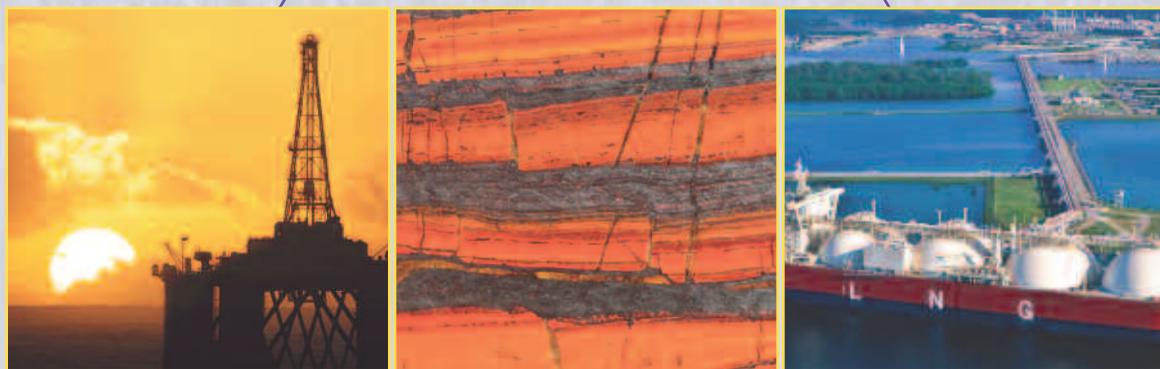


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The Aluminum Industry in West and Central Africa



Lessons Learned and
Prospects for
the Future

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**World Bank Group's Oil, Gas, and Mining Policy Division
Oil, Gas, Mining, and Chemicals Department**

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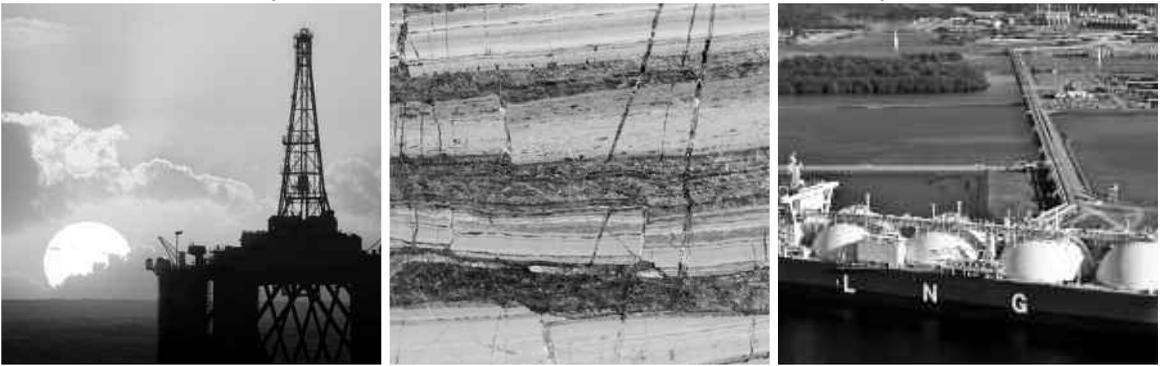
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Cover Photos: Oil rig, hematite-banded ironstone, LNG tanker

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Acronyms and Abbreviations

Alcoa	Aluminum Company of America
Alscon	Aluminium Smelter Company of Nigeria
Alucam	Aluminium Cameroon (Compagnie Camérounaise de l'Aluminium)
BFIG	BFI Group of California
BOT	Build, operate, and transfer
BPE	Bureau of Public Enterprises (Nigeria)
CBG	Compagnie des Bauxites de Guinée
CBK	Compagnie des Bauxites de Kindia
DRC	Democratic Republic of Congo
ECA	Economic Commission for Africa
EIA	Environmental Impact Assessment
FCFA	Franc Communauté Financière Africaine
GAC	Guinea Aluminum Corporation
GDP	Gross domestic product
GOC	Government of Cameroon
GOG	Government of Ghana
GORG	Government of the Republic of Guinea
GORSA	Government of the Republic of South Africa
GON	Government of Nigeria
IFC	International Finance Corporation
IPP	Independent Power Producer
kWh	Kilowatt hour
LPD	Lom Pangar Dam
MCDT	Mozal Community Development Trust
MW	Megawatt
RTA	Rio Tinto Alcan
Rusal	United Company Rusal
SAPP	Southern Africa Power Pool
Semi	Semi-processed aluminum
SMEELP	SME Empowerment Linkages Program
SMEs	Small and medium enterprises
Tpy	Metric tons (tonnes) per year
UN	United Nations
UNDP	United Nations Development Program
USGS	United States Geological Survey
Valco	Volta Aluminum Company
VRA	Volta River Authority
WAGP	West African Gas Pipeline
WAPP	West African Power Pool

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This working paper, undertaken by the Oil, Gas, Mining and Chemicals Department of the World Bank, presents the findings of a study to evaluate the future of the aluminum industry in West and Central Africa, with a focus on aluminum smelting. The report was sponsored by Africa Regional Integration Department of the Bank to contribute towards a better understanding by high level policy makers and Bank staff, involved in the expansion of electric power in countries in this region, to carefully assess the costs and benefits of using the aluminum industry as an anchor customer for new power generation and make informed strategic long-term decisions.

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Executive Summary

The purpose of this working paper is to evaluate the future of the aluminum industry in West and Central Africa, with a focus on aluminum smelting and its relationship with power generation and availability in the regions. While there is no doubt that the region will continue to be an important global bauxite producer and could become a significant global producer of alumina, the future of aluminum smelting is less clear. Although the production of aluminum was initiated with some success in West and Central Africa in the 1960s to underpin large hydropower generation projects within the regions, for a variety of reasons these operations have in recent times run into trouble and undermined the viability of the power utilities and the smelters—in Cameroon and Ghana. This study assesses the challenges associated with the first generation of aluminum smelters in the regions; determines if there are conditions under which they could be turned around and continue to be viable, including in the context of an integrated aluminum industry; and finally draws lessons from these and other experiences in Southern Africa to assess the opportunities for new aluminum smelters and regional cooperation in the region. This analysis should assist the reader—especially high level policy makers and Bank staff—to make informed strategic long-term decisions in their respective countries. It will also assist other countries in West and Central Africa that are currently or likely to be involved in the expansion of electric power to carefully assess the costs and benefits of using the aluminum industry as an anchor customer for new sources of power.

The smelting of alumina into aluminum is by far the most power intensive major metal industry in the world. Decisions to invest in an aluminum smelter are therefore made largely on the availability of a reliable source of low-cost electric power for a significant length of time, usually in excess of 20 years. While smelters can represent good base load customers for major power developments, without careful long-term power planning, they can eventually lead to significant energy deficiencies for other consumers. Governments should therefore avoid tariff subsidies to encourage energy intensive investments and seek to create efficient energy markets that lead to long-run marginal cost pricing of electricity and full cost recovery as quickly as possible. Consequently, given the potential impact on the energy situation in a country, it is necessary for government

to be an integral part of the decision making process when a company is considering building an aluminum smelter. This is in contrast to most other mining or mining related industries, the development of which is seldom based on the availability of low-cost power as a main input. On the other hand, the upstream refining of bauxite to alumina is not dependent on a low cost power source. Accordingly, the decision to build an alumina refinery is independent of and very different to the one to build an aluminum smelter and generally results in locating the refinery at or near the deposits of bauxite.

The smelters in Cameroon and Ghana,—the only fully operational smelters in the two regions—have encountered similar problems. Over the years hydro generation capacity in each case remained static, while overall power demand steadily increased and competed for the limited supplies of low cost power to the smelters. While the aluminum industry was not the cause of the supply failure, it nonetheless became both an albatross and a scapegoat. The experience of a third smelter in Nigeria has been even more complicated. It was built on the assumption of low cost thermal power using gas associated with oil production, but ten years later neither the pipeline to deliver the gas nor the power plant has been built.

In recent years there has been an upsurge in the price of aluminum—still above trend despite the recent collapse in commodity prices—largely due to increased demand from China and India. It is forecast that there will be a shortage of global aluminum smelting capacity within five years. Consequently, there are strong incentives and pressures to find ways to keep the existing smelters in West and Central Africa in operation. While it is not clear that this will be possible under the current conditions, the two regions are home to large resources of untapped hydro energy particularly along the Inga rapids on the Congo River in DRC, but also in Cameroon and Guinea. Consequently, there is a potential case for the expansion of the smelter in Cameroon to support a large hydro power initiative. In addition, a new smelter could be justified in the Democratic Republic of Congo to support a major hydro power initiative on the Inga Rapids. The study also concludes from an industry integration perspective that the presence of bauxite results in a cost advantage for local alumina refining. However, the benefits for a smelter of having an in-country alumina source are quite limited.

The activities of the aluminum sector have occurred almost entirely in four countries in West and Central Africa—Cameroon, Ghana, Guinea and Nigeria. Bauxite has been mined in Guinea and to a lesser extent in Ghana. Lower grade bauxite deposits occur in Cameroon but as yet remain undeveloped. Alumina has been produced and exported in Guinea while aluminum has been smelted in Cameroon and Ghana and to a minor

extent in Nigeria, all based on imported alumina; some downstream processing of aluminum occurs with semis produced in Cameroon and Ghana and finished products in Nigeria and, to a much smaller extent, in Cameroon and Ghana.

Ghana

The Valco aluminum smelter in Tema, with an annual capacity to produce 200,000 tonnes of aluminum, is the largest aluminum smelter in Africa outside of South Africa and Mozambique. Aluminum and the Valco smelter have played an important historical role in the economic development of Ghana. The construction of the Akosombo Dam, completed in 1966, would almost certainly not have been undertaken until many years (or decades) later if Valco had not been built to act as a base load anchor for the project. As late as 1994, Valco was using 45 percent of the electricity supplied by the VRA, but there was enough power available to meet nearly all the other demands from Ghana, Togo, and Benin in years of normal rainfall. However, domestic demand for electricity has increased 8 percent per year since 1988, outstripping available capacity, leading to power shortages and a growing share of thermal generation.

The Valco smelter was closed in 2003, sold to the Government of Ghana in 2004, and reopened in 2005. Energy shortages, however, continued to plague the plant, which was only run at 30 percent of capacity until it was closed again in 2007. The current status of the Valco smelter is unclear, although, if rainfall is favorable, there are indications that it may be restarted in 2009. On the one hand, there is pressure to reopen the plant and, in fact, develop an integrated aluminum industry—including domestic bauxite mining and alumina refining—in Ghana. On the other hand, there is pressure from the general public and other industries not to resume power supplies and subsidies to Valco, given that this would force consumers to rely even more heavily on alternative more expensive power sources. Despite its key historic role, Valco was by the late 1990s consuming large amounts of power for which other customers (including neighboring countries) were willing to pay a much higher price.

Cameroon

The history of the aluminum industry in Cameroon has been dominated by the Alucam aluminum smelter in Edea. There are also very large bauxite deposits in Cameroon of uncertain quality that would require significant infrastructure expenditures to exploit. There is transformation of primary aluminum to semis in Cameroon and several companies in the region produce finished goods out of the semis.

Alucam, which began operations in 1957, is currently owned by Rio Tinto-Alcan (RTA) and the Government of Cameroon (GOC) (47% each). Its power is provided by the Edea Hydroelectric Dam, whose power generation capacity was quintupled in 1958 using Alucam as a long-term base load customer.

In 1998 Cameroon and Alucam began to face consistent power shortages, due partly to a revival of economic growth and power demand in Cameroon, and to recurrent droughts. It is likely that the opportunity cost of power has been significantly greater than the price paid by Alucam since currently the entire amount used by Alucam could likely be absorbed by other consumers at higher prices.

The current situation of Alucam is very much in flux. On the one hand, the power shortages are leading to increasing pressure to close the smelter. On the other hand, there are well advanced plans to expand the existing plant from 90,000 to 300,000 tpy and even to construct, in addition, a large new smelter of 400,000 tpy. Both plans are based on new large hydro power developments in which Alucam would play an important financial and managerial role. The Alucam expansion project depends upon the upstream construction of the Lom Pangar Dam reservoir. Total estimated cost of the dam, smelter upgrade and expansion, hydro power station (at Nachtigal), and transmission lines to Alucam is US\$1.6 billion. The GOC would pay for the cost of the dam (US\$ 200m), which would enable it to develop other hydro power sources based on this reservoir and recover its costs from user fees to downstream users. Alucam would build and own the Nachtigal power plant, which would draw water at an appropriate cost from the Lom Pangar Dam reservoir. The greenfield development, which is at a very preliminary stage, would follow a similar organizational pattern.

The current Alucam smelter appears not to be viable once its power contract runs out at the end of 2009 and aluminum prices revert back to trend levels. It is, however, possible to construct a case for the viability of a major extension of Alucam under reasonable assumptions with respect to the cost of and demand for power and the various economic and social contributions. This, however, depends on several critical variables on which more information is necessary including (i) the willingness to pay of other Cameroonian power consumers for large blocks of power above their projected allocation; (ii) the variation in delivery costs of HV versus MV and LV power (including transmission costs and technical and non technical losses of the various distribution systems); (iii) Alucam's projected direct fiscal contribution; and (iv) the multiplier effects of Alucam operations.

The proposed project should only proceed if it is possible to plan and implement a series of relatively low cost hydropower developments in Cameroon, timed to meet the growing demand for power beyond that required by the smelter to provide safeguards for other consumers. Moreover, the hydraulic rent paid by Alucam for water flow should at a minimum cover the full capital and operating costs of the dam. Over time, this rent could be increased by indexing the rent to the price of aluminum.

