appliances is likely to soar as per capita income increases towards the levels that triggered similar booms in Korea and Taiwan in the 1980-1995 period. Finally, Chinese aluminum demand is also fueled by Chinese exports of manufactured goods to North America and Western Europe. In fact, CRU estimates that almost 10% of U.S. aluminum demand has been “transferred” to China since 2000 through this effect.

Eventually, Chinese growth is bound to slow down as the economy becomes more developed and the focus of consumer spending shifts from infrastructure, housing and major consumer durable goods to services. This clearly happened in Japan in the late-1970s and in Korea and Taiwan in the late-1990s. CRU’s forecast has this occurring in China at some point around 2015. However, we then see the potential for India to begin filling this gap. Indian aluminum consumption is growing rapidly – up from 600,000 tpy in 2002 to 940,000 tpy in 2005. Again, residential and commercial construction, urban infrastructure, and, later on, automobiles and other major consumer durable markets seem likely to be the principal drivers of aluminum demand in that country.

Even in the advanced industrial countries, the prospects for aluminum remain reasonably favorable. Lightweighting of transportation equipment, particularly automobiles, is one key to improving fuel economy. Aluminum undoubtedly has a significant role to play in addressing this issue. How significant, of course, depends on the ultimate technology solution that prevails. However, all of the credible candidates use more aluminum than today’s vehicles. In these regions the container and packaging markets are mature. However, there remain niche opportunities – for example, the use of one-way glass bottles and steel beverage cans in Europe remains far above U.S. and Japanese levels, implying continued aluminum substitution potential.

The following table summarizes CRU’s base case long-term aluminum forecast year-by-year to 2010 and in terms of growth thereafter.

Table 3.2: Primary aluminum consumption – base case forecast

						Trend Growth	
Volumes in (000 t)	**2005**	**2006**	**2007**	**2008**	**2009**	**00-10**	**10-25**
EU/EAA	7248	7491	7641	7755	7925	2.5%	1.0%
Other Europe	766	815	855	895	939	9.4%	3.4%
CIS	840	884	915	956	1017	5.4%	2.6%
North America	7085	7239	7186	7359	7524	0.7%	1.8%
Latin America	1363	1455	1500	1568	1630	5.5%	3.8%
Middle East/Africa	1090	1148	1193	1238	1291	4.1%	6.2%
China	7161	8223	9419	10283	11276	14.4%	3.0%
India	940	1000	1052	1130	1220	8.3%	7.0%
Japan	2408	2476	2510	2553	2596	1.6%	-0.2%
South & East Asia	2652	2809	2947	3114	3294	5.7%	3.8%
Oceania	392	399	404	412	422	3.3%	0.3%
Adjustment to CRU July 2005		2	-5	-7	-14		
Total World	31945	33942	35618	37257	39121	5.1%	2.7%
% Change	*5.6%*	*6.3%*	*4.9%*	*4.6%*	*5.0%*		

Source: CRU Analysis

In the first part of this forecast, aluminum is expected to continue growing faster than world GDP mostly due to the metals-intensive phase of development that China and, later, India will find themselves in during this period. At some point in the period 2010-2025, we expect growth to drop back closer to 2.7%, which is about three-quarters of the rate predicted for world GDP. This reflects the maturing of these geographic markets, while still recognizing the favorable fundamentals for aluminum in the industrial world.

The reasonableness of the above forecast can be evaluated by reference to the following table, which shows the implications of CRU's base case forecast for long-term penetration of aluminum in the world economy measured both in relation to GDP and population.

Table 3.3: Aluminum consumption – long-term penetration

	Intensity of Use (kg/$mn)			Consumption/Capita (kg)		
	1980	2000	2025	1980	2000	2025
Western Europe	609	579	490	9.8	13.7	20.0
Eastern Europe	2365	1483	1600	4.9	3.9	14.8
CIS	4597	2031	1400	8.9	3.0	9.7
North America	848	683	465	18.4	22.7	27.3
Latin America	483	527	700	1.8	2.2	5.6
Middle East/Africa	514	1026	1400	0.8	1.7	4.6
China	2574	2561	2100	0.6	2.5	13.3
India	1488	1266	1600	0.3	0.6	3.4
Japan	573	508	340	13.8	18.6	19.8
South & East Asia	685	1300	1300	0.5	2.4	5.9
Oceania	1022	867	430	13.5	17.0	14.7

Source: CRU Analysis

The table shows that intensity of use in North America and Western Europe has fallen and is expected to continue to do so. Intensity of use is higher in absolute terms in less developed countries simply because these regions have a much higher proportion of their GDP associated with construction and manufacturing activities as compared with services. However, the forecast shows that China's intensity of use will begin to fall very rapidly from its current high levels, and intensity of use in Africa and India will peak out at levels that currently exist in Eastern Europe and Southeast Asia. In per capita consumption terms, the projections also appear to be reasonable.

In 2005 world primary aluminum consumption was approximately 32 mn tonnes. By 2010 our forecast implies that the world consumption level will be around 41 mn tonnes, and by 2025 we envision 65 mn tonnes. Current global smelting capacity is 34 mn tonnes. In other words, there is no fundamental demand side reason to permanently abandon any aluminum smelter, including those in the Pacific Northwest. Every smelter closed here will have to be replaced by additional capacity elsewhere over and beyond the very extensive new smelter construction program that will anyway be needed to meet growing world demand for this commodity.

2. Aluminum production

The following table summarizes the structure of aluminum production in 2005 and how this has changed over time.

Table 3.4: Primary aluminum production – historical trends

	2005	Share of World Production (%)				
	000t	1960	1974	1979	1989	2005
Western Europe	4,706	21.8%	24.6%	24.3%	18.8%	14.6%
Eastern Europe	545	0.8%	2.4%	2.7%	3.6%	1.7%
CIS	4,185	15.4%	15.0%	15.5%	18.2%	13.0%
North America	5,382	55.4%	39.2%	35.7%	29.6%	16.7%
Latin America	2,391	0.4%	1.8%	4.4%	9.0%	7.4%
Middle East/Africa	3,448	1.0%	3.2%	3.5%	5.3%	10.7%
China	8,140	1.5%	2.0%	2.4%	4.0%	25.2%
India	960	0.4%	0.9%	1.4%	2.2%	3.0%
Japan	6	2.9%	8.0%	6.7%	0.2%	0.0%
South & East Asia	231	0.2%	0.4%	0.6%	1.2%	0.7%
Oceania	2,252	0.3%	2.4%	2.8%	7.9%	7.0%
Total World	32,246	100.0%	100.0%	100.0%	100.0%	100.0%

Sources: Metallgesellschaft, CRU Analysis

China has now become the world's largest producer of aluminum with 8.1 mn tonnes of capacity, which represents a 25% market share. Almost all of this growth has occurred since 1989. Since China does not have particularly cheap or plentiful electricity supplies, this development has been very unusual compared to aluminum industry trends elsewhere in the world.

Chinese growth is largely a function of the modernization of its aluminum industry. A decade ago, China had about 1 mn tonnes of aluminum smelting capacity concentrated in around 80 small soderberg plants with average capacity in the range of 7,000-15,000 tpy. By contrast, in the Western world, average smelter capacity was in excess of 150,000 tpy, and new plants were being constructed with capacity of 250,000 tpy. These small, technologically obsolete, and environmentally polluting plants were widely expected to close in the face of rising power prices implicit in the growth of competing electricity demands in China, the imposition of modern emissions standards, and competition from newer, larger smelters. Indeed, it was official Chinese government policy to close such plants down. The actual outcome turned out to be quite different. At least 80% of these plants decided to modernize their operations rather than close. They converted to pre-bake smelting technology, a decision that was inevitably associated with a major increase in capacity, typically to around 100,000 tpy and in some cases considerably more.