Nigeria

The aluminum industry in Nigeria is comprised largely of a number of finished aluminum goods producers and the Alcon smelter in Akwa Ibom State in southeastern Nigeria, which in the spring of 2008 began to produce aluminum ingots on a small scale. There is also some transformation of primary aluminum into semis in Nigeria.

Alcon was partially completed in 1997 at a cost of US\$ 2.5 billion, operated for three years on a trial basis, and closed in 2000. Rusal acquired a majority stake (77.5%) in Alcon, although the Government of Nigeria (15%) is still a shareholder. In mid-2007 Rusal began a program to recommission the smelter, and which was reopened on a partial basis in the spring of 2008.

The long-term future of Alcon largely depends on whether it is economical to capture and sell gas that would have been flared to provide the power to operate the smelter. The most immediate issue is the pricing of the gas at a tariff that is acceptable to its producers and not sold at a subsidized price.

Guinea

Guinea is home to 33 percent of the world's known bauxite reserves and is the fourth largest producer and second largest exporter of bauxite. In 2006 Rusal bought the only operating alumina refinery in the country and began a major expansion program (\$US300 million) that is expected to double capacity. In addition, GAC and BHP are constructing a large alumina refinery in Sangaredi at a total investment cost of US\$ 2.3 billion. The capacity of the plant will be 1.5 million tpy of alumina, with the intent to eventually double its size.

At first glance, Guinea seems the most likely place to locate an aluminum smelter in West and Central Africa, if not all of Africa; it has large bauxite reserves, considerable hydroelectric potential with limited domestic demand, and one alumina refinery with another under construction. Moreover, much of the transport infrastructure is already being developed in the context of the new alumina refinery, which would greatly reduce the

capital costs of a new smelter. However, much of the hydroelectric potential of Guinea is scattered around the country in small projects, with over two thirds of the reported 6,000 MW being associated with installations of less than 200 MW, many of which would not be viable in the 8 month dry season.

The Experience of Southeastern Africa

The boom in aluminum production in Southeast Africa resulted largely from the excess generation capacity built in the 1980s. In 1971 aluminum smelting was pioneered by the South African Industrial Development Corporation at Bayside in Richards Bay to exploit the available low cost coal-fired thermal power. BHP Billiton—Bayside's current owner—was also motivated by the availability of this low cost power to build the Hillside smelter in Richards Bay in 1996 and the Mozal smelter in Mozambique in 2000.¹

Although Bayside was the one of first large industries in the Richards Bay area, the Hillside Aluminum Smelter was part of an ongoing initiative between government and the private sector to transform the area into an important industrial cluster. The two aluminum smelters have played a key role in South Africa with respect to job creation and the development of human capacity by creating 5,200 jobs through domestic outsourcing and over 17,000 jobs through forward linkages. The smelters are involved in pilots to assist potential entrepreneurs from local communities with the establishment and management of their own aluminum manufacturing enterprises from infancy through to independence. Finally, the smelters place considerable emphasis on employee training and skills development.

In some ways the situation in Mozambique is more dramatic, given the poor state of its economy at the time of Mozal's construction. In addition to the provision of a large amount of infrastructure, Mozal created over 1100 direct jobs, of which 89 percent were Mozambican and 2,500 indirect jobs through linkages with the rest of the economy, as well as supporting SME development through ongoing contracts with local suppliers. The company also supports Mozlink, which assists SMEs in winning and delivering contracts to its operations, and the Mozal Community Development Trust to support small business development and social services and infrastructure for local communities.

Unfortunately, the story of the aluminum smelting industry in Southeastern Africa is not entirely a success story. As in Ghana and

¹It is also important to note that due to the hydropower plant at the Cahora Bassa Dam, Mozambique has a large surplus of electricity, which is indirectly supplied to Mozal through the South African Power Pool.

Cameroon, power demand in South Africa has caught up with supply due to a combination of rapid economic growth, increased rural access and limited investment in new generation. This has led recently to a dramatic shortage of power in the region, systematic brown outs, an annual cut back in production of about 120000 tonnes by BHP-Billiton, and the unavoidable delay of a large new aluminum project (Coega).

In drawing lessons for West and Central Africa from the southern African experience, two main issues arise:

- How can economies of scale or scope be exploited with respect to regional infrastructure development? and
- How can backward and forward linkages be enhanced through the use of a significant domestic outsourcing to contribute to community and regional development and the eventual development of an industry cluster.

The main lesson to be drawn by countries in West and Central Africa is not that a country should develop its infrastructure to attract an aluminum smelter, but rather that strong attention must at the outset be paid to infrastructure considerations or the smelter will be operated in an enclave and not realize the potential benefits of the operation. If the rationale for promoting aluminum smelting goes beyond using it as an anchor for a large power project, it is essential that the mechanism/incentives are put in place to encourage the development of upstream and downstream linkages as well as to attract other large investments.

Cross-Cutting Issues

There are five important issues that cut across all the countries above, including power pricing, net fiscal revenues, developing an integrated aluminum industry, local community and regional benefits, and long-term sources of cheap power.

Historically, the most important cross-cutting issue has been the availability and pricing of electricity, including the need for long-term bulk supply contracts to include contingency measures that are acceptable to both parties. To sustain power sector reforms and the financial viability of its utilities, Governments should avoid tariff subsidies to encourage energy intensive investments and seek to create efficient energy markets that lead to long-run marginal cost pricing of electricity and full cost recovery as quickly as possible.

The second issue of realizing net fiscal revenues from aluminum smelting is related to power prices, although not the only factor. While it is essential that governments avoid giving large power subsidies to commercial aluminum companies, it is also essential that these companies contribute

positively to the fiscal revenues of the country and, more importantly, to the local development of the communities in which they operate.

The third cross-cutting issue deals with the rationale behind developing an integrated aluminum industry. Governments in Cameroon, Ghana and Guinea have all indicated this as a desirable goal at one time or another. However, when one takes into account the large power demands, it may be more productive to discuss an integrated aluminum industry at the regional level rather than the country level.

The fourth issue addresses the lack of a systematic attempt to increase the benefits to local or regional communities, particularly with respect to outsourcing, although Alucam and more recently, in Nigeria and Guinea, Rusal and GAC, respectively, are making important efforts to increase the local spin-offs of their operations.

Finally, it is important to emphasize that the long-term future of aluminum smelting in West and Central Africa will likely be shaped by the power developments in the DRC with its abundant hydro power potential. It is estimated that the 'Grand Inga' project would be able to provide 40,000 MW of power to Africa in general.²

Conclusions

The analysis concludes that:

- Due to its energy-intensity, aluminum smelting is quite different from most other industries—it depends on a low cost source of electric power for very long periods of time (usually at least 20 to 25 years). Consequently, it is unlikely that a company on its own can undertake an independent analysis of the viability of a smelter and then make its decision. Given the importance of energy in any economy, the government and power utilities must, of necessity, be heavily involved in most cases in the decision making process. Hence, an aluminum company and the government jointly agree on whether or not to open a smelter, even in an economy that is market oriented.
- Only if there is an “abundance” of potential power available—which can be defined as meeting or exceeding the combined power needs of the smelter under consideration plus the projected increase in power consumption by other users/consumers over the next 20 to 25 years—is a government in a position to consider entering into a long-term power contract with an aluminum smelting company, either directly or through a regulated utility.

²In 2007 BHP Billiton signed an agreement with the Government of the DRC to fund a feasibility study for an Inga III hydro power project. The study will include the development of plans for an 800,000 tpy aluminum smelter in the Bas Congo region, not far from Kinshasa. The US\$ 3 billion smelter would have a power requirement of 2000 MW.

- It is essential that the tariff for this power covers the long run marginal costs of supply. In addition, given that the operation of the smelter will be highly dependent on the country's natural resources, the government should ensure that it obtains its fair share of the resource rents through the structuring of a long-term power contract which is indexed to the price of aluminum, with a floor price providing for full recovery of the cost of power. Any rents (upside) obtained through such indexing should be split between the smelter owner, the power company (through the power tariff) and the Government (through the hydraulic rent accruing to the government).
- One of the main inputs in aluminum smelting is alumina, which in turn depends on bauxite as a critical input. Accordingly, many countries with bauxite deposits are interested to develop an 'integrated aluminum industry'. Given that these are globally traded commodities with global prices, each of these investments has to be evaluated on its own merits. In strong contrast to aluminum smelting, it should be noted that the decision to invest in a bauxite mine or an alumina refinery does not depend on an inexpensive power source. In a developing country with few major industries, it is often argued that a government should subsidize a select number of industries, partially to offset other disadvantages. (e.g., poor infrastructure, small local markets). Nevertheless, such a subsidy is always at the expense of other industries and tax paying consumers. There are job creation and related benefits to having a mine, a refinery or a smelter located in the country, but the backward and forward linkages are often relatively weak and normally don't justify the significant power or tax subsidies required for such integrated developments.

These conclusions lead to the following specific recommendations on the aluminum industry in West and Central Africa.

- Unless a new source of low cost power becomes available, the reopening of the Valco smelter in Ghana would entail substantial subsidies and should be avoided.
- The continuation of the current Alucam smelter in Cameroon without a major expansion and hydropower development is questionable. However, studies indicate that a major expansion could be feasible as Cameroon has the hydro-power capacity potential with low production and low opportunity cost. It is not clear that the planned expansion in power in Cameroon—both hydro and thermal power—will result in a surplus for a period long enough to sustain this tariff and ensure the viability of the smelter; further studies on several key variables are necessary.

- The viability of the Alcon smelter in Nigeria depends heavily on the availability of power from a natural gas powered thermal plant. It is essential to determine whether this gas, including associated infrastructure, can be provided at a price that covers full cost but which is low enough to make the smelter viable.
- Given the small size and seasonality of most potential hydro power sites in Guinea, it is questionable that the country can provide enough low cost power to justify the construction of an aluminum smelter.
- The one country in the region that has the potential for abundant low cost power over a long time horizon is the DRC at the Inga Rapids on the Congo River. The studies, which are currently underway, aim to demonstrate the viability of using an aluminum smelter as a base load customer to support the further development of this power source. In the long-run, after the development of extensive infrastructure, this power could be a vital resource for economic development throughout Sub-Saharan Africa.

Introduction

The smelting of alumina into aluminum is the most power intensive major metal industry in the world. Decisions on where to invest in an aluminum smelter are made largely on the availability of a low-cost source of electric power for a significant length of time, usually at least 20 years. While smelters can represent good baseload customers for major power developments, without careful long-term power planning, they can eventually lead to significant energy deficiencies for other consumers. Consequently, given the long-term impact on the energy situation in a country, it is critical for government to be an integral part of the decision making process when a company is considering building an aluminum smelter. This is in stark contrast to most other mining or mining related industries, the development of which should be based on more straight forward profitability considerations (subject to the relevant laws of the country). In this regard, it should be noted that the refining of bauxite to alumina is not dependent on a low cost power source. Accordingly the decision to build an alumina refinery is independent of and very different to the one to build an aluminum smelter and generally results in locating the refinery at or close to the bauxite deposit.

The production of aluminum was initiated with some success in West and Central Africa in the 1960s to underpin the large hydro generation projects within the region. For approximately 30 years these aluminum smelters made a significant contribution to the economies of the regions both directly through their own activities and indirectly as a base load for large power projects, which enabled the export or use of power by other consumers. However, these operations have in recent times run into trouble and threatened to undermine the viability of regional power utilities. This study assesses the problems associated with the first generation of aluminum smelters in the region; determines if there are conditions under which they could be turned around and continue to be viable; and finally draws lessons from these and other experiences in Southern Africa to assess the opportunities for new aluminum smelters and regional cooperation. This analysis will help the countries where smelters are located to make informed strategic long-term decisions with respect to reviving and/or expanding the downstream processing of alumina into aluminum. It will also assist all countries in West and Central Africa that are currently or

likely to be involved in the expansion of electric power to carefully assess the costs and benefits of using the aluminum industry as an anchor customer for new sources of power.

In the last few years large aluminum smelters have been commissioned along the southeastern coast of Africa attracted by historically low power costs. While this suggests that West and Central Africa may be able to follow suit and benefit from a similar developmental strategy, the regions have experienced a less than satisfactory outcome of the initial phase of their aluminum industry. There have been only two fully operational smelters in the region—in Cameroon and Ghana—both of which have encountered similar problems. Absent technical innovation and subsequent (additional) low cost power they have run into financial and/or production difficulties, which in turn have had serious repercussions on the financial situation of the power providers. Nonetheless, they were critical to the development of hydro power in the region and were commissioned at a time when there was a surplus of electricity available under fixed long-term bulk supply contracts. Hydro generation capacity has remained static while demand has steadily increased over the years and this excess supply no longer exists. The publicly-owned electric utilities, however, remain committed to supply the smelters at below cost and great financial loss to themselves and, ultimately, to the treasury and citizens of the countries in which they operate. While it was not the cause of the failed power system, which did not develop further over the decades, the aluminum industry eventually became both an albatross and a scapegoat. The experience of a third smelter in Nigeria is complicated partially due to ill advised political objectives, a lack of low-cost power and inadequate infrastructure. To date, the plant has only operated on a trial basis, but it has recently been privatized amidst significant controversy and lack of transparency. Two additional points should be emphasized. First, in all three cases there are strong political economy reasons (and political pressures) to continue the operation of the smelters. Second, it is difficult to have a viable aluminum industry in the long-term in the context of a small power pool; hence the need for a regional outlook.

In recent years there has been an upsurge in the price of aluminum, largely due to increased demand from China and, to a lesser extent, India.³ While supply has kept pace, partly through the expansion or reopening of older, less competitive factories, which are often in areas that once had an advantage with respect to energy costs. It is forecast that there will be a shortage of global aluminum smelting capacity within five years; moreover,

³Although the global slowdown and financial crisis have led to a dramatic fall in most commodity prices, aluminum prices in November 2008 remain above trend.

many of the existing smelters are relatively high cost producers taking advantage of the current above trend price of aluminum (CRU, 2006: vii).

In this global context, there are strong incentives and pressures to find ways to make the existing smelters in West and Central Africa profitable. However, it is not clear that in any or all cases this will be possible unless new sources of energy searching for an anchor customer (and hence with low marginal cost) are found. The two regions are home of the largest resources of untapped hydro energy in Africa, particularly along the Inga rapids on the Congo River in DRC, but also in Cameroon and Guinea. There is also potential for low-cost power based on natural gas (most of which is currently flared) in Nigeria. Nevertheless, even if these energy sources can be drawn upon, it is not obvious that the export of any excess power to other countries in the regions—or even southern Africa in the case of the Congo would not be more attractive financially and economically—although this would often entail a very large investment in infrastructure that may take many years to fully come on line.

The current global situation of the aluminum industry and the potential of new sources of low-cost energy also mean that investors are likely to show a keen interest in exploring new possibilities in the regions. Aluminum is an industry that migrates to wherever the comparative advantage happens to lie and, to be economic, must be undertaken on a large scale requiring large long-term base load electric power. The two regions are also home to important international sources of bauxite, the main raw material for the production of aluminum. Moreover, a large plant for refining bauxite into alumina—which is then smelted into aluminum—is nearing completion in Guinea. This suggests that specific countries or groups of countries in the two regions could have a comparative advantage in developing an integrated aluminum industry, including the mining and refining of bauxite into alumina and the smelting of alumina into aluminum.

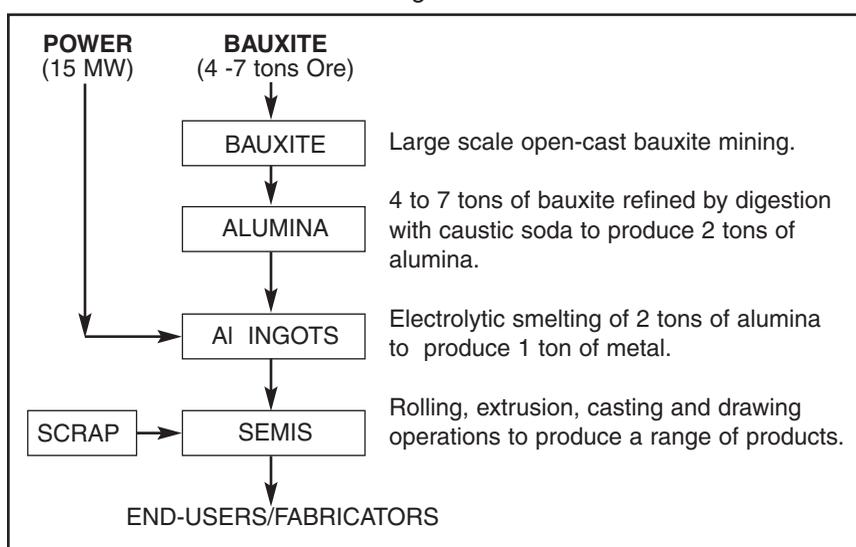
The organization of this study is as follows. It continues with an overview of the global aluminum industry, including a description of the production process, current and projected supply and demand, and the most important cost considerations for companies investing in the industry. Chapter 2 provides a brief history and future prospects for the aluminum sector in West and Central Africa. Chapter 3 contains an analysis of the viability of the two most important existing smelters in the regions, Valco in Ghana and Alucam in Cameroon, as well as a briefer analysis of Alscon in Nigeria and the potential for other smelters in the regions. In Chapter 4, the recent experience of the three large aluminum smelters in southeast Africa is reviewed and lessons are extracted for West and Central Africa. Conclusions and recommendations are in Chapter 5.

The Global Aluminum Industry

– Key Features and Trends

Global demand and consumption of aluminum—the largest of the non-ferrous metal industries—is expected to increase from 32 millions tonnes in 2005 to approximately 57 million tonnes in 2020. Aluminum products are produced in four stages: (Figure 2.1) the mining of bauxite (the raw material); the conversion of bauxite to alumina (aluminum-trioxide) in a refinery; the conversion of alumina through electrolytic smelting to primary aluminum in a smelter and finally semi fabrication to produce extrusions, casting and cable. A fifth stage comprises the recovery and smelting of secondary aluminum (recycling). The main markets are packaging, construction, transportation and electrical transmission. The bauxite, alumina and aluminum stages of the business are global in nature and are natural resource based (see Figure 2.1), while the fabrication and secondary stages are market driven businesses and are usually located near major markets.

Figure 2.1: The Aluminum Production Process
Natural Resource Rights



Global production of bauxite, alumina and aluminum for various years since 1990-2005 is presented below in Tables 2.1 to 2.3, respectively. Although bauxite occurs widely throughout the more temperate regions of the world, 80 percent of world production is mined in some 6 countries—Australia, Brazil, China, Guinea, Jamaica and India.

Table 2.1: Bauxite Global Production by Major Producing Countries: 1990-2005 (000 tonnes)

Countries ⁴	1990	2000	2002	2004	2005
Australia	41,400	53,802	54,135	56,593	60,000
Brazil	9,680	13,790	13,260	19,700	19,800
China	2,400	9,000	12,000	15,000	18,000
Greece	2,500	1,991	2,492	2,444	2,450
Guinea	15,800	15,700	15,300	15,000	15,000
Guyana	1,420	2,471	1,690	1,466	1,500
India	4,850	7,562	9,647	11,285	12,000
Jamaica	10,900	11,127	13,120	13,296	14,100
Kazakhstan	na	3,730	4,377	4,706	4,800
Russia	na	4,200	4,500	6,000	6,400
Surinam	3,280	3,610	4,002	4,052	4,580
Venezuela	771	4,361	5,191	5,842	5,900
Rest-of-the-World ⁵	19,999	4,656	4,586	4,616	4,620
Total Production	113,000	136,000	144,000	160,000	169,000

Source: U.S. Geological Survey Minerals Yearbook, Various Issues.

While the geographical distribution of the production of alumina is more diverse than bauxite, there has been a clear trend away from the major metal-consuming and smelting countries towards the bauxite producing countries over the past 15 years. Expansions in the first group of countries have been minor—debottlenecking/efficiency improvement investment in existing plants—while the bulk of the capacity expansion has taken place in bauxite-producing countries (with China the exception as it has built a number of refineries based on imported bauxite). As noted above, alumina

⁴ Countries included averaged at least 1,500,000 tonnes per year from 2000-2005. Data on excluded African countries is in Table 3.1.

⁵ While their relative importance has changed over the years, other significant producers include Hungary, Indonesia, Sierra Leone, and Yugoslavia.

refining is not power intensive, as it uses a chemical process to precipitate aluminum oxide from bauxite, and accordingly situational decisions are not based on the availability of low-cost power.

Table 2.2: Alumina Global Production by Major Producing Countries: 1990-2005 (000 tonnes)

Countries ⁶	1990	2000	2002	2004	2005
Australia	11,200	15,680	16,382	16,700	17,704
Brazil	1,660	3,743	3,972	5,315	5,320
Canada	1,090	1,023	1,125	1,170	1,214
China	1,460	4,330	5,450	6,990	8,610
India	1,600	2,280	2,800	2,600	2,700
Ireland	885	1,200	1,100	1,100	1,100
Jamaica	2,870	3,600	3,631	4,023	4,086
Kazakhstan	NA	1,217	1,386	1,468	1,505
Russia	5,900 ⁷	2,850	3,131	3,269	3,259
Spain	1,000	1,200	1,100	1,100	1,100
Surinam	1,530	1,800	1,900	2,039	1,950
Ukraine	NA	1,360	1,351	1,563	1,632
United States	5,230	4,790	4,340	5,350	5,220
Venezuela	1,290	1,755	1,901	1,900	1,920
Rest-of-the-World ⁸	7,785	4,672	4,631	4,913	5,080
Total Production	42,600	51,500	54,200	59,500	62,400

Source: U.S. Geological Survey Minerals Yearbook, Various Issues.

Low cost power to a large extent explains the geographical pattern of production in the aluminum industry, with (Table 2.3) growth in metal production concentrated in locations where energy is abundant. The smelting of aluminum can present a convenient way of transforming this surplus energy into a value-added commodity that can be traded internationally, and because of relatively low freight costs, are not limited to areas endowed with abundant bauxite reserves.

⁶ Countries included averaged at least 1,000,000 tonnes per year from 2000-2005.

⁷ The 1990 figure is production in the entire USSR.

⁸ While their relative importance has changed over the years, other significant producers include (included) Germany, Greece, Guinea, Hungary, and Italy.

Table 2.3: Aluminum Global Production by Major Producing Countries: 1990-2005 (000 tonnes)

Countries ⁹	1990	2000	2002	2004	2005
Australia	1230	1,769	1,836	1,894	1,900
Bahrain	213	509	519	532	751
Brazil	931	1,277	1,318	1,457	1,500
Canada	1,570	2,373	2,709	2,592	2,890
China	850	2,800	4,300	6,670	7,800
Dubai (UAE)	174	470	536	683	750
Germany	740	644	653	668	668
India	433	644	671	862	898
Mozambique	0	54	268	549	560
Norway	845	1,026	1,096	1,322	1,370
Russia	3,520 ¹⁰	3,245	3,347	3,592	3,650
South Africa	159	673	707	863	851
United States	4,050	3,668	2,707	2,516	2,481
Venezuela	590	571	605	624	610
Rest-of-the-World ¹¹	3,995	4,577	4,938	5,076	5,185
Total Global Production	19,300	24,300	26,100	29,900	31,900

Source: U.S. Geological Survey Minerals Yearbook, Various Issues.

Technological Development and Investment

Over the past 40 years there has been a continuous improvement in the technology used to produce aluminum (the Hall-Heroult process). The focus has been on the size of the electrolytic pot in which the aluminum is smelted and the amperage at which it is operated through the introduction of the pre-baked anode technology, which replaced the Soderberg technology. Whereas in the 1960s a typical new smelter operated at 120KA, improved smelting technology raised the amperage of potlines progressively, where today 300KA technology is widespread and 350KA technology is available.

The benefits include a reduction in electric power consumption. Energy consumption of 13.5 MWh per tonne is possible in new smelters, compared with 16-17 MWh per tonne in older Soderberg smelters (such as Valco in Ghana) and 150 MWh per tonne in less modern pre-bake smelters (such as

⁹ Countries included averaged at least 500,000 tonnes per year from 2000-2005 with the exception of Mozambique. Data on excluded African countries is in Table 3.2.

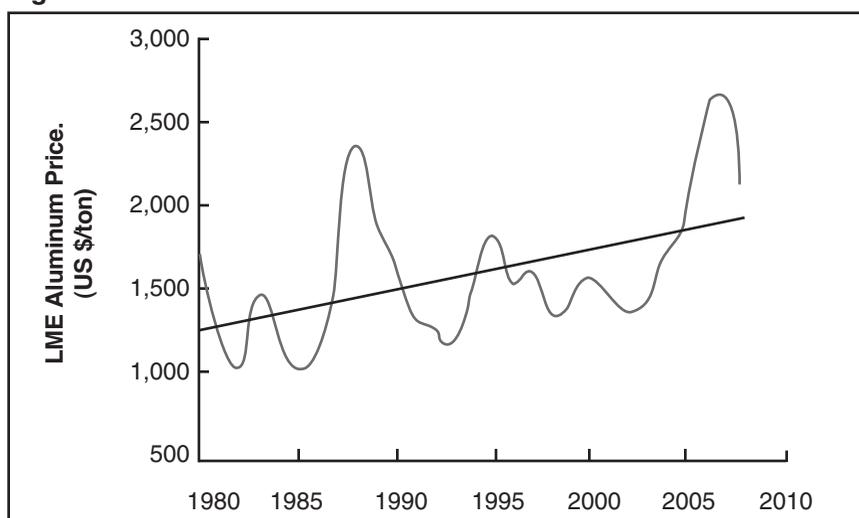
¹⁰ The 1990 figure is production in the entire USSR.

¹¹ While their relative importance has changed over the years, other significant producers include (included) Argentina, France, Iceland, Mozambique, Netherlands, New Zealand, Spain, Tajikistan, and the United Kingdom.

Alucam in Cameroon). Higher labor productivity and reduced fixed costs per tonne are also achieved in large-scale modern smelters.¹²

Investment in the first three stages of the aluminum industry is largely cost-based rather than price-based. Given the long gestation periods of investment in mining bauxite, refining alumina, and smelting aluminum, the primary concern of the company is the competitive cost positioning of the firm. As prices fall from their recent highs (see Figure 2.2), firms that are in the bottom half or bottom quartile of the global cost curve will have a better chance of surviving the downswing. In the past, firms in the various metals industries tended to make their investments based more on prices, which exacerbated the commodity price fluctuations and often led to large failures.