There were three fundamental drivers of this change. Firstly, local governments were not prepared to accept the employment consequences of the smelter closures. As a result, they provided assistance in the form of land, infrastructure, and financing to facilitate the conversions and expansions. Secondly, the limitations in the Chinese power grid meant there were many isolated electricity generators often with access to nearby low-cost coal mines. Such firms saw aluminum smelting as virtually the only feasible way to develop their business. Thirdly, the domestic Chinese market was growing at double-digit rates behind relatively high tariff walls, which produced an attractive local market price significantly above international levels. In CRU's opinion, none of these drivers are sustainable. Consequently, we expect the headlong growth of Chinese production to slow dramatically in the near future.

Aside from China, the above table shows quite clearly the role of cheap electricity on aluminum industry location choices elsewhere in the world. Prior to 1974, for example, when oil was cheap, Japan was able to develop an aluminum smelting industry. The two oil crises of the 1970s caused this sector to completely disappear by the mid-1980s. In the 1974-1979 period, higher fossil fuel prices caused the focus of aluminum industry growth to shift to Latin America, where Brazil and Venezuela, in particular, developed smelters based on their hydroelectric resources. The period 1979-1989 saw a continuation of growth in Latin America, but the energy base was widened to include gas in the Middle East and low-cost coal in Southern Africa and Australia. Since 1989, and excluding China, it is the Middle East and Africa that have accounted for most of the growth, based on gas and coal respectively. In almost all of these Western cases, the energy suppliers in question saw the aluminum industry as a vehicle by which low value energy resources (remote hydro, low BTU coal, associated gas, and so forth) could be commercialized.

Despite the focus on finding new low-cost energy sources for primary aluminum production, significant capacity is still located in advanced industrial countries such as the United States and continental Europe. These regions with relatively high power costs still have capacity in excess of 6 mn tpy. While it is not attractive to construct new smelters in such regions, existing plants with sunk capital costs can continue to operate profitably as long as they are very carefully managed and the electricity supply industry exerts reasonable cost discipline. As pointed out earlier, the cheap power available to some smelters can confer a cost advantage of up to $465/t. However, when one considers that the capital cost of a new smelter is around $4,500 per annual tonne and when one takes into account the debt-servicing requirement on such an investment, it is possible to see that even disadvantages of this nature can potentially be overcome.

CRU maintains a smelter-by-smelter database of current and projected new capacity. This includes not only new projects and major potline expansions, but it also contains an allowance for so-called "capacity creep" – progressive marginal improvements in production as the result of such things as increased amperage and higher current efficiency in aluminum potlines. By comparing the information in this database with forecast demand, we can determine the adequacy of future aluminum smelting capacity. In particular, we can identify the timing of any need for new investment. This information is summarized in the following table.

Table 3.5: Primary aluminum investment requirement

Volumes in (000 t)	2006	2007	2008	2009	2010	2020	2030
World Consumption	33942	35618	37257	39121	41068	58235	69150
% Change	6.2%	4.9%	4.6%	5.0%	5.0%	2.5%	1.3%
Strategic Stocks	0	0	0	0	0	0	0
World Demand	33942	35618	37257	39121	41068	58235	69150
Inventory Level	2956	3379	3767	4385	5053	7180	8525
Days Consumption	32	35	37	41	45	45	45
Change in Inventories	45	423	388	617	668	178	112
Hidden Stocks & Errors	-300	-300	0	0	0	0	0
Market Balance	-255	123	388	617	668	178	112
Optimal Production	33687	35741	37645	39738	41736	58413	69261
Required Capacity (93.5%)	36028	38226	40262	42501	44638	62473	74076
Projected Capacity	38526	39358	40673	42277	44154	43597	43047
Investment Need	-2498	-1132	-410	224	484	18877	31029

Source: CRU Analysis

This table shows that the current forward investment program in the aluminum smelting industry is adequate to meet predicted amounts through 2009. Approximately 500,000 tonnes of new capacity is required in 2010, and this number then increases steadily. By 2020 the world needs an additional 17 mn tonnes of new capacity beyond the current project pipeline.[1]

3. Alumina supply

More than 90% of all alumina is consumed by the aluminum smelting industry. The balance is sold as feedstock to the alumina chemicals industry, which in the past two decades has grown at a similar rate or slightly below that of aluminum smelting. For all practical purposes, therefore, forecasts of primary aluminum production can be translated directly into forecasts of alumina demand.

Unlike primary aluminum smelting, which is an industry that can relocate to places where low-cost electricity is available, alumina refining is a resource-based activity and must be developed where the natural resource, bauxite, is available. This is illustrated in the following table.

Table 3.6: Alumina production – historical trends

	2005	Share of World Production (%)				
	000t	1966	1974	1979	1989	2005
Western Europe	6,658	15.3%	15.2%	15.6%	14.1%	10.0%
Eastern Europe	1,614	1.7%	3.0%	4.6%	5.3%	2.4%
CIS	6,809	17.6%	10.3%	9.8%	14.2%	10.2%
North America	7,043	42.0%	27.9%	23.0%	14.8%	10.6%
Latin America	13,404	10.7%	15.8%	12.6%	15.9%	20.1%
Africa/Middle East	748	3.6%	2.2%	2.0%	1.5%	1.1%
China	8,324	1.2%	1.7%	2.2%	3.1%	12.5%
India	3,047	1.1%	1.0%	1.5%	3.4%	4.6%
Japan	748	4.5%	6.2%	5.6%	2.0%	1.1%
South & East Asia	35	0.2%	0.2%	0.2%	0.0%	0.1%
Oceania	18,200	2.1%	16.8%	22.8%	25.6%	27.3%
Total World	66,629	100.0%	100.0%	100.0%	100.0%	100.0%

Sources: Metallgesellschaft, CRU Analysis

The most striking feature of this sector is the declining market share of North America, Western Europe, and the CIS. In 1960 these regions accounted for 75% of alumina production. Currently, they account for only 31%. Latin America (mainly Brazil), Australia, and, most recently, China have been the main areas of growth. Basically, this industry has moved from one that traded aluminum raw materials in the form of bauxite, to one that now trades these raw materials in the form of alumina. The last new standalone alumina refinery, apart from a small chemical plant recently constructed in Korea, was the Shannon refinery in Ireland, which was built in 1983. Since then, all new plants and all significant expansions have been physically integrated with bauxite mining.

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[1] CRU Analysis currently assumes that all the Pacific Northwest smelters owned by Alcoa, Glencore and Golden Northwest Aluminum, whose capacity amounts to 1 mn tpy, remain technically available to produce aluminum. To the extent that any of these plants are permanently closed and dismantled like the former Kaiser and Reynolds operations, the future investment requirement of the world's aluminum industry will be correspondingly increased.

Alumina has been in short supply for the last few years. The fundamental reason for this is the unexpected increase in Chinese aluminum smelting capacity discussed earlier. This took the alumina industry by surprise. Ironically, the West Coast electricity crisis of 2001, which caused a major curtailment of production and thus reduced the demand for alumina, masked this problem for one or two years. The alumina that would have been used in the Pacific Northwest was effectively diverted to China. However, the scale of Chinese expansion has now outstripped the alumina available as a result of the Pacific Northwest curtailments, and markets have become extremely tight. Chinese alumina refineries themselves are, of course, being expanded. However, China is clearly unable to meet all of its increased demand for alumina because its bauxite resources are quite limited and have lower quality than those available in tropical regions. In particular, Chinese bauxite requires much higher energy inputs for conversion to alumina.

Against this background, alumina refinery operating rates have risen to an unprecedented 98% level in 2004 and 2005. Spot market prices have tripled from less than $200/t to more than $600/t. Medium-term contract terms, which averaged 12% historically and fluctuated over a range from 10% to 14%, have now risen to the 17-19% range, and single year contract terms have been reported in excess of 20%. Even at these high prices, the market is extremely illiquid. Alumina shipments are just not available. In fact, CRU’s current assessment is that lack of alumina (which has been committed to other lower cost smelters), along with power price uncertainties, are the main reasons why more Pacific Northwest smelting capacity has not already been restarted. The alumina outlook is summarized in the following table.

Table 3.7: Alumina investment requirement

Volumes in (000 t)	2006	2007	2008	2009	2010	2025	2030
Smelter Production	33687	35741	37645	39738	41736	58413	69261
Alumina Ratio (inc stocks)	1.922	1.947	1.950	1.950	1.950	1.950	1.950
Metallurgical Use	64735	69577	73408	77489	81386	113905	135059
Chemical Use	5509	5549	5610	5762	5917	7724	10082
% Change	*0.8%*	*0.7%*	*1.1%*	*2.7%*	*2.7%*	*2.7%*	*2.7%*
Total Use	70244	75126	79018	83251	87303	121629	145141
Required Capacity (95%)	73941	79080	83177	87633	91898	128030	152780
Projected Capacity	73952	79827	88897	93475	97265	107695	119244
Investment Need	-11	-748	-5720	-5842	-5367	20335	33536

Source: CRU Analysis

This table shows that the alumina refining sector has already reacted vigorously in terms of addressing the supply problem in response to the price signals that have been given in recent years. In fact, we show a surplus of alumina of 6 mn tpy in the 2008-2010 period, suggesting possible short-term over-investment. Longer-term, of course, new alumina refining capacity will be needed to meet demand – around 20 mn tonnes by 2020. In summary, our forecast suggests there is a strong likelihood that alumina will be readily available to operate Pacific Northwest smelters in the period relevant to the current BPA review.

4. Market price and smelter margin implications

The following table draws together our consumption and production analysis and shows the medium-term primary aluminum market balance through 2010.

Table 3.8: Medium-term aluminum market balance

					Forecast		
Volumes in (000 t)	2004	2005	2006	2007	2008	2009	2010
World Consumption	30323	31947	33942	35618	37257	39121	41068
% Change	*9.7%*	*5.4%*	*6.2%*	*4.9%*	*4.6%*	*5.0%*	*5.0%*
Strategic Stocks	0	0	0	0	0	0	0
World Demand	30323	31947	33942	35618	37257	39121	41068
Existing/Planned Capacity	34527	36753	38526	39358	40673	42277	44154
Operating Rate	*87.5%*	*87.7%*	*87.4%*	*90.8%*	*92.6%*	*94.0%*	*94.5%*
Forecast Production	30195	32246	33687	35741	37645	39738	41736
Market Balance	-129	299	-255	123	388	617	668
Change in Inventories	-661	19	45	423	388	617	668
Hidden Stocks & Errors	533	281	-300	-300	0	0	0
Inventory Level	2893	2911	2956	3379	3767	4385	5053
Days Consumption	*34.8*	*33.3*	*31.8*	*34.6*	*36.9*	*40.9*	*44.9*

Source: CRU Analysis

During this period the global market appears to be reasonably well balanced, as the current smelter investment program is well aligned with prospective demand. Given the absolute size of the market and the uncertainties implicit in the quality of the industry's statistics, imbalances of less than 500,000 tonnes either way cannot be considered significant. However, this balanced market outlook does depend on an increase in the operating rate from today's level of less than 90% to the 94-95% range by 2010

CRU's analysis is that this will become possible at some point in 2007/2008. The basis for this assessment is the alumina outlook, which is shown in the following table.

Table 3.9: Medium-term alumina market balance

Volumes in (000 t)	2004	2005	2006	2007	2008	2009	2010
Smelter Production	30195	32246	33687	35741	37645	39738	41736
Alumina Ratio (inc stocks)	*1.919*	*1.897*	*1.922*	*1.947*	*1.950*	*1.950*	*1.950*
Metallurgical Use	57954	61161	64735	69577	73408	77489	81386
Chemical Use	5272	5468	5509	5549	5610	5762	5917
% Change	*10.6%*	*3.7%*	*0.8%*	*0.7%*	*1.1%*	*2.7%*	*2.7%*
Total Use	63226	66629	70244	75126	79018	83251	87303
Exisiting/Planned Capacity	64364	68060	73952	79827	88897	93475	97265

Source: CRU Analysis

According to our refinery-by-refinery records, a very large increase in alumina supply is scheduled for 2007 and for several years thereafter. This implies that refinery operating rates will drop from around 95% in 2006 to less than 90% by 2008.

The implication of these forecasts for metal and alumina prices in gross smelter margins is shown in the table below.

Table 3.10: Metal price and margin forecasts

US$/Tonne	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
LME 3 Months, Nominal	1721	1899	2523	2178	2144	2087	2047	1863	1913
LME 3 Months, 2005$	1779	1899	2450	2076	1981	1870	1779	1571	1565
Alumina, fob Australia, Nominal	211	240	328	284	255	227	200	211	239
Alumina, fob Australia, 2005$	218	240	318	270	236	203	174	178	195
Alumina, % of Metal	12.2%	12.6%	13.0%	13.0%	11.9%	10.9%	9.8%	11.3%	12.5%
Gross Smelter Margin, Nominal	1316	1438	1893	1634	1654	1651	1662	1457	1455
Gross Smelter Margin, 2005$	1361	1438	1839	1557	1529	1480	1445	1229	1190

US$/Tonne	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
LME 3 Months, Nominal	1964	2016	2066	2117	2169	2223	2278	2355	2433
LME 3 Months, 2005$	1558	1551	1542	1532	1523	1514	1505	1509	1512
Alumina, fob Australia, Nominal	261	271	278	284	291	298	305	312	320
Alumina, fob Australia, 2005$	207	209	207	206	204	203	201	200	199
Alumina, % of Metal	13.3%	13.5%	13.4%	13.4%	13.4%	13.4%	13.4%	13.3%	13.2%
Gross Smelter Margin, Nominal	1462	1495	1533	1571	1611	1651	1693	1756	1819
Gross Smelter Margin, 2005$	1160	1151	1144	1137	1131	1125	1119	1125	1130

US$/Tonne	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
LME 3 Months, Nominal	2493	2555	2618	2683	2751	2820	2891	2964	3039
LME 3 Months, 2005$	1503	1494	1485	1476	1467	1459	1451	1443	1435
Alumina, fob Australia, Nominal	328	335	343	352	360	369	378	387	397
Alumina, fob Australia, 2005$	197	196	195	193	192	191	190	188	187
Alumina, % of Metal	13.1%	13.1%	13.1%	13.1%	13.1%	13.1%	13.1%	13.1%	13.0%
Gross Smelter Margin, Nominal	1864	1911	1959	2008	2059	2111	2165	2221	2278
Gross Smelter Margin, 2005$	1124	1117	1111	1105	1098	1092	1087	1081	1075

Source: CRU Analysis

The outlook is for a very sharp increase in conversion margins in 2006. However, it should be noted that this assessment is based on average alumina prices rather than spot prices. The latter is still around $600/t. Even if the year average turns out to be lower than current levels, it is still quite likely that spot prices will exceed average prices by some $250/t. This lagging phenomenon is a function of the multi-year contract structure of the alumina refining industry. If smelter decision makers are looking at spot price margins, then these will be some $450-500/t less than the figures stated in the table. However, the table clearly shows that both nominal and real smelter margins in the period 2007-2010 will be above the level of 2004 and years prior. This is consistent with our forecast that market pressure should be sufficient to trigger the restart of some of the smelters around the world that are currently operating at reduced capacity or which are idle.

This assessment does not, however, explicitly take account of power industry pricing issues. Current operating costs, excluding power but including alumina freight, metal realizations costs, and a reasonable allowance for sustaining capital at older smelters, are in the range of $650-750/t. Since gross smelter margins are forecast to be around $1,500/t in 2008-2010, in theory it may be possible to pay up to $750/t for power. If we take 16 Mwh/t, this implies that power prices in excess of $40/Mwh are potentially affordable as long as metal prices remain at the favorable levels, which we forecast.