Figure 2.2: LME Aluminum Price 1979 – 2008



Source: Compiled from data from the London Metal Exchange

Historically, the typical cost structure of aluminum smelting is, in descending order, capital costs (about 35 percent), electricity (25 percent), alumina (20 percent)¹³, electrode carbon and fuel (7 percent), labor (5 percent), freight (4 percent)¹⁴, and others (4 percent). However, due to large price increases, alumina has been in the range of 30 to 35 percent of total costs in recent years (CRU, 2008).¹⁵ There are also two other costs that are important in some operations—political risk and infrastructure. Political risk will raise the risk premiums and costs of capital and thus increase the construction cost of the smelter, a cost that otherwise is fairly uniform around the world. Infrastructure is another

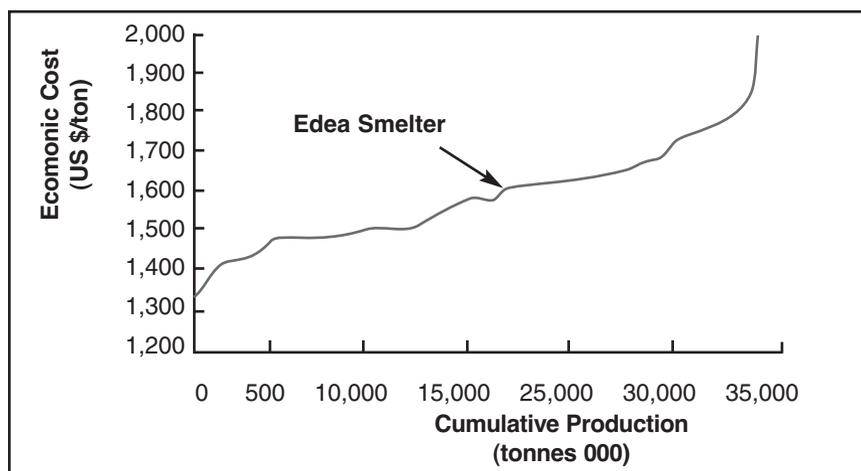
¹²Although the pre-baked technology is environmentally much better than the Soderberg technology, it has the disadvantage that in the process the anode is consumed, releasing CO₂ and other emissions. A new technology under consideration involves the use of inert anodes that are not consumed in the smelting process. As CO₂ or other emissions would not be released, the smelter would not require a carbon plant, reducing capital costs.

type of capital cost that a firm may have to incur in relation to power generation, importing alumina and other inputs, and exporting aluminum output. Clearly, if political risk is high, this second type of capital cost will be higher than otherwise.

Over the past 30 years the capacity of a typical new smelter has increased from 60,000-120,000 tpy to 300,000-500,000 tpy, with a similar trend for refineries. With the exception of plants built in China, unit capital costs have also risen due to: i) more stringent environmental legislation and control; ii) the drive for increased operational efficiency; iii) the associated infrastructure costs of new plants in more remote areas; and iv) the escalation of construction costs in real terms. Capital costs per tonne of installed capacity for new smelters are currently in the range of US\$ 3500 to US\$ 5000 (with lower costs for brown field expansions and plants built in China). As a result of these trends, the initial stage of a world-class smelter now typically costs US\$ 1.5 billion or more with a similar amount for a world-class alumina refinery.

Industry cash operating costs for primary aluminum in 2005 ranged from US\$ 900 to US\$ 2400 with the highest 12 percent of world capacity above US\$2000 per tonne. CRU (2006: 2-17) predicts that the operating costs in real terms of smelters built in the next five years will be between US\$ 1300 and US\$ 2000 per tonne as illustrated in Figure 2.3 below.

Figure 2.3: Unit Break Even Production Cost



Source: Compiled from CRU 2006 Data

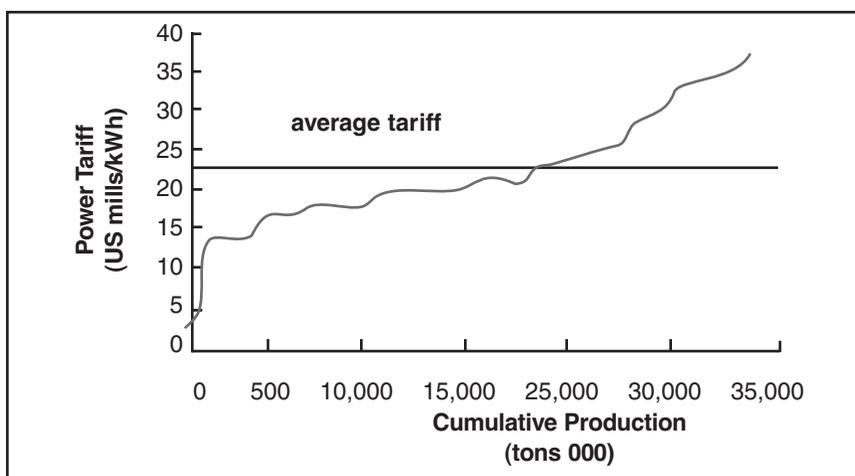
¹³ The cost of bauxite is approximately 25% of the operating costs of producing alumina. The other two most important operating costs are caustic soda (20%) and fuel and electricity (25% to 30%).

¹⁴ Freight charges can increase greatly if inland transport of alumina is necessary, as is usually the case in China. For example, in Canada (where inland transport charges are nil), total freight charges average 2.5% of total costs, while in China they average about 8% of total costs.

¹⁵ While it will likely be 5 years or more before a new 'long-term' equilibrium is reached with respect to costs as new bauxite deposits are developed and new refineries and smelters are opened, it does seem likely that alumina will continue to account for a larger percentage of costs than historically. CRU (2008) estimates that alumina purchases will account for about 25% of total smelting costs in 2012.

As noted above, electrical energy and alumina are the major costs, with alumina costs surpassing power costs for the first time in recent years, and long-term trends pointing to similar weights for the two inputs. While alumina costs are very similar for all smelters, power costs range from US cents 0.5/kWh (for Alcan's hydro plants in Canada) to US cents 3.5/kWh (for Chinese smelters) resulting in a cost difference of more than \$420 per tonne. Electricity tariffs above US cents 3.5/kWh are uneconomic and between US cents 2.5 to 3.5/kWh only marginally competitive based on long-term aluminum price trends. The current industry average is around US cents 2.5/kWh as indicated in Figure 2.4.

Figure 2.4: Global Aluminum Power Tariffs (2006)

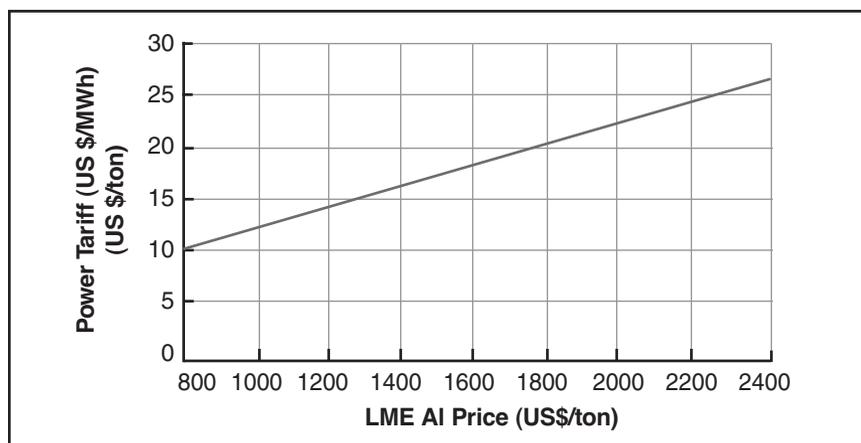


Source: Compiled from CRU 2006 Data

With power the main variable cost in the smelting process, both smelters and power-providers have been looking for ways to deal with the cyclical nature of the aluminum price. This has led in a number of cases to the introduction of metal price linked power-tariffs to provide risk-sharing. Approximately one third of the world's primary aluminum smelting capacity is currently covered under this type of metal-linked contracts. The objectives of these contracts can be (i) to attract new investment; (ii) to protect existing power-loads in case of a downturn in the industry and; (iii) to enable power companies to share in the profits in case of high prices. This is done either through full risk-sharing over the whole range of possible metal prices as presented in Figure 2.5 for the South African smelters or through partial risk-sharing by introducing a floor or ceiling price or both. A floor-price ensures that the power rates will cover the operating costs of the power-plant, while a ceiling is generally introduced to enable the smelter to capture the upside compensating the granting of a floor to the power

company. Hydro-based power contracts have typically a floor to their power prices, which are relatively low, while above a certain aluminum price the rates rise in proportion to the metal price. This arrangement can be seen as a way to collect a certain resource rent by the power company or the Government.

Figure 2.5: Southern African Smelters Power Tariffs



Source: BHP-Billiton

Nevertheless, the outlook for competitive power costs is not clear. Given the large increases in general energy prices, the number of low cost power sources that would be available in the future to new aluminum smelters is likely to be quite limited. Therefore, over the next few years, there is likely to be an upward drift in the maximum electricity tariff for the marginally competitive aluminum smelter.

In general, hydro power has the lowest cost of production followed by low-cost coal and natural gas fired thermal generation. Nuclear and imported coal-fired generation have an intermediate cost position. Governments, however, have a significant influence on actual power tariffs. Around 80 percent of the power supply to the aluminum-industry is government controlled, either directly (supply from a state-owned utility) or indirectly through tariff regulation, concessions and royalties for hydropower resources. Government tariffs are sometimes significantly modified to reflect priorities of industrial or more general economic policies. This explains in part the recent emergence of South Africa and Mozambique as significant producers, based largely on coal-fired power.

Bahrain and Dubai in the Middle East use natural gas to produce power for smelting aluminum. Smelters in both locations are expanding further, and new smelters are at the planning stage in Abu Dhabi, Oman and Saudi Arabia. India's expansion in smelting is not explained entirely by the

availability of power; it owes much to the availability of bauxite and alumina, plus some tariff protection on aluminum metal. Australia's smelting industry is based principally on coal-fired power, but the opportunities for further expansion there are small.

Box 2.1: The Role of Government

With the prices of bauxite and power—the two most important inputs—under government control, governments can and do have considerable influence on entry and development of private sector investors. Governments exercise this prominent role in their capacity as:

- Regulators: tax regimes, price controls, environmental, commercial and industrial policies.
- Suppliers or Granters of Access for mining rights and power development.

As indicated in the main text, the tax regime for bauxite mining is an important factor in the competitive development of bauxite mines and positioning of alumina refineries, while the viability of existing and new smelters to a large extent is determined by the way governments set power tariffs. Regional differences in production costs and the geographic focus of the industry are largely the result of how government has exercised this control.

However, the country with the largest smelting capacity, China, does not fit the model of the rest of the world. China neither has low-cost power nor sufficient bauxite and alumina production to supply its smelting industry. Its cost advantages lie in low labor cost and access to cheap capital. These two elements have an important impact on the capital cost of constructing smelters, which is at least 30 percent lower in China than the rest of the world, however it is not clear that the lower construction cost is enough to offset the expensive power, especially in case of an industry downturn. The enormous increase in smelting capacity in China—from 854,000 tpy in 1990 to 7.8m tpy in 2005—is largely explained by rapid economic growth and the associated increase in demand for aluminum, a desire for self-sufficiency and a strong desire to generate employment. Many local authorities and private investors constructed smelters, often with minimal economic analysis to support the investment. The future of aluminum smelting in China is discussed further below.

Similar differences have developed with the unit cash costs of alumina plants, mainly due to bauxite costs. Where the alumina plant is not located on or close to the bauxite mine, transportation costs are a major source of cost-variance. The freight advantage of transporting alumina instead of bauxite (the alumina content of exported bauxite is approximately 50

percent) is a clear economic incentive for on-site refining.¹⁶ While historically on-site refining was always a feature of the industry (France, USA, Jamaica), the large capital exposure associated with refining in developing countries resulted in a shift of alumina plants to the main aluminum smelting locations (e.g. Europe and North America). Political risk avoidance outweighed the economic benefit of nearby bauxite locations. However, the competitive success of the low-cost export refineries (especially in Australia) has led to a reappraisal and a general acceptance that future refineries are best located at the bauxite source to be competitive (e.g. Guinea). Another major factor in the cost per tonne of alumina is the tax regime imposed by government on the mining of bauxite. High taxes in the past seriously eroded the competitiveness of several bauxite producing countries, reinforcing the trend toward bauxite and alumina production in moderate tax countries, most significantly Australia and Brazil.

Future Primary Aluminum Supply

CRU (2006, vii) estimates that there will be sufficient smelter capacity to meet production needs until 2011 with a capacity deficit of 1.5 million tonnes appearing at that time. In fact, due to obsolescence and increasing consumption, it is estimated that from 2011-2030 an additional capacity of 29 million tonnes will be required, which is equivalent to about 90 new average sized smelters. While aluminum prices in 2006 were almost \$1000 per tonne above long-run marginal costs, according to CRU (2006, xi)—\$2665 versus \$1671—encouraging several marginal producers to continue production, investment in future aluminum smelting capacity will continue to be driven primarily by the availability of reliable low cost electric energy. These locations are becoming more concentrated, as power prices in the developed economies move far beyond the level at which smelters can operate profitably. Areas where energy resources are plentiful and from which the energy cannot be easily transported to areas of high demand are increasingly rare.

The USA and Western Europe accounted for almost 50 percent of world smelter production in 1990; this fell to 30.4 percent in 2005 and will be only 23.6 percent in 2010 (Table 2.4). With the exception of Canada, Norway and Iceland, smelting is no longer an industry that will attract any major investment in North America and Western Europe. Indeed, after 2010, smelting capacity in those areas is likely to decline. Australia will see virtually no further investment in smelting capacity, and Eastern Europe will remain insignificant as a smelting location.

¹⁶ The very large increase in shipping rates over the last 5 years highlighted this advantage, but in recent months freight rates have fallen dramatically and are very much in flux.

Table 2.4: Location of Primary Aluminum Production, 1990 – 2010

Location:	1990 (%)	2005 (%)	2010 (est) (%)
North America	29.4	16.8	13.1
Western Europe	20.3	13.6	10.5
Asia	3.5	3.9	4.4
Middle East	2.6	5.5	7.5
Africa	3.1	5.5	5.8
Australasia	7.8	7.0	5.5
Latin America	8.9	7.5	8.1
Eastern Europe	1.6	1.5	1.4
China	4.4	24.4	30.1
CIS	18.0	13.1	12.8
Production (000 t)	19,306	31,959	42,017

Source: CRU (various issues)

The areas that are expected or predicted to see major increases in smelting capacity are the Middle East (Bahrain, Dubai, Abu Dhabi, Oman and Saudi Arabia); Africa (Mozambique and Cameroon); Latin America (Trinidad, Argentina, Venezuela and to a lesser extent Brazil); and the CIS (brownfield expansions in Russia, Kazakhstan); and China.

In recent years, most of the increase in capacity has come from new smelters in China. However, predicting future aluminum production in China and its exports is a difficult task. While it seems likely is that the massive investment in China was mostly intended to match its rapidly increasing internal demand, China is now one of the leading exporters of combined primary and semi-processed aluminum (see Table 2.5). However, there are serious questions about its ability to maintain that role. China is not a low cost power producer, freight charges are on average very high, and there are likely to be upward pressures on wages and its exchange rate that could weaken its competitive position. Aluminum consumption is increasing rapidly in China, and it will be difficult for profitable production and exports to keep pace. Low capital costs are currently by far the most important factor that keeps Chinese smelters competitive. With respect to operating costs, of 72 firm, under construction, or potential smelter projects ranked by CRU (2006: 2-18), the average ranking of the eight Chinese entries is 60th, with six of the eight smelters being ranked 60th or lower. Accordingly, the ability to keep capital costs low is paramount for the Chinese aluminum smelting industry, which may be difficult in the ever-expanding Chinese economy.¹⁷

¹⁷Recent developments in China suggest strongly that China will not maintain its current position, at least with respect to primary aluminum. As of January 1, 2007 the 5% import duty on aluminum was eliminated. Moreover, on July 1, 2007 the VAT rebate of 11% for aluminum extrusions was also eliminated. In fact, the Chinese government introduced a 15% export duty on primary aluminum and non-alloyed rod and bar, with the intent of reducing the most energy intensive, polluting industries while simultaneously cooling down the overheating economy (Schwarz, 2007: 25). The cost of capital is also rising. In addition to the appreciating yuan, the Central Bank of China raised interest rates four times in 2007 (Schwarz, 2007: 29). The result to date of these measures is that primary aluminum exports from China fell 56.8% from January 2007 to August 2007, although there is some indication that firms have been nominally processing aluminum to try to avoid the export duties (Schwarz, 2007: 25).

Table 2.5: Primary Aluminum Exports by Country: 1995-2006 (000 tonnes)¹⁸

Country ¹⁹	1995	2000	2002	2004	2005	2006
Australia	961	1402	1527	1540	1588	1624
Brazil	703	760	749	818	753	842
Canada	1719	1837	2133	1999	2240	2367
China	191	209	787	1683	1319	1212
Dubai (UAE)	na	574	379	327	303	na
Germany	299	375	408	413	447	451
Mozambique	0	0	240	500	na	779
Netherlands	577	549	467	635	610	712
Norway	811	1042	1128	1484	1524	1539
Russia	na	3195	2794	3447	3395	4050
South Africa	na	504	544	620	650	614
United States	448	451	305	344	379	419
Venezuela	408	388	459	387	401	374
Rest-of-World	3550	2844	3101	2055	3107	2046
Total Exports²⁰	9095	14130	15021	16252	16716	17029

Source: UN Comtrade Database, various years.

High prices and a growing capacity gap offer plenty of scope for new entrants in the aluminum smelting sector. Prices are high and there is a growing excess demand (or capacity gap). Even if all current commitments are honored, there will soon be a need for more smelters. However, only two of the 48 new smelters or extensions that are expected to be on line by 2010 are in Sub-Saharan Africa—expansions at Edea in Cameroon and Mozal in Mozambique (CRU, 2006: 2-4). Moreover, only 5 of the 72 smelters listed by CRU (2006: 2-17) as firm, under construction, or potential are in Africa.²¹ However, the high cost of capital in most Sub-Saharan countries will have a negative effect on the viability and, if constructed, profitability of an aluminum smelter. High capital costs most likely reflect a combination of political risk and the need for companies to build part or all of the required infrastructure.

¹⁸ As the title suggests, this table does not include exports of 'semis', so can give a misleading picture as to the relative importance of aluminum exporters. Since new taxes were placed on exports of primary aluminum in China, some companies have likely been processing them slightly into semis to avoid the taxes; these exports would not be captured here. Unfortunately, it is difficult to obtain good data on exports of semis as the most common export categories contain a mix of semis and final products.

¹⁹ Countries included exported at least 300,000 tpy of unwrought aluminum from 2002-2006.

²⁰ This figure includes only exports reported to the United Nations Statistical Office. It would be a significant underestimate in 1995 due to the exclusion of Russia and South Africa.

²¹ One of the five listed smelters is at Sangaredi, Guinea, which currently is not even in the planning stage. It is interesting to note that when only considering operating costs, smelters in Sub-Saharan Africa rank 2nd (Mozambique 1), 23rd (Guinea), 26th (Cameroon), 28th (Mozambique 2), and 36th (South Africa). However, when total economic costs are calculated, these 5 smelters rank 11th (Mozambique 1), 36th (South Africa), 37th (Cameroon), 59th (Mozambique 2), and 63rd (Guinea) (CRU, 2006: 2-17 – 2-21).

History and Prospects of the Aluminum Industry in West and Central Africa

When all four phases of the aluminum industry are included, the activities of and related to the sector have almost all taken place in four countries in West and Central Africa—Cameroon, Ghana, Guinea and Nigeria. Bauxite has been mined in Guinea and to a much lesser extent in Ghana as set out in table 3.1. Lower grade bauxite deposits do occur in Cameroon but as yet remain undeveloped.

Table 3.1: Bauxite Production in West and Central Africa (000 tonnes)

Country	1990	2000	2005
North Ghana	381 (0.34%) ²²	504 (0.37%)	734 (0.43%)
Guinea	15,800 (13.98%)	15,700 (11.54%)	15,000 (8.88%)
Sierra Leone	1,430 (1.27%)	0	0
Global Output	113,000	136,000	169,000

Source: USGS, “Aluminum Statistics and Information”, various issues.

Alumina on the other hand has to date only been produced in Guinea, while aluminum has been smelted in Cameroon and Ghana and to a very minor extent in Nigeria as demonstrated in table 3.2; some downstream processing of aluminum occurs with semis produced in Cameroon and Ghana, and finished products in Nigeria and, to a much smaller extent, in Cameroon and Ghana.

²² The figures in parentheses are the percentage of global bauxite production in that year.

Table 3.2: Aluminum Production in Sub-Saharan Africa: 1968-2006 (000 tonnes)

	1968	1975	2000	2002	2004	2006
Cameroon	50	57	86	67	86	87
Ghana	120	158	137	117	0	60
Mozambique			54	268	549	560
South Africa		84	673	707	863	890
Total	170	299	950	1,159	1,498	1,597
Global Output	8,800	13,400	24,300	26,100	29,900	33,100
SSA Output/ Global Output (%)	1.9	2.2	3.9	4.4	5.0	4.8

Source: USGS, “Aluminum Statistics and Information”, various issues.

The focus of this section will be on a qualitative analysis of the historic contribution of and problems associated with the aluminum sector in these four countries. This qualitative analysis is based on ongoing activities, firm commitments, and potential investments in the aluminum sector, with a heavy emphasis on the first three productive stages—bauxite mining, alumina refining, and aluminum smelting. In section 4 a quantitative analysis is undertaken of aluminum smelting, the main focus of this report. Given its enormous hydro electric potential, the Democratic Republic of Congo (DRC) will also be included in this discussion. Given that the integration of the industry has been on a country rather than a regional basis, the history and current situation of the four most important countries—Ghana, Cameroon, Guinea and Nigeria—will be discussed in turn, followed by a brief analysis of common outcomes and challenges.

Ghana

The Valco aluminum smelter in Tema, with an annual capacity to produce 200,000 tonnes of aluminum, is the largest aluminum smelter in Africa outside of South Africa and Mozambique. Although since independence, and especially in recent years, there has been discussion of the development of an integrated aluminum industry in Ghana, large-scale exploitation of the substantial bauxite reserves and the refining of bauxite into alumina have never passed beyond the exploratory stage. There is some further processing of the primary aluminum produced by Valco into semis by Aluworks (17,000 tonnes in 2005-2006), which is sold in Ghana and neighboring countries—48 percent of output was exported in 2006. Since Valco shut down, it has been importing primary aluminum from South Africa and

India. In turn, there is a small finished aluminum goods industry, of which the most important companies are Ghana Aluminium Company, Pioneer Aluminium Factory, Domod Aluminium Company, Metalex Limited, Lion Aluminium and Ridge Alumetal Products Limited.

Aluminum and the Valco smelter have played an important historical role in the economic development of Ghana. The Akosombo Dam—the centerpiece of the Volta River Authority (VRA)—would almost certainly not have been undertaken until many years (or decades) later if Valco had not been built to act as a base load anchor for the project, which was completed in 1966. Even as late as 1994, Valco was using 45 percent of the electricity supplied by the VRA, and there was enough power available to meet nearly all the other demands from Ghana, Togo, and Benin in years of average rainfall. However, domestic demand for electricity has increased more than 8 percent per year since 1988, outstripping available capacity.

Aluminum ingots and semis were consistently one of Ghana's top exports—along with gold and cocoa—since the development of the smelter.²³ It is only since 2003, when serious long-lasting power shortages became a semi-permanent feature of life in Ghana, that aluminum could no longer play its historic role (although due to power shortages, there were large declines in aluminum production in 1983 and 1998). However, it may be difficult to assess the contribution of aluminum in recent years given the power subsidies Valco has received, either implicitly or explicitly. While it is not entirely clear when these subsidies began—that is, when the opportunity cost of power exceeded the price paid by Valco—it seems likely that they were substantial as early as 1998 (Werhane and Gorman, 2005: 18). Moreover, in several years the cost of producing this power was substantially more than that paid by Valco, as indicated by the large government transfers to the VRA to keep it solvent.

The original owners of Valco were Kaiser Aluminum and Chemical Corporation (90 percent) and Reynolds Metals (10 percent). However, Reynolds sold its shares to the Aluminum Company of America (Alcoa) before the plant began operation in 1967. Kaiser closed the plant in 2003 in a situation of generalized bankruptcy and pressure by the Ghanaian government for substantially higher electricity prices. In September 2004 it sold its holdings to the Government of Ghana for between \$35 million and \$100 million (depending on performance), plus the assumption of all of Kaiser's related liabilities and obligations in Ghana. Alcoa continues to own 10 percent of the shares and played a major role in reopening the smelter in 2005. Energy shortages, however, continue to plague the plant and it was

²³ Economic data on Ghana is very scarce so it is not possible to say exactly where aluminum ranked with respect to exports or manufacturing output

only run at about 30 percent of capacity before being shut down again in early 2007.

The current status of the Valco smelter is unclear, although there have been suggestions that it will reopen in 2009 if rainfall and hydropower are substantial. On one hand, there is pressure to reopen the plant and, in fact, to develop an integrated aluminum industry—including bauxite mining and alumina refining—in Ghana for political reasons. On the other hand, there is pressure from the general public and other industries not to resume power subsidies to Valco, given that this would force them to shift even further towards expensive thermal generated power.

There is some potential to develop additional new hydroelectric power in Ghana. With partial Chinese financing (and expertise) the construction of a new dam at Bui in the Black Volta region in mid-western Ghana began in late 2007; it is projected to increase hydro power by 400 MW starting in 2012.²⁴ However, in light of the chronic power shortages in the country, much of this power will likely have a (non-smelting) domestic market. Furthermore, the cost of power from Bui will exceed Valco's ability to pay. Another option would be to obtain power from the new thermal plants connected to the development of the WAGP and the associated infrastructure. However, preliminary indications are that the cost of this power would be at least US 4.2 cents/kWh²⁵, making it too expensive for Valco. Finally, there is the possibility in the longer term of importing low opportunity cost power through the West African Power Pool (WAPP). It seems likely that such power would have to come from new developments in Guinea, although the actual amount of low cost power available from this source is unclear (see section 34).

On January 25, 2005 the Government of Ghana and Alcoa signed a memorandum of understanding to create an integrated aluminum industry in Ghana. The gist of the MOU was that if feasibility studies were positive, the large bauxite reserves in Ghana would be exploited, refined into alumina using power from WAPP at competitive rates, and then smelted at Valco. Of course, given the current situation at Valco, the possibility of this happening depends greatly on the development of a new source of relatively inexpensive power. Section 4.2 contains a quantitative analysis of Valco's future.

Cameroon

The history of the aluminum industry in Cameroon has been dominated by

²⁴ While 400MW is the official figure with respect to the new power capacity, some observers believe that the true amount will be closer to the 150MW to 200MW range.