The above scenario is CRU's base case forecast. We recognize, however, that there are uncertainties surrounding these projections. To address them, CRU's long-term forecasting model incorporates a Monte Carlo analysis feature that allows us to examine the implications of the major risks to the forecast. These fall into the following categories:

i) macroeconomic risks related to the growth of the world economy; these include uncertainties surrounding the fundamentals of long-term growth – such as population, employment rates, and productivities in different countries and regions;

ii) monetary risks; these include uncertainties surrounding the inflation rate of the U.S. dollar and real interest rates, as well as the inflation rates of other aluminum producing countries plus related exchange rate changes;

iii) key country risks; these include uncertainties that are specific to Chinese growth arising either from a financial crisis, similar to that which occurred in Southeast Asia in the late-1990s or Latin America in the 1980s, or from internal political pressures relating to the growth in inequality between different regions within China;

iv) commodity market risks; these include uncertainties in the markets for oil, coal and gas, as well as for other key inputs into the aluminum smelting industry such as caustic soda, calcined petroleum coke, and pitch; they also include uncertainties surrounding ocean freight rates and their effect on the relative value of metal at different smelting locations in the world;

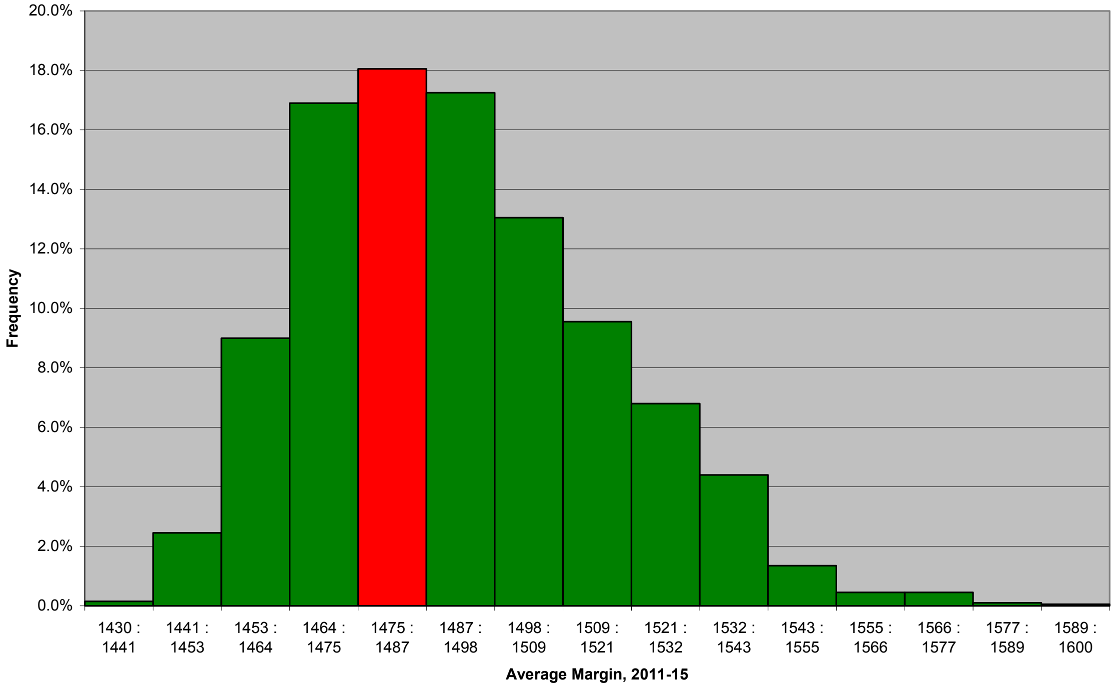
v) aluminum industry demand risks; these include uncertainties surrounding the impact of changing auto industry technology on aluminum use and uncertainties related to the competitive pressures exerted by alternate materials;

vi) aluminum industry capacity risks; these include uncertainties surrounding the rate at which obsolete smelting and refining capacity will be closed down and the rate at which existing plants will improve their production on an incremental (creep) basis;

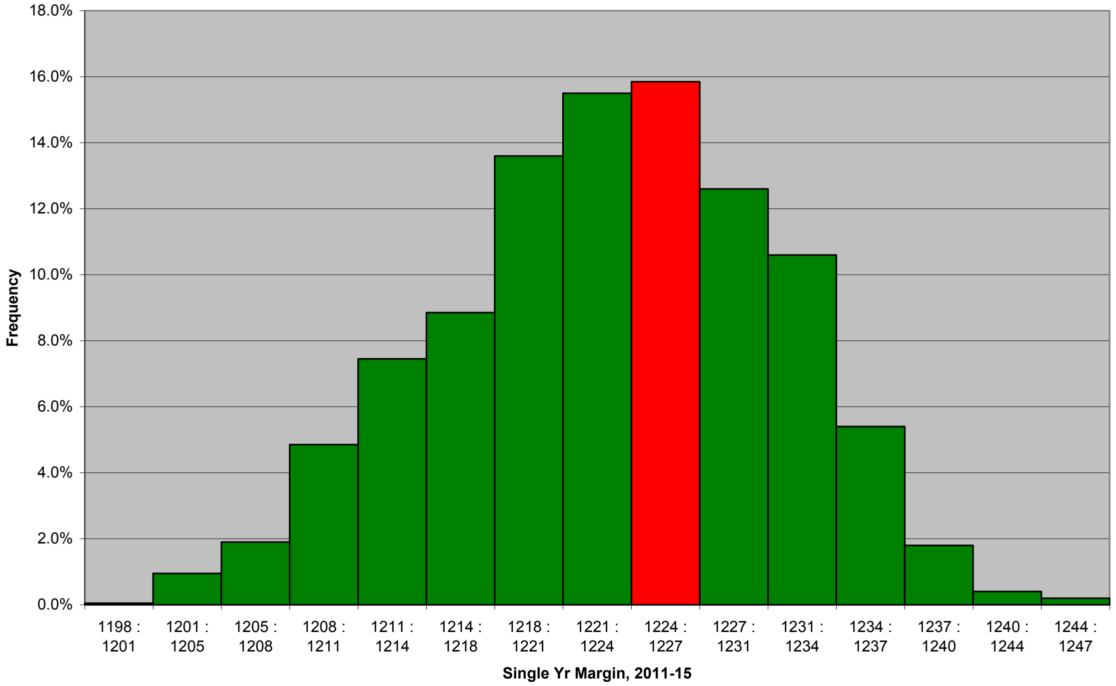
vii) aluminum industry productivity risks including uncertainties surrounding the rate at which new and existing plants will be able to improve their labor productivity, energy efficiency, and capital productivity; and

viii) institutional and political risks; these include uncertainties surrounding the reduction or elimination of tariffs on the imports of aluminum in Europe and China, the potential for the introduction of new inert anode technologies, which could potentially dramatically lower the industry’s cost structure, and changes in political risk premiums associated with investments in key alumina and aluminum producing countries.

CRU has used its risk analysis model to evaluate the gross conversion margin forecast. In the base case, the average margin for the 5-year period 2011-2015 is expected to be $1,480/t. The following chart shows a degree of uncertainty associated with this projection.



The chart shows a classical asymmetrical risk. Downside risk is about $40/t and is dictated by the cost structure of the industry. Upside risk is significantly greater – about $100/t. This is typical of the commodity market where troughs in price cycles tend to be longer but less extreme than peaks. It should be noted, however, that this chart refers to the average margin over a 5-year period. The single year margin risk is more significant even though, as pointed out above, it can potentially be managed through hedging operations. The following chart shows the lowest price that is likely for any given year between 2011 and 2015.



From this chart we have concluded that the lowest single year conversion margin that is likely to be encountered in this timeframe lies in the range of $1,200-1,250/t. It must be emphasized that these figures are in current dollar terms and embody an expected inflation rate of 2.5% per annum from a 2005 starting point. If we compare this single year risk figure with the $650-750/t estimate of non-power operating costs at older smelters, then somewhere between $450-600/t may be available to pay for power. At a specific consumption rate of 16 Mwh/t, this implies tariffs in the region of $28-37/Mwh. In summary, therefore, our high level analysis suggests that the ability to operate older smelters will be very sensitive to the precise price at which BPA offers power to the aluminum industry.

It must be appreciated that calculations of this nature can do no more than provide a general indication of the order of magnitude of prices that will be feasible for aluminum smelters. There are a series of practical constraints on the industry's decision-making process. In particular, the industry's assessment of risk is critical. In this context what is relevant is (a) the quantity of cost-based power that is made available, (b) the predictability of the cost-based price and (c) the duration of the contracts offered. If, for example, the quantity of power is sufficient to operate the smelter at a relatively high utilization rate, the cost changes from year to year are expected to be minimal, or at least not significantly in excess of inflation generally, and contracts of 5 years or longer are offered, the industry is likely to be able to entertain prices at the upper end of the range. On the other hand, if the quantities of power fall seriously short of needs, costs are not well controlled and contract terms are limited to one or two years, the prices that are feasible will be at the low end of the range. The reason for this is straightforward. Companies like Alcoa have to invest in start-up costs and sustaining capital projects to operate these plants. In a high-risk environment higher returns are required than in a low risk environment. Thus, in addition to the absolute level of the cost-based price, the precise contracting environment proposed by BPA will be a key issue, as will be BPA's cost control efforts.

Chapter 4

Operating prospects for the Alcoa smelters

This chapter examines the specific circumstances of the Wenatchee and Ferndale smelters with a view to developing a more precise assessment of the probability that they will operate at different rates over the time period in question.

Alcoa's two Pacific Northwest plants currently have a rated capacity of 470,000 tpy on a hot metal basis. Of this, 185,000 tpy is located at Wenatchee and 285,000 tpy is located at Ferndale. To operate fully, they need approximately 827 MW of continuous power, of which approximately 344 MW is required at Wenatchee and 483 MW at Ferndale.

The Ferndale smelter has three identical 144 KA pot lines. Each of these draws about 161 MW and produces 95,000 tpy of aluminum. This plant dates from the 1960s and is representative of the typical efficient smelter in North America and Western Europe.

The Wenatchee smelter has four pot lines. Three of these date from the early-1950s and consist of 103 KA pots, whereas one of them is from the early-1960s and uses 132 KA pots. The Wenatchee smelter is also different from Ferndale in two other important respects. First, it is inland and, therefore, suffers from lower gross margins due to higher alumina freight costs. Secondly, it has access to around 200 MW of cost-based hydroelectric power from the Rocky Reach project of the Chelan Public Utility District (PUD). Because of the significantly different technical, economic, and power availability circumstances, we discuss the prospects for each of these plants separately.

1. Ferndale

Ferndale is currently operating one of its three pot lines. CRU's 2004 survey estimates that non-power, non-alumina operating costs in that year were $666/t. There are serious diseconomies of scale involved in operating a plant at this level. If Alcoa were to operate all three lines, then CRU's estimate is that the production costs would have been reduced to $552/t. These figures include an allowance for sustaining capital expenditures and thus represent the full cash outlays of the plant. Between 2004 and 2006 there have been significant increases in a number of the components of aluminum production costs, including carbon materials and energy. The overall structure of non-power operating costs has risen by at least 10%. We must also allow for inflation between 2006 and the period 2011-2015. On the basis that this is around 2.5% per annum, CRU considers that the average cost structure during this period will be about 27.5% higher than the base numbers reported in CRU's 2004 report. Accordingly, our best estimate of Ferndale's cost structure at full operation during this period is $703.80/t. On this basis the average margin earned by Ferndale before power costs is estimated at $748.65/t. The following table shows how this figure changes as the smelter operates at different rates and what this implies for the a maximum theoretical price. It must be emphasized that these are purely theoretical calculations that allows no margin to compensate for risk and no return on historically invested capital. Later in this chapter, we examine the question of power price affordability on a more realistic, risk-adjusted basis.

Table 4.1: Impact of power availability on Ferndale's theoretical price

Lines operating	Average theoretical price	Single year theoretical price
1	$40.72	$23.21
2	$45.62	$28.12
3	$50.53	$33.02

Source: CRU Strategies

In CRU's opinion, the prospects for the restoration of full production at Ferndale are not very good in the absence of a meaningful quantity of BPA power at a cost-based price. The background to this statement is our observation that during the period 2004-2005 the mid-Columbia market prices averaged around $50/Mwh. Even if Ferndale operates all of its pots in the improved aluminum market environment that we foresee for the period 2011-2015, this is still a marginal proposition on a long-term basis. On the other hand, if BPA can offer power for two lines in the range of $30-35/Mwh, then the average price to Ferndale will be driven down to around $41/Mwh. This will provide Ferndale with a reasonable margin. Specifically, it could be sufficient to fund a careful hedging strategy designed to manage the single-year risk. Alternatively, it could fund the cost of a temporary closure during periods of low prices.

2. Wenatchee

Wenatchee is currently operating two of its four pot lines. CRU did not include Wenatchee in its 2004 production costs survey. However, on the basis of Ferndale's costs, adjusted for the smaller size of the Wenatchee pots and for lower overall scale, we estimate that, at its full potential rate of operation, Wenatchee has a non-power, non-alumina cost structure that is around 14% higher than Ferndale. On that basis, and again escalating for the probable inflation between the present and the period 2011-2015, we estimate that Wenatchee's cost structure in that time period will be around $802.33/t, which gives Wenatchee a margin of $620.56/t on average. As with Ferndale the following table shows how this margin changes under different operating profiles.

Table 4.2: Impact of power availability on Wenatchee theoretical price

Lines operating	Average theoretical price	Single year theoretical price
2	$32.56	$16.66
3	$35.30	$19.40
4	$38.04	$22.14

Source: CRU Strategies

The implication of these calculations is that Wenatchee's present operation can be sustained on a long-term basis only on the basis of the company's contract for a cost-based share of the Rocky Reach hydroelectric project. This contract will expire in 2011, and the terms of its renewal are not currently available to us. However, if the contract can be renewed at around the $20/Mwh mark and if BPA power is then available for the balance of the plant at $30-35/Mwh, a blended price of around $26/Mwh is indicated. This provides a reasonable margin to allow the company to operate at full production and manage potential single-year risk through an appropriate hedging program. If the balance of Wenatchee's power must be obtained from the open market at the mid-Columbia price of around $50/Mwh, then the blended price would be around $34/Mwh. This means there will be a smaller but, nevertheless, still positive margin. However, the implication is that this plant will almost certainly need to be operated on a swing basis.

3. Risk analysis

Any consideration in the future operation of Alcoa's Pacific Northwest smelters needs to recognize that there are numerous uncertainties involved. In Chapter 3 we quantified the range of uncertainties surrounding the aluminum price, the alumina price, and the implications for the potential conversion margin earned by smelters. Additional risks for the Wenatchee and Ferndale smelters surround uncertainties relating to other market factors, such as the premiums earned on metal delivered to the Far East or U.S. Midwest, as well as uncertainties related to operating costs, freight rates, interest rates, and so forth.

For the purpose of this report, CRU has constructed a simple Monte Carlo model to simulate the effect of all of these uncertainties on the affordable price of the two smelters. The basic assumptions made and the risks considered are summarized in the following table.