²⁵ World Bank West Africa Gas Pipeline PAD, annex 10, table 10.2

the Alucam aluminum smelter in Edea. In recent years there has been discussion of the development of an integrated aluminum industry in Cameroon, although it should be noted that when the Edea plant was built it was believed that in a few years it would use locally mined and processed bauxite. There is transformation of primary aluminum to semis in Cameroon, through Alucam's subsidiary, Socratral, which is on the same site. With a capacity of 23,000 tpy, Socratral is the largest producer of rolled aluminum in the two regions. It exports about 30 percent of its production. There are several companies in the region that are making finished goods out of the semis. While several of these were subsidiaries of Alucam, they were all divested in 2007 except Alubassa, based in Cameroon, but even it has been facing financial problems and its future is uncertain (Carbonell, 2007: 142).

The Alucam smelter has played an important role in the Cameroonian economy since independence. The plant began operations in 1957 with Pechiney of France owning 58 percent of the shares and the Government of Cameroon 42 percent. In 2003 the Pechiney interest was mostly bought by Alcan, leaving both the GOC and Alcan with 47 percent of the total shares. The Edea Hydroelectric Dam was built on the Sanaga River in 1953. Its installed power was quintupled in 1958 using Alucam as its base load customer. The Edea Hydroelectric Plant was the main provider of electricity in Cameroon at independence and is now second only to Song-Loulous; it still provides over 30 percent of the country's electric power.

Alucam accounts for more than 34 percent of total power consumption in Cameroon and is 'guaranteed' a supply of 145 MW during the dry season and 165 MW during the wet season; however, this is not a full guarantee as during periods of severe drought or very high public sector demand, it has had to cut back on production. It has a tariff cap of 7 FCFA/kWh (currently about US 1.7 cents) until the end of 2009, compared to tariffs of US cents 11.4/kWh and 13.6/kWh for medium and low voltage customers, respectively. This is all taking place in the context of increasing power cuts throughout the country. As the location of the power plant beside the smelter makes transmission costs negligible, Alucam claims that it pays full production cost and does not receive a cross-subsidy, although clearly it does not pay the full opportunity cost of power.

Throughout its history, Alucam has been confronted with a situation where it had to reduce output due to lack of power, normally linked to drought conditions. While these were particularly severe in the mid-1980s, for most of the 1990s Alucam had sufficient power due to the general drop in demand related to negative growth of the Cameroonian economy. Only in 1998 did Alucam begin to face consistent power shortages, due partly to a revival of economic growth and power demand in Cameroon—at an

annual growth rate of 7 percent since that time—and partly to drought. It is likely that the opportunity cost of power was significantly greater than the price paid by Alucam since 1998.²⁶ Note that when the power shortages began, Alucam was still playing an important role as a base load customer, but over the last ten years the demand for power appears to have grown to the point that the entire amount used by Alucam could likely be absorbed by other consumers willing to pay higher tariffs (see section 4.1).

While the aluminum industry has not been as significant for the economy in Cameroon as in Ghana—mostly due to the presence of substantial oil production—it still plays an important role. In 2005, aluminum ingots were the fifth most important export product, accounting for 3.8 percent of total exports.

Although dwarfed by oil revenues, the tax contribution (not deducting any implicit power subsidy) of the industry is also important, amounting to 2.8 percent of fiscal revenues from 2001-2006.²⁷ This figure does not include indirect revenues from income taxes on employees, sales taxes on their purchases or taxes generated in the course of the multiplier effect of their expenditures; accordingly, it underestimates the impact of the industry on the fiscal accounts. Of course, in recent years it is argued that Alucam has been receiving an implicit power subsidy, albeit one that falls within their negotiated contract.

Similar to Valco in Ghana, the current situation of Alucam is very much in flux. On the one hand, the power shortages are leading to pressure to close the smelter. On the other hand, there are well advanced plans to more than double the size of the plant from 90,000 to 300,000 tpy and even to construct a larger new smelter of 400,000 tpy, both based on new large hydro power developments—an option not open to Valco—in which Alucam would play important financial and managerial roles.²⁸

The project to expand Alucam will only become a reality if another project, the Nachtigal hydroelectric dam is implemented, which in turn depends upon the Lom Pangar Dam reservoir being constructed upstream. Total estimated cost of the smelter upgrade and expansion, hydro power station, and power lines to Alucam is US\$ 1.4 billion. The hydro station will increase electricity output in Cameroon by 330 MW, of which 260 MW will be dedicated to the smelter, although there will be some release of its electric demands on the existing Edea hydro power plant. The GOC will pay the cost of the Lom Pangar Dam, estimated at US\$ 200 million, and

²⁶ It is ironic that the much brighter future of Alucam compared to Valco is to some extent due to much higher average annual GDP growth in Ghana than Cameroon in the last 20 years (4.6% versus 0.5%), which has meant a much faster growth in the demand for electric power in Ghana.

²⁷ This figure includes taxes paid directly by Alucam and taxes generated by the indirect impacts of Alucam on other economic activity. The former averaged 1.2% from 2001-2006.

²⁸ The GOC and Alucam have signed a Letter of Intent for this green-field smelter.

will have the ability to develop other hydro power sources based on this reservoir. Alucam would own the new hydro station, so the water fees that it would be charged from the LP Dam flow are the main cost concern. These fees should cover capital costs, operating costs, and environmental and social costs in order to avoid a subsidy to Alucam.²⁹

With respect to the greenfield development, it would also depend upon a new dedicated hydro power plant—to be built by Rio Tinto-Alcan (RTA)—and a new dam (to be built by the GOC). The current plan is for a 1000 MW power plant that would be built at Song Mbengue at a cost of around US\$ 1.7 billion. It is likely that the smelter would cost around US\$ 3.5 billion.

With respect to bauxite and alumina Cameroon has a vast potential in bauxite in quantity terms although there are significant uncertainties in regard to the quality of its reserves.³⁰ In 2006 it was announced that the Chinese were planning to exploit the reportedly 2 billion tonne bauxite deposit in the area of Ngaoundal in central Cameroon. Subsequently, in 2007 it was announced that an American company, Hydromine, possibly in conjunction with Alucam or the Dubai Aluminum Company, is planning to exploit these deposits, and build an alumina plant with an annual capacity of 2.8 million tonnes. The development could include a specialized rail transport to Kribi on the coast and a deep water port.³¹ However, it must be emphasized that these plans have not resulted in any commitments.

Nigeria

The aluminum industry in Nigeria is largely a number of finished aluminum goods producers and the Alscon smelter in Ikot Abasi, Akwa Ibom State in southeastern Nigeria (90 kilometers southeast of Port Harcourt), which, as of March 2008, produces aluminum ingots on a small scale. There is also some transformation of primary aluminum into semis

²⁹ There are also concerns that the GOC could do better by building or commissioning the power plant itself and exporting any short-term and medium-term excess supply to other countries, particularly Nigeria. This possibility will be discussed in section 4.1.

³⁰ It is difficult to get a definitive statement on the aluminum content of Cameroon's main bauxite reserves, whether due to uncertainty or secrecy; nevertheless, it is generally believed that that it is about 43%, which would mean that unless the silica content is very low, the reserves are marginal for now given the large infrastructure expenditure that their exploitation would demand.

³¹ A report from the US Department of State indicates that Hydromine signed an agreement in January 2006 to build a BOT rail line from the region to Kribi on the coast, which would be used to bring the bauxite to the coast for processing to alumina. (<http://209.85.165.104/search?q=cache:qYn9bl-sbhUJ:www.state.gov/e/eeb/ifd/2007/80687.htm+%2BNgaoundal+%2Bcameroon+%2Bhydromine&hl=en&ct=clnk&cd=3&gl=us>)

A more recent report by Reuters, June 2007, indicates that the alumina plant would be in Ngaoundal. (http://209.85.165.104/search?q=cache:fcCn6gQbQMAJ:www.entrepreneurnews.com/2007/06/ameroonian_dem.html+%2BNgaoundal+%2Bcameroon+%2Bhydromine&hl=en&ct=clnk&cd=1&gl=us) To confuse matters more, in a report from the Agence Presse Francaise in May 2007, the legitimacy of Hydromine is questioned, as an exiled opposition leader, Ndzama Seme, claims that it is just a go-between for the family of President Biya. (http://209.85.165.104/search?q=cache:Ma24ZvFnYY0J:www.apanews.net/apa.php%3Fpage%3Dshow_article%26id_article%3D43446+%2BNgaoundal+%2Bcameroon+%2Bhydromine&hl=en&ct=clnk&cd=10&gl=us)

in Nigeria. The most important firm is Towers Aluminium Nigeria PLC, which both produces semis and finished aluminum goods. Its extrusion plant, Tower Extrusions, has a capacity of 10,000 tpy and its rolling mill has a capacity of 12,000 tpy.

The primary motivation for building Alcon was to take advantage of the abundance of natural gas, particularly gas that was being flared as a waste product of the oil industry. Alcon was partially completed in 1997 at a cost of US\$ 2.5 billion, operated for three years on a trial basis, and was closed in 2000. Its original owners were the Government of Nigeria (70 percent), Ferrostaal AG of Germany (20 percent) and Reynolds Aluminum (10 percent). In 2004 Alcoa (which had bought Reynolds) sold its shares to the GON. In addition, on the basis of GON investment in necessary infrastructure, Ferrostaal's share was reduced to 75 percent, leaving the GON with a total of 92.5 percent. In 2006 the Government of Nigeria (GON) sold a 77.5 percent share of the smelter to Rusal for US\$ 250 million, leaving it with 15 percent of the shares and Ferrostaal with 75 percent. In mid-2007 Rusal began an ambitious program to get the smelter operational, and it reopened on a partial basis in February 2008.³² While a substantial investment is being made by Rusal, full operation of the plant will depend a great deal on the Government of Nigeria, particularly with respect to infrastructure development and gas access and supply.³³

Clearly, given its history and the size of the Nigerian economy, the aluminum industry has not played an important macroeconomic role in Nigeria. Nevertheless, it has contributed to the fiscal deficit to a degree far beyond its current importance. The GON and its partners invested US\$2.5 billion in a smelter that has only produced 40,000 tonnes of aluminum to date. It paid approximately US\$ 6 million each year in wage and maintenance costs for what was a non-producing facility (Daily Independent Online, 2004.)

The smelter, with an annual capacity of 193,000 tonnes of aluminum, could have important local or regional impacts. First, as noted above, it could provide an outlet for gas that was previously flared, both reducing environmental damage and providing a large market for this gas. Second, the local region in which it is located is a poor, relatively underdeveloped part of Nigeria, where 70 percent of the population is still involved in agriculture, primarily of a subsistence nature. Third, Akwa Ibom is in a region of Nigeria that has seen significant social unrest due to the belief

³² The sale of Alcon to Rusal has been shrouded with controversy and is still being contested at the Supreme Court by BFI Group of California (BFIG), which was the original bid winner.

³³ Note that top government officials undertook a last minute boycott of the launch of Alcon by Rusal as the challenge by BFIG on the bidding process is still at the Supreme Court.

that it is not getting its fair share of the benefits with respect to oil proceeds. The presence of a major industry in the state with potential local spinoffs could help reduce social tensions and Alscon in Nigeria may be a classic example of 'let bygones be bygones'. Although Alscon has been largely a fiscal burden to date, it may make a positive contribution to the local and regional economy in the near future. The most important consideration is that it does not continue to be a net recipient of direct or indirect subsidies from the GON (or state and local governments); that is, at a minimum Alscon should be making a positive contribution to the fiscal accounts of the GON and/or the local and state governments. In addition, the presence of a nearby source of aluminum may also have some benefits for the relatively large finished aluminum goods sector in Nigeria

Guinea

The history of the aluminum industry in Guinea is mostly the history of the mining of bauxite, the main raw material that is refined and smelted into aluminum. Guinea is home to 33 percent of the world's known bauxite reserves and is the only country in Africa that produces more than 1 percent of global production (see Table 3.1).³⁴ In 2003, Guinea was still the world's second largest producer of bauxite—a position it had held continuously since 1982 when its production was 15 million tonnes, about 12 percent of global production of 127 million tonnes. With no increase in production from 2000 to 2006 Guinea is now the 4th largest producer, behind Australia, Brazil and China, although it remains the second largest exporter of bauxite. The most important bauxite mining operations in Guinea are Compagnie des Bauxites de Guinée (CBG) with an annual capacity of 14,000,000 tonnes, Compagnie des Bauxites de Kindia (CBK) with an annual capacity of 3,000,000 tonnes; and Alumina Company of Guinea with an annual capacity 2,800,000 tonnes.³⁵

In conjunction with the Sangaredi Refinery Project—see below—, a nine million tonnes per year bauxite mine is being planned, which would increase the production capacity of the country by almost 50 percent and could move it back to second place on the global production table.

The refining of bauxite into alumina has taken place in Guinea since 1959 at the ACG/Friguia bauxite and alumina complex in Fria, 160 kilometers north of Conakry. The capacity of the plant—the only alumina refinery in

³⁴ Sierra Leone was a minor but not insignificant producer until the civil war in the mid-1990s closed down the industry; in each year from 1990 to 1993, between 1% and 1.5% of global output was mined in Sierra Leone. Production has resumed this year and seems likely to be back to its previous global level in 3 to 5 years. Since 1990 Ghana has produced between 0.25% and 0.65% of global output each year. No other country in Africa has ever produced as much as 0.1% of global production.

³⁵ Data from Bermúdez-Lugo (2006, 3).

Sub-Saharan Africa—is 700,000 tonnes of alumina per year—1.1 percent of global output—and 1.9 million tonnes of bauxite. Approximately 13 percent of the country's bauxite production has been refined into alumina at this plant each year since 2001 with the remainder being exported. This factory was bought by Rusal in April 2006, which had been managing it since 2002. Soon after Rusal began a major expansion and infrastructure modernization program that is expected to double capacity. The company will invest over US\$ 300 million in a three year period.