Table 4.3: Key assumptions and risks

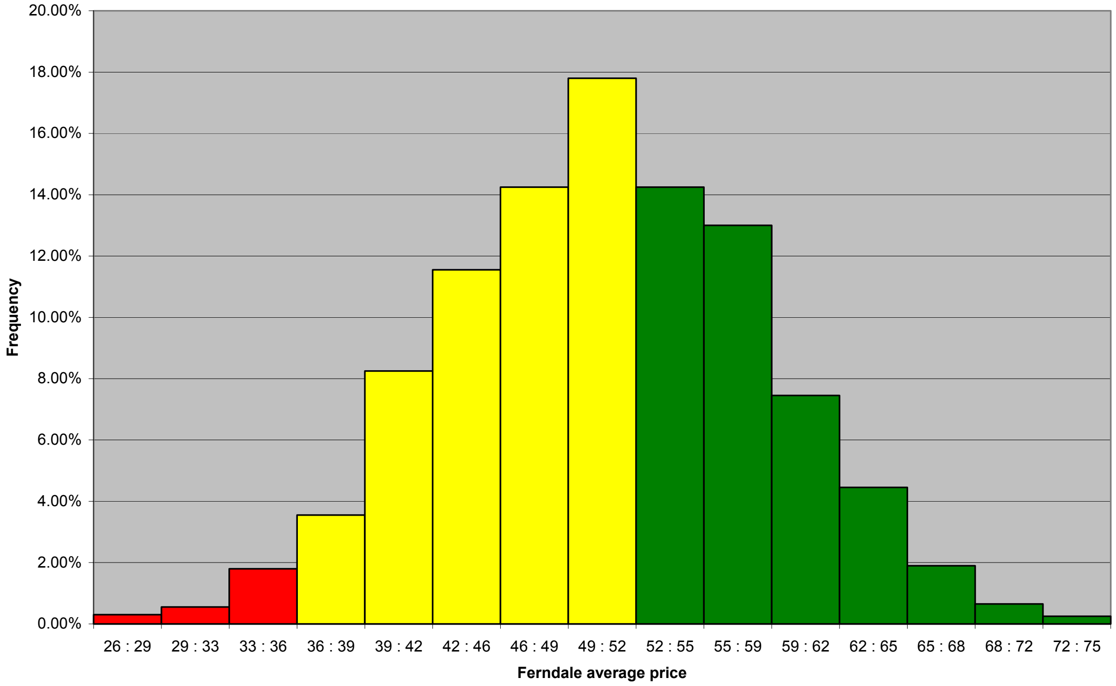
NORMAL DISTRIBUTIONS		Value Selected	Most Likely	Standard Deviation
Alumina Exchange Ratio	% of Metal	13.50%	13.50%	1.20%
Cif Japan/Far East Premium	$/t	65.00	65.00	17.50
Midwest Premium	$/t	100.00	100.00	*correlated with cif Japan*
Non-Power Operating Cost Risk	Index	1.00	1.00	0.15
Industry WACC		9.50%	9.50%	0.50%

TRIANGULAR DISTRIBUTIONS		Value Selected	Low	Most Likely	High
Gross Margin - Average	$/t	1490.00	1430.00	1490.00	1600.00
Gross Margin - Single Year	$/t	1225.00	1195.00	1225.00	1245.00
Ocean Freight Index	Index	1.00	0.75	1.00	1.75

OTHER ASSUMPTIONS		Value Selected
Ferndale 1 Line Costs	$/t Al	849.20
Ferndale 2 Line Costs	$/t Al	776.50
Ferndale 3 Line Costs	$/t Al	703.80
Wenatchee 2 Line Costs	$/t Al	891.66
Wenatchee 3 Line Costs	$/t Al	847.00
Wenatchee 4 Line Costs	$/t Al	802.33
Wenatchee-Davenport freight	$/t Al	90.00

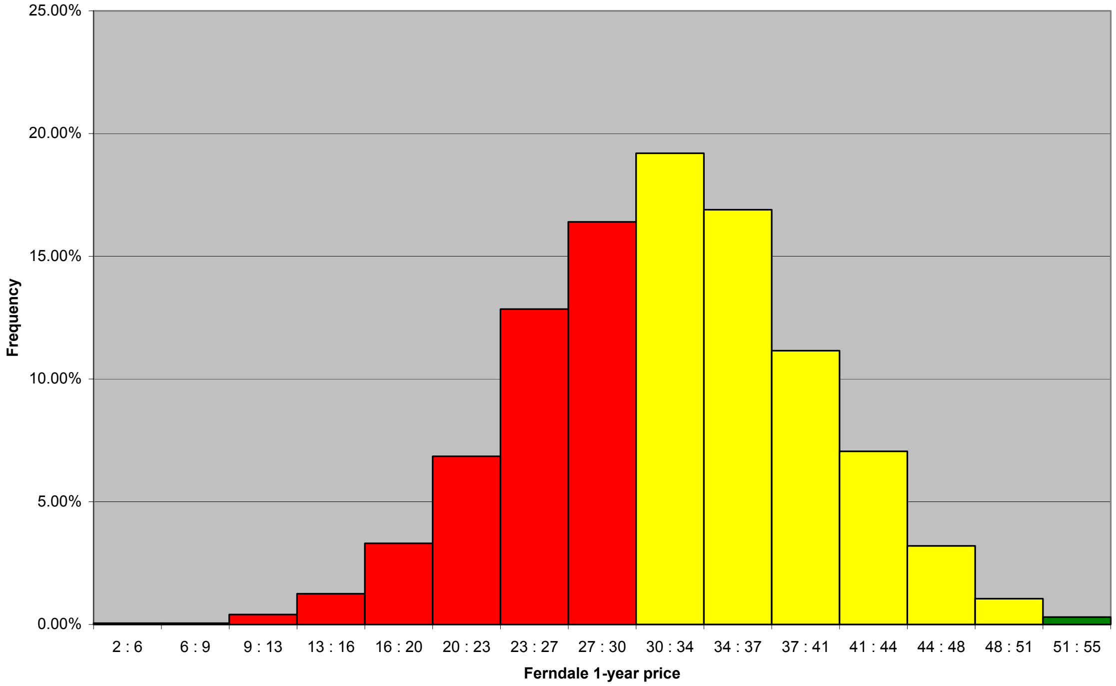
Gross margin risks, as specified above, reflect the conclusions reached in Chapter 3. CRU feels confident that the uncertainties associated with its estimate of non-power operating costs are limited to +/-15% at one standard deviation surrounding the central estimate. The risks associated with various premiums and other factors are derived from fluctuations in the historical data over the past 15 years.

The following chart shows the effect of these assumptions on the average price that Ferndale can afford to pay over the 2011-2015 assuming the full operation of all three lines.



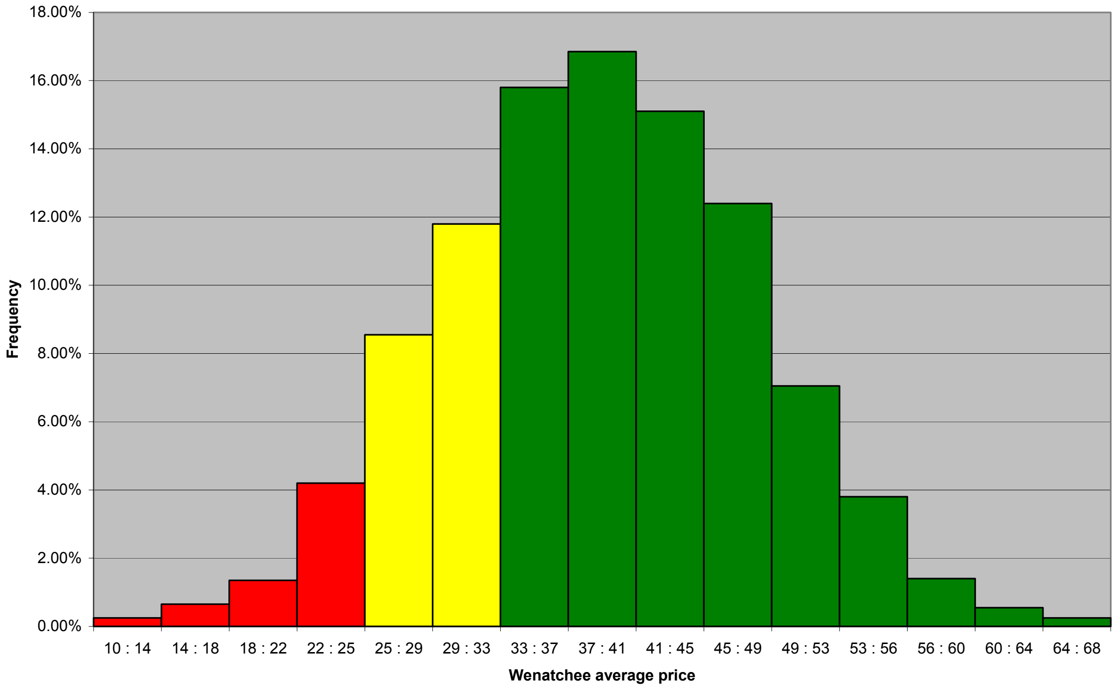
There is less than a 50% probability that Ferndale can afford to pay the mid-Columbia price, which is assumed to be $50/Mwh. If we hypothesize that BPA power is available at $30/Mwh for two lines, then the average price is around $37/Mwh. The chart shows there is a better than 95% probability that the smelter can operate successfully on this basis. At an average price of $40/Mwh, there is still around a 90% chance of successful operation.