In partnership with BHP, GAC is constructing a large alumina refinery in Sangaredi, 100 kilometers inland from the port of Kamsar. The total investment will be US\$ 2.3 billion. With a capacity of 1.5 million tpy of alumina, the plant will approximately double the alumina refining production in the country, even with the expansion at Friguia. Moreover, it is intended to eventually expand the plant to 3 million tpy. Even if the output from the associated bauxite mine is included, eventually there will be enough capacity in Guinea to refine between 30 percent and 40 percent of its annual bauxite output into alumina. Similar to bauxite, there are various other initiatives under discussion with respect to alumina in the two regions but all are still in their infancy. In 2005 Alcoa and Alcan signed an agreement with the Government of the Republic of Guinea (GORG) with respect to the development of a 1.5 million tpy alumina refinery. Since then the companies have held consultations with the GORG and key communities, conducted environmental assessments, and developed resettlement plans for residents potentially affected by the project. In July 2007 the group formally recommended to locate the refinery at a site near Kabata, north of Kamsar.

Aluminum smelting has never taken place in Guinea. While the country is currently deficient in power generation capacity, Guinea has the second largest potential for new hydro electric power in Africa after the Democratic Republic of Congo. However, as discussed further in section 4.3, this capacity is fragmented across many small sites, which may not make it suitable for aluminum smelting.

The bauxite and alumina sector is responsible for the largest direct contribution to GDP in Guinea; in 2005, mining (dominated by bauxite and alumina) accounted for 20 percent of GDP versus 12.9 percent for agriculture. Moreover, bauxite and alumina have historically been by far the most important exports of Guinea, accounting for 64 percent of total exports in 2006. In addition, direct tax revenues from the bauxite and alumina industries have typically accounted for more than 15 percent of government finances. Both exports and fiscal revenues have likely increased both absolutely and relatively in recent years.

Nevertheless, there has often been substantial domestic dissatisfaction with the bauxite and alumina industry in Guinea. The processing of bauxite, and downstream linkages in general, has been limited to the one relatively small alumina plant. The various operations tend to operate in enclave fashion with limited upstream linkages and out-sourcing to local communities. In essence, there has been little employment outside of the mines and alumina plant, which themselves have provided only a small amount of employment. However, GAC is undertaking a major effort to increase community employment and other benefits with its new alumina refinery.

Cross-Cutting Issues

There are at least five important issues that have or will cut across all the countries above—power pricing, net fiscal revenues, developing an integrated aluminum industry, local community and regional benefits, and long-term sources of cheap power.

Historically, the most important cross-cutting issue has been the availability and pricing of electricity, including the need for long-term power contracts to include contingency measures that are acceptable to both parties. It is important to emphasize, however, that when a large investment like an aluminum smelter is considered, it immediately will give rise to strong interest groups. Accordingly, there is always the danger that, even with ‘proper’ contracts, political economy considerations may dominate decisions. Nonetheless, to sustain power sector reforms and the financial viability of its utilities, Governments should avoid tariff subsidies to encourage investments in energy intensive investments and seek to create efficient energy markets that lead to long-run marginal cost pricing of electricity and full cost recovery as quickly as possible.

The second issue of net fiscal revenues is related to power prices, albeit not the only factor. While it is essential that governments avoid giving large power subsidies to the companies involved, it is also important that these companies contribute to the fiscal revenues of the country and, perhaps even more so, the development of the local communities in which they operate.

The third cross-cutting issue has to do with the rationale behind developing an integrated aluminum industry.³⁶ Governments in Cameroon, Ghana and Guinea have all indicated that this is a desirable goal at one time or another. However, it is important to determine how much

³⁶In West and Central Africa this is generally meant to include bauxite mining, alumina refining, and aluminum smelting, although of course it could be extended to semi-finished and finished aluminum goods manufacturing.

advantage the domestic availability of bauxite has for alumina refining and the domestic availability of alumina for aluminum smelting—or, for that matter, the domestic availability of aluminum for manufacturing finished aluminum products. A large part of the advantage would be due to the saved overseas shipping (discussed in Box 4.2). Moreover, like all minerals the quality of bauxite deposits can vary widely both with respect to aluminum content and the cost of processing. The capital cost of the project can also vary greatly if a large-scale infrastructure project needs to be undertaken when the deposit is exploited, (as would be the case in Cameroon). In addition, in strong contrast to aluminum smelting, the decision to invest in a bauxite mine or alumina refinery does not depend on the availability of low-cost power. When the large power demands for aluminum smelting is taken into account, it may be more useful to discuss an integrated aluminum industry at the regional level rather than the country level.

The fourth issue is related to the third. Historically, there has not been a systematic attempt to increase the benefits to local or regional communities, particularly with respect to outsourcing. Nevertheless, it was noted that in Nigeria and Guinea, Rusal and GAC, respectively, are making important efforts to increase the local spin-offs of their operations. It will be important to monitor the results of these efforts and for other governments and companies to take heed of the lessons that will be learned. There is also a wide and growing experience (and related literature) on how to best increase benefits to communities and regions hosting large natural resource based operations that should be drawn upon.

Finally, it is important to emphasize that the very long-term future of aluminum smelters in West and Central Africa will likely depend on power developments in Guinea and the DRC. While Guinea has substantial hydro electric potential, estimated at 6,000 MW, over two-thirds of it would come from a number of small dams—hydro potential of less than 200 MW—that would not likely be able to offer power at the price needed for an aluminum smelter. More importantly, there is only one river basin, the Konkoure, which has the potential for more than 1000 MW (1300 MW), which is considered the minimum for a new world class smelter (Amisshah-Arthur, 2007: 9). The DRC, however, has an abundant hydro power potential more than the rest of Africa combined at the Inga rapids in the lower Congo. It is estimated that the ‘Grand Inga’ project would be able to provide 40,000 MW of power to Africa in general.

Quantitative Analysis of Aluminum Smelting in West and Central Africa

This section discusses the scenarios under which aluminum smelting is likely to be viable in the short-term and medium-term in West and Central Africa. The focus is on the Alucam smelter (plus expansion) in Cameroon, section 4.1, and the Valco smelter in Ghana, section 4.2. In both cases, a quantitative analysis is made to determine the conditions under which the smelters are most likely to be viable and make a net contribution to their economies. The final subsection, 4.3, contains a discussion of the current and potential situation with respect to smelting in Nigeria, the pros and cons for locating a smelter in Guinea, and the potential role that hydro power from DRC's Inga Rapids could have on the aluminum industry in West and Central Africa.

The Alucam Smelter in Cameroon

Scenario Building in Cameroon

The aluminum smelting situation is reaching a critical stage in Cameroon. First, the existing smelter is operating close to full capacity. Second, plans for a major expansion of the smelter are moving forward quickly. Third, there are tentative plans for a new, larger smelter in addition to the expanded existing smelter. Fourth, and perhaps most important, Cameroon, unlike Ghana, has significant untapped hydroelectric potential. In addition to these factors, Cameroon also possesses large deposits of bauxite, although there is uncertainty about the quality and possibly high infrastructure costs required to bring it to market.

There are four plausible scenarios with respect to the aluminum industry in Cameroon: (i) business as usual; (ii) extend the existing smelter expanding capacity three fold and build the required hydro power plant; (iii) in addition to extending the existing plant, build a large greenfield aluminum smelter and another power plant; and (iv) all of the above plus the upstream mining of bauxite and refining of alumina from the area of Ngaoundal in central Cameroon.

The possibility of exporting electricity on a large scale could have been added to the list above. However, this is not a serious option for at least the

next 10 to 15 years for the following reasons. First, with the exception of Nigeria, all of Cameroon's direct neighbors have their own relatively inexpensive power (Gabon, DRC, Congo-Brazzaville, Equatorial Guinea) or have very small markets (Chad, Central African Republic). Moreover, the Central African Power Pool is currently in its infancy and many years away from implementing major projects. Second, while Nigeria appears to have a large power deficit, this is an 'artificial' deficit. With a combination of proper gas pricing and repairs to existing infrastructure, Nigeria could provide all the power that it needs. Moreover, there are also plans in Nigeria to build a 10,000 MW power plant (in 3 stages) at Mambila on the Katsina Ala River, which flows into the Benue River, a major tributary of the Niger River.

In the first scenario the plant continues as before, perhaps with an upgrade but no major extension. This will require the availability of sufficient long-term low-cost power once Edea's current power-contract expires at the end of 2009 and also an assessment of the plant's long-term viability at its current size. The current smelter is clearly too small and uncompetitive in today's aluminum industry. The plant does not have the economies of scale other modern installations provide. Its cost-structure in regard to cash operating costs is not cost-competitive (at US\$1500 per tonne in 2005 compared to an industry average of US\$1186) making it vulnerable in case of an industry down-turn. Therefore, even if the power would be available at a favorable cost, the Government of Cameroon might still find that the plant could close or shut down as soon as aluminum prices revert to historic long-run levels. In view of this vulnerability, an analysis of the electricity cutoff price will be a critical element to determine if the smelter could continue to operate and what that would mean with respect to the net fiscal contribution of Alucam to the GOC.

The second scenario, the modernization of the existing plant and the installation of a new pot-line using state of the art technology (AP37) would lift overall capacity to 304,000 tpy, which would require the construction of new hydro power capacity in addition to the investment in the smelter. As currently discussed, Alucam would pay the cost of the smelter extension and power plant while the GOC would pay for the construction and maintenance of the Lom Pangar Dam.³⁷ The Nachtigal hydro power dam would provide 330MW of power of which 260MW would be provided to Alucam with 70 MW for general consumption. AES Sonel would then provide 250 MW from Edea and the new gas thermal power plant at Kribi (with capacity of 150 MW). Given the average consumption of Alucam previously from Edea, this would mean that about 50 MW of additional power would be available for general consumption or 120 MW in total.

³⁷ It is also unclear whether the GOC will continue to maintain its current 46% share of Alucam, in which case if there were to be a power subsidy, the amount actually going to RTA would be reduced accordingly.

The expansion of the plant would result in an improvement in the competitive position of Alucam on the global cost tonnage curve as Alucam will be able to benefit from the economies of scale provided by the larger plant and reduced power consumption per tonne of metal as a result of the new technology. However, despite these improvements CRU (2008) estimates that Alucam's cost structure (cost per tonne) will be close to the average cost for the industry (based on a power tariff of 2.3 cents/kWh). Alucam has no particular comparative advantage in regard to imported inputs (alumina, pitch and coke, et cetera) or in the export of its products due to its location and the associated port and transportation logistics and limitations. Its comparative advantage is based on the cost of labor and, mostly, power, which in turn depends of course on the future tariff structure.

Based on its projected average cost position on the global industry cost tonnage curve—for both capital cost per annual tonne installed and operating costs per tonne produced—Alucam has limited freedom for what it can pay for the power it consumes. With no other comparative cost advantages beyond labor to offset high power cost, Alucam can only consider a power tariff in the range of US cents 2-2.5/kWh to stay competitive as an average cost producer.

Three important issues on the potential power subsidies implied by this case include:

- As Alucam would own Nachtigal, the extent of the power subsidy on this portion of the power supply would to a large degree depend on whether it was paying the full cost for the water flow derived from the LP dam, including environmental and social costs, particularly those associated with the reservoir and the Nachtigal plant.
- Alucam could receive a subsidy from AES Sonel on the 250 MW that it supplies to Alucam, the opportunity cost of which would be determined by its value in the domestic market. However, since AES Sonel is a private, regulated company, there would not be a direct government subsidy to Alucam. Nonetheless, if there is a domestic demand for this power at a higher price, then there is an implicit cost to the country.
- Given that GOC is constructing the LPD, it may also be preferable for it to build the hydroelectric power plant or allocate the hydropower site to an IPP through a competitive bidding process. In essence the smelter extension would only be profitable if Alucam was able to purchase power below a certain price. It may well be in this sub-scenario that Alucam's demand would still be needed to act as a base load anchor for the power development.³⁸ In any event, political economy considerations suggest that any subsidy to Alucam in this regard may not be as significant as it may seem, as it would be difficult for the GOC to raise the funds and manage the development of the Nachtigal power plant.

There are, however, strong positive externalities to the people (and government) of Cameroon of having the private sector provide the funds and manage the process.

From an analytical viewpoint, the third scenario is similar to the second. There would be a second smelter (compared with a major extension) that would necessitate another dam. The question arises as to who builds what and what is the true opportunity cost of the water and/or power. There is also the question of a subsidy to Alucam by allocating the power site to the company in a non-competitive process.

The fourth scenario includes, in addition to the smelter extension, power plant and dam, the integrated development of the sector comprising bauxite mining, refining of the bauxite into alumina, and the development of a rail line from central Cameroon to the coast and the construction of a deep water port.³⁹ While this seems much more complex than the second scenario, the reality is that for the most part the two parts of the scenario can be analyzed separately. It would only be relevant if the reduction in transport costs for alumina inputs were significant enough to overcome power tariffs that would normally be above the cut-off price.

It will also be necessary to assess the externalities of these additional activities. If a considerable amount of employment and indirect tax revenues are generated by an operation, it may be justified for a government to provide some subsidies. While it is difficult to estimate these without a full-blown model, the recent Prescriptor (2008) study of Alucam gives a good indication of the number of companies that depend on Alucam either as a supplier or a downstream producer. Estimates are also made of the number of jobs generated directly and indirectly by Alucam and the corresponding amounts of fiscal revenues.