However, as the next chart shows, Ferndale will remain at risk individual years of potentially low profit margin.



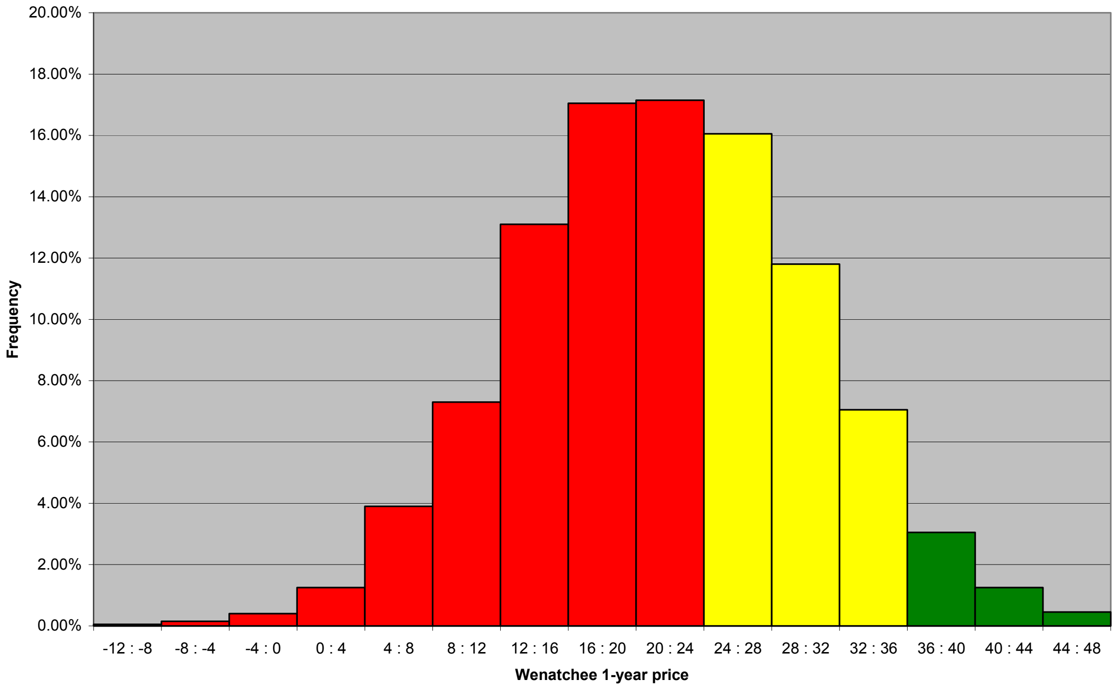
This chart shows that even a $30/Mwh price creates a 50% risk that Ferndale will have to close during a cyclically weak market year. This basically confirms recent experience when Ferndale has been operating unprofitably on a single pot line primarily to preserve the option to restart when better market conditions return. This very high single-year risk, however, is not necessarily fatal. As long as Alcoa can be confident that Ferndale will be reasonably profitable over the cycle as a whole, they can manage this risk by careful hedging – either in the market offered by the LME or internally through the risk offsets available elsewhere in the Alcoa system.

Turning to the effect of uncertainty on Wenatchee, there is a different dynamic due to the availability of the tranche of lower priced Rocky Reach power. As described above, the potential blended Wenatchee price is in the $26-34/Mwh range. As the following chart shows, this leads to a somewhat higher but, in CRU's opinion, acceptable risk.



Whereas the risk of long-term losses was around 3% at Ferndale, the risk at Wenatchee appears to be around 7-8%. Offsetting this to some extent is the higher probability of a positive result. Since Wenatchee needs less BPA power to operate lines 3 and 4 than Ferndale needs to operate lines 2 and 3, the availability of power from BPA becomes the critical issue. If only a small quantity of power is available, then it may be lower risk to use this at Wenatchee rather than Ferndale.

Finally, the following chart shows Wenatchee's single-year risk is very high – almost as high as Ferndale's. Again, CRU believes this is manageable, but only if the plant can demonstrate reasonably attractive returns over the cycle as a whole.



4. Operating prospects

Given the favorable global industry outlook for primary aluminum smelting, the only reason why a company like Alcoa would consider permanently abandoning its Pacific Northwest smelters is on the basis of uncompetitive energy costs. Here the global picture is also changing. From 1984 – when CRU and its predecessor companies first began tracking average power prices to the aluminum industry – to approximately 2004, the average price of power paid by the world aluminum smelting industry was less than $20/Mwh. It was flat in nominal terms – implying a steep decline in real terms. This picture is now changing. In recent years the natural gas glut has disappeared and the long decline in real coal mining costs has come to an end. New smelters, previously looking at power prices of around $15/Mwh or less, are now facing effective prices closer to $20/Mwh. Brownfield projects are now being constructed on the basis of $25/Mwh power compared with prices that were closer to $20/Mwh a few years ago. Finally, European power prices have moved up to the $40 range from the low-$30s for old smelters. CRU expects that such factors as the globalization of the natural gas market through the expansion of LNG trade and the construction of an efficient national energy grid in China will significantly reduce the number of low cost energy "islands" that are available for the exploitation by the aluminum industry, thereby permanently raising the average price of power paid in this industry. Potentially, this raises the scenario that the competitive position of the Pacific Northwest may very well improve in the medium-term.

Against this background, CRU believes that the Pacific Northwest aluminum industry still has a significant role to play by operating both base load and swing capacity on a profitable basis. However, to do so a more predictable and stable energy-pricing regime is needed. It is clear that, at times of high aluminum prices, the aluminum industry can probably afford to pay the market price for electricity – assuming that this price is set in a liquid and transparent manner and that the manipulations and abuses of the 2000-2001 period are avoided. It is equally clear that, at times of low water and high power price, aluminum smelters represent a load that is at least partially interruptible and, as such, can help the region to manage these risks. There are elements in this outlook, therefore, that represent a potential win-win proposition for the BPA, its other customers, and the aluminum companies themselves.

The problem is that it is far from costless to switch aluminum smelters on and off. We know from the most recent cycle that a completely idle smelter of the size of Wenatchee or Ferndale will cost around $12-15 mn/yr in standby costs, assuming that about three-quarters of the employees are laid off. Restart costs are probably around $7 mn / pot line. Laying off such a large proportion of the employees is not likely to be acceptable as a normal operating mode in any case. If employment of a core group of around 400 staff per smelter is to be maintained, this will cost $24 mn/yr per smelter and raises the standby costs to nearer $30 mn/yr in total.

For these reasons what the aluminum industry really needs is a relatively low, cost-based price for a portion of the plant, to allow the company to operate a critical mass of its pots on a base load basis all of the time. This dramatically reduces both the human and corporate costs associated with swing operations. Past experience very clearly demonstrates the advantage of this in the case of Wenatchee where such a low cost tranche of power has been available from Rocky Reach. Despite the fact that Wenatchee is at an inland location and has significantly higher operating costs than Ferndale, Wenatchee has significantly lower risks in cyclical operation. In practice, this has allowed Alcoa to manage the most recent cycle in a reasonable manner at this location.

In an ideal world, BPA would offer Alcoa sufficient power to run all of its plants, namely 627 MW.[1] Assuming the cost of service based price is in the region of 35/Mwh, CRU's opinion is that Ferndale would run in all but the most extreme recession conditions and that Wenatchee would run only one of its four lines on a cyclical basis.

If BPA offers a lesser quantity of power, Alcoa will prefer, if possible, to use this at Ferndale, as this is the most modern smelter. If the amount offered is sufficient for three lines, namely 483 MW, the outcome will be similar to the above. Ferndale will run under all but the most extreme market conditions. However, Wenatchee's operating rate will be more variable. Unless mid Columbia prices decline below $30/Mwh, we will probably see Wenatchee operating only its two Rocky Reach supplied pot lines on a continuous basis. The other two lines will be swing capacity.

If the BPA power quantity is further reduced, Alcoa will probably continue to concentrate use of this power at Ferndale as long as two lines can be supplied, namely 322 MW. Our assessment is that there is still a positive margin available on that basis, although it is quite small. However, because of the negative effect of two line operation on overall plant economics, there is a significant cyclical risk, and it becomes quite likely that Ferndale will periodically reduce production for one or two

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[1] This assumes a continued 200 MW from Rocky reach for Wenatchee.

years during normal business cycles. On this scenario, Wenatchee lines 3 and 4 are also cyclical swing capacity.

If the BPA power offer falls materially below that needed for two lines at Ferndale, Alcoa's ability to operate this plant at a positive margin over the cycle becomes compromised. In those circumstances it is probably better for Alcoa to concentrate BPA power at Wenatchee and try to run that smelter as a baseload facility. This requires 144MW of BPA power.

The following table summarizes the above. It shows the potential relationship between the availability of cost-based power from BPA and probable smelter operations over the cycle at Alcoa's two locations. It should be emphasized that these consequences are sensitive to the conversion margin available in the aluminum market, to the BPA's cost of service based price and to the price of power on the free market at mid-Columbia. However, in CRU's opinion, this is the scenario that currently seems the most likely given what we know about the aluminum market and the regional energy market at the time of this report.

Table 4.4: Impact of BPA power availability on smelter operations (MW)

	Ferndale		Wenatchee		Regional Total	
BPA Offer	Normal	Recession	Normal	Recession	Normal	Recession
627	483	483	344	272	827	755
483	483	483	200-344	200	683-827	683
322	322	161	200-344	200	522-666	361
144	0	0	344	344	344	344

Notes

1. Assumes BPA rates circa $35/Mwh, mid-Columbia circa $50/Mwh

2. Wenatchee normal operation on non-BPA power highly sensitive to metal and power prices

3. Excludes extreme recessions similar to 1993

Chapter 5
Conclusions

Conditions in the world aluminum industry have recently improved, thanks mainly to strong demand growth from China in particular and Asia generally. Moreover, even in the advanced industrial countries the fundamentals of this industry are sound. There is no question that the world will need a great deal more aluminum smelting capacity in the decade 2011-2020. Moreover, there is every likelihood that there will be more than enough alumina supply to facilitate this growth. Basically, CRU believes that the bottleneck in the aluminum industry will shift from alumina refineries back to its traditional place in the aluminum smelting sector well before 2010.

Against this background, the only reason why a company like Alcoa would consider permanently abandoning its Pacific Northwest smelters is on the basis of uncompetitive energy costs. Here the global picture is also changing. From 1984 – when CRU and its predecessor companies first began tracking average power prices to the aluminum industry – to approximately 2004, the average price of power paid by the world aluminum smelting industry was less than \$20/Mwh. It was flat in nominal terms – implying a steep decline in real terms. This picture is now changing. In recent years the natural gas glut has disappeared and the long decline in real coal mining costs has come to an end. New smelters, previously looking at power prices of around \$15/Mwh or less, are now facing effective prices closer to \$20/Mwh. Brownfield projects are now being constructed on the basis of \$25/Mwh power compared with prices that were closer to \$20/Mwh a few years ago. Finally, European power prices have moved up to the \$40 range from the low-\$30s for old smelters.

This changed energy market environment is one of the factors that has led to a structurally high level of aluminum prices than those to which we have become accustomed over the past two decades. CRU expects that such factors as the globalization of the natural gas market through the expansion of LNG trade and the construction of an efficient national energy grid in China will significantly reduce the number of low cost energy “islands” that are available for the exploitation by the aluminum industry, thereby permanently raising the average price of power paid in this industry. Potentially, this raises the scenario that the competitive position of the Pacific Northwest may very well improve in the medium-term.

Against this background, CRU believes that the Pacific Northwest aluminum industry still has a significant role to play by operating both base load and swing capacity on a profitable basis. However, to do so a more predictable and stable energy-pricing regime is needed. It is clear that, at times of high aluminum prices, the aluminum industry can probably afford to pay the market price for electricity – assuming that this price is set in a liquid and transparent manner and that the manipulations and abuses of the 2000-2001 period are avoided. It is equally clear that, at times of low water and high power price, aluminum smelters represent a load that is at least partially interruptible and, as such, can help the region to manage these risks. There are elements in this outlook, therefore, that represent a potential win-win proposition for the BPA, its other customers, and the aluminum companies themselves.

The problem is that it is far from costless to switch aluminum smelters on and off. We know from the most recent cycle that a completely idle smelter of the size of Wenatchee or Ferndale will cost around $12-15 mn/yr, assuming that about three-quarters of the employees are laid off. Restart costs are probably around $7 mn / pot line. Laying off such a large proportion of the employees is not likely to be acceptable as a normal operating mode in any case. If employment of a core group of around 400 staff per smelter is to be maintained, this will cost $24 mn/yr per smelter and raises the standby costs to nearer $30 mn/yr in total.

For these reasons what the aluminum industry really needs is a two-tier power pricing structure. This would consist of a relatively low, cost-based price for a portion of the plant, with a higher market-related price for the balance of the load. The low cost price would allow the company to operate about half the plant on a base load basis all of the time and would, thus, dramatically reduce both the human and corporate costs associated with swing operations. Our study very clearly demonstrates the advantage of this in the case of Wenatchee where such a low cost tranche of power is effectively available from Rocky Reach. Despite the fact that Wenatchee is at an inland location and has significantly higher operating costs than Ferndale, this feature results in Wenatchee having significantly lower risks in cyclical operation and has, in practice, allowed Alcoa to manage the most recent cycle in a reasonable manner at this location.

The provision of BPA power to Alcoa post-2011, in our opinion, offers the potential for an equivalent structure to develop at Ferndale, provided that BPA’s costs remain under control. In this context we refer specifically to the provision of enough power for two lines (325 MW) at a price of less than $35/Mwh, and preferably closer to $30/Mwh.

On this scenario CRU believes that it will be reasonable for Alcoa to operate two lines at Wenatchee using Rocky Reach power and two lines at Ferndale using BPA power on a long-term base load basis. Depending on market conditions, it may then be possible to use any additional power from BPA or from other sources for the remaining capacity on a swing basis. If additional cost-based power can be provided on a long-term basis, then Ferndale is probably the best place to use it, since this is the more efficient location. BPA power in the amount of 480 MW, for example, would probably result in significant reinvestment at Ferndale to develop it as a 3-line base load operation. On the other hand, if less power is available, then rather than reducing Ferndale to one line, it might be better for Alcoa to use this power at Wenatchee and aim to operate that plant at its full potential.