Similarly, certain services, such as railways and ports that are used for other industries or consumers, may be dependent on the operations of a larger firm such as Alucam. There also may be important political economy reasons to subsidize an industry, such as an attempt to reduce regional disparities. This last factor may be particularly important in Cameroon with respect to the mining and refining of bauxite, although less so for the aluminum smelter which is in the most industrialized and highest income region of the country.

Finally, Alucam could be an important net contributor to the balance of payments and, thus, help provide foreign currency needed to buy inputs, capital goods, and consumer goods. Therefore, its contribution to foreign currency generation should also be considered in a final decision.

³⁸ As noted above, we do not think that it is feasible in the medium-run to export large amounts of power.

³⁹ While it has not been possible to obtain solid information, it is generally believed that the bauxite content is around 43 percent, which is borderline for development unless silica levels are low.

Quantitative Analysis of Aluminum Smelting in Cameroon

The analysis begins with an evaluation of the situation for Alucam with its current technology and current prices. It is clear, however, that critical decisions to be made in the upcoming year or two will depend much more on the medium-run and long-run prices for aluminum, alumina and electricity. Accordingly, the conditions under which the current smelter will remain a viable operation are then analyzed. This is followed by an analysis of the conditions under which a major extension of the smelter is viable, with the emphasis being on the availability and pricing of power, which in turn partly depends on the price that the GOC will charge Alucam for the water flow from the new LPD. In both cases a key variable is the price of electricity that enables the smelter to break even (given the other price assumptions). An estimate is then made of the effect of the development of an integrated aluminum industry would have on the break-even electricity price and any power subsidy. Then, based on recent estimates of linkage effects of Alucam, employment and tax revenues generated directly and indirectly by Alucam can be presented

Business as Usual (Basic) Scenario⁴⁰

There has been considerable debate (and concern) that Alucam is receiving a power subsidy at the expense of other consumers in Cameroon. Given that in 2007 MV and LV customers in Cameroon paid 62.2 and 77.5 FCFA/kWh, respectively, whereas Alucam paid 8.3 FCFA/kWh—all in the context of a general power shortage—there appears to be a strong argument that Alucam received a power subsidy. However, when a broader perspective is taken, the situation is not so clear. First, power shortages only became serious in Cameroon in the early 2000s (or perhaps the late 1990s). Before that time Alucam served as a very necessary base load customer. Part of the risk of having Alucam play this role was that it was necessary to enter into a long-term power contract with Alucam, which expires in 2009. Hence, it was legally entitled to what became much-in-demand power. Second, the Alucam plant is located near the power plant so has low transmission costs and efficiency losses (a great deal of which is attributable to non technical losses) compared to MV and LV customers. Given that Black and Veatch (2003, 9) reported that technical and commercial losses in the Cameroonian electric distribution system were 35 percent, it can be justified on a cost basis to charge other customers a significantly higher price than Alucam, although most likely not 7.5 to 9 times higher as was the case in 2007. Nevertheless, while it is highly possible that Alucam was covering the cost of its power supply, it is not likely that it was paying the full opportunity cost.

Currently, the most crucial decision that stakeholder's need to make is

⁴⁰ See Annex 1 for the model underlying the calculations in this section.

whether the Alucam smelter is viable at trend aluminum prices. This is particularly urgent given that the current power pricing contract is near the end of its lifetime. Accordingly, in the negotiation of a new agreement (assuming for now that there is no extension), it is important to know, first, at what power price the smelter is viable and, second, whether power can be realistically supplied at this price without depriving other customers with a much higher willingness to pay.

It was noted in the previous sub-section that Alucam's operating costs are well above the industry average, with its only advantages being in power and labor costs. If the CRU (2008) predictions are used for long-run prices of aluminum and alumina at \$1831 and \$363 per tonne, respectively, then the smelter would be just viable at 1.8 cents/kWh. It is unlikely that this type of power will be available once the current contract ends. Alucam, itself, has indicated that in the major extension scenario, which includes the new Nachtigal power plant, it expects to pay 2.3 cents/kWh. If this extension does not take place and given the other demands for power in Cameroon, it is to be expected that power would either be priced much higher than 2.3 cents/kWh or the GOC would have to grant Alucam a very large power subsidy (CRU, 2008: 5-6). According to this analysis, it may well be that the only viable options for Alucam and the GOC are to shut Alucam down or consider a major extension of the plant.

Major Extension

Under this scenario the main issue is whether or not Alucam could build and operate a major extension of its smelting operations (to 304,000 tpy capacity) without receiving a power subsidy from the GOC (either directly or indirectly through below market prices from AES Sonel). Note that environmental costs of the new dam and power plant have not been factored in directly but they would have to be considered before a final analysis could be made. It is assumed that Alucam would receive 260 MW from Nachtigal and 250 MW from AES Sonel.

In CRU (2008: 5-10) it is estimated, using data provided by Alucam, that the much larger smelter would be close to the middle of the cost curve at a power price of 2.3 cents/kWh. They then assume that in an industry downturn, any firm with lower costs than all but the smelters producing in the top 15 percent of the cost curve are likely to survive. Accordingly, Alucam would have a margin of safety of \$233 per tonne, which means that the break-even power price would be almost 4 cents/kWh.

The cost of production and HV transmission of hydro power in Africa lies between 1.5 to 4.0 cents/kWh, excluding the hydraulic rent. Given Alucam's own predictions that its average cost of power, including the large portion supplied by AES Sonel, will be 2.3 cents/kWh, it seems that Nachtigal will be in the lower end of the range. It is currently understood that the hydraulic rent will be well below 0.1 cents/kWh, which leads to two conclusions. First,

if the cost of Nachtigal power is anywhere below 2.0 cents/kWh, the extension to the smelter is likely to be feasible even when environmental and social costs are taken into account. Second, there is some flexibility for negotiation with respect to the level of the hydraulic rent.

However, under this scenario, Alucam will still have to source almost half of its power needs from AES Sonel. According to recent estimates, the average cost of the hydro and thermal power provided by AES Sonel would be about 2.4 cents/kWh in this scenario. Moreover, as discussed above, the provision of HV power is much less expensive than MV or LV power for AES Sonel. Accordingly, on a cost basis, there is room for AES Sonel to make a profit and provide power to Alucam at a price at which its operations would be viable, even if AES Sonel had to pay a significantly higher hydraulic rent. These calculations suggest that the main outstanding issue is whether or not the opportunity cost of this power is higher than this and would yield greater return if directed toward other activities in Cameroon; that is, at a price higher than Alucam is willing to pay (adjusted for transmission costs and efficiency losses), would the excess demand from other consumers be greater than the extra 120 MW that is currently slated for their consumption in the smelter extension scenario?

Unfortunately, the answer to this question is not straight forward due to the bulk nature of power generation. For example, it may well be that other consumers would be willing to purchase an extra 50 MW of power at or above the indicated price that Alucam would pay; however, without this power the smelter extension would likely not be viable and without the smelter the power project would not be viable; hence, we would revert to the basic scenario. However, there does seem to be considerable excess demand for power at current prices, and therefore even if Alucam was shut down and Kribi Power Corporation's HFO plant was on line, by 2014 the power from the Kribi gas fired power plant would still be needed.

A true comparison therefore seems to be between the net benefits to the economy of Alucam closing down and the extension. If Alucam was closed down, including the additional 86 MW from the new HFO plant that comes on line in 2009, there would be about 231 additional MW for general consumption.⁴¹ In the extension scenario there would be about 201 additional MW of power available for general consumption—86 MW from the HFO plant and 115 MW from Edea, Kribi and Nachtigal (see Table 4.1). Hence, there would only be an incremental increase of 30 MW in the close down scenario, which would likely be compensated for by the value added and other benefits of the aluminum production—over three times the current level—that are discussed below.⁴²

⁴¹ The HFO plant (86 MW) is already under construction, although the gas-fired plant at Kribi (150 MW) has not been approved yet and presumably would be delayed until needed if Alucam shut down.

⁴² If recent projections are correct, it is only in or about 2014 that there would be a demand by other customers for all of this 30 MW, indicating that the implicit subsidy to Alucam would rise from a very low level in 2008 to the potential extra value of this 30 MW in 2014.

Table 4.1: Supply and Allocation of Power in Cameroon (MW)⁴³

	Current	Closure of Alucam	Extension of Alucam
Supply			
Edea	263	263	263
HFO Plant	0	86	86
Kiribi Gas Plant	0	0	150
Nachtigal	0	0	330
Allocation			
Alucam	145	0	510
Other Consumers	118	349	319
Net change to Other		231	201
Consumers			

However, this is only true until around 2014 when, without further power developments, there would again be a power shortage for general consumption. Without Alucam, this is when Kribi is scheduled to come on line but with the smelter extension it would all be accounted for. Accordingly, after 2014 the opportunity cost of the power could be approximated by the willingness to pay (WTP) of general consumers for the additional 30 MW that would have been available if Alucam closed plus a steadily increasing amount from Kribi. It is difficult to calculate this amount without a large degree of guesswork, particularly as it depends partly on the (currently unknown) transmission and efficiency costs of an ever increasing number of general consumers in Cameroon. This strongly suggests, however, that power contract provisions with Alucam and the development of power supply in Cameroon should take these potential future shortages into account. For example, it seems possible to develop new relatively inexpensive sources of power in Cameroon. These could be staggered in such a way that new (hydro) power plants came on line about the time that existing suppliers no longer need to depend on the aluminum smelter as a base load consumer.

Integrated Aluminum Industry

From the perspective of the smelter, the only significant change here would be if the cost of aluminum fell due to (primarily) a large drop in shipping costs of alumina. It is assumed that the price of alumina excluding shipping does not change, given the global market for alumina. Following the discussion on the domestic impact of shipping costs for alumina in Box 4.2, it is assumed that the price of alumina to Alucam falls 4 percent if there is an integrated aluminum industry in Cameroon.

⁴³This table only refers to power generated at Edea and new power developments.

Box 4.2: Impact of Shipping Costs on the Aluminum Industry

It is often argued that a country has a competitive advantage in alumina refining—and other stages of the aluminum industry—given a local source of bauxite. Of course, if large infrastructure investments are necessary, this competitive advantage would disappear quickly. The importance of local sourcing is illustrated by the shipping costs of bauxite from Guinea to the United States, which added 29% to the free on board price in 2005 and 2006. Since the cost of bauxite averaged 27% of the total cost of refining alumina in 2005 and 2006 (Coté, 2006: 20), the cost savings of locating an alumina plant near a bauxite mine is about 8%, plus the environmental externalities of disposing of the extensive amounts of “red mud” waste in more industrialized regions.

There is little advantage of having an alumina refinery near an aluminum smelter. The cost of shipping alumina to the United States, for example, averaged about 4% from 2004-2006 (USGS, Minerals Yearbook). Since alumina is from 20% to 33% of smelting costs, there is only a 1% competitive advantage of having an alumina refinery nearby, which is likely to be of secondary importance compared to other cost factors.

Locally produced aluminum ingots and semis could reduce costs for domestic firms and allow for expansion of these industries. Shipping costs of rolled aluminum are difficult to obtain but it was estimated in 2003 that shipping costs from South Africa to the United States for example added 6% to the price of aluminum excluding inland freight. According to Socratel, recent shipping costs of rolled aluminum from Cameroon to Europe were about US\$ 75 per tonne, which is about 7% of the price assuming more ‘normal’ or trend prices. It is likely that a local source of rolled aluminum, would give local producers of finished aluminum products a 5% advantage over imported aluminum goods.

In the long-run, the challenge for the West Africa region is to become competitive in more sophisticated aluminum products, particularly for the auto and other transport industries. However, this requires local markets to be large enough to justify the economies of scale required, especially in view of the high transportation costs associated with the export of these products to developed markets in Europe and North America.

We use the assumption of CRU (2008, 5-9) that in the long-run purchases of alumina will comprise 44 percent of Alucam's operating costs. Consequently a 4 percent reduction in its price would result in an overall drop in production costs of aluminum of 1.76 percent. Given that power is expected to be 21 percent of costs, this means that power prices could rise by 84 percent and leave Alucam in the same position as previously. Therefore, if the break-even power price for Alucam was 2.3 cents/kWh in the non-integrated industry scenario, it would now be close to 2.5 cents/kWh. In practical terms, this could have repercussions for the hydraulic rent charged by the GOC or the regulated power price charged by AES Sonel but would not likely be a major determinant of the viability of the smelter.

Benefits to the Economy Generated by Alucam

It is important to have a rough idea of what fiscal revenues and employment are to understand the contribution that the industry can make to the economy. In turn, the justification of a power (or any other type of) subsidy to an aluminum smelter should depend significantly on its overall contribution. In this section we will examine the economic benefits provided and expected to be provided by Alucam in the future.

Benefits from the smelter include its contributions to value added, investment, local purchases, direct and indirect employment, training, fiscal revenues, the balance of payments, training, and social programs.⁴⁴ Table 4.2 has estimates of these for the existing smelter and projections for the future extension. Alucam had made and can continue to make an important contribution in many ways to Cameroonian society. It is interesting to note that it has been more than an 'exporter of electricity' as the value added from 2001-2006 was about 2.6 times the value of the power used as an input. In determining whether a power subsidy (if needed) is justified, the various amounts above should play an important role. Several of these figures have been calculated with the use of a specific multiplier, so clearly this is an important variable that should be calculated as carefully and transparently as possible, especially in a country with a general shortage of good economic data.

⁴⁴ As power has already been discussed at length, it is not included in this section.

Table 4.2: Contribution of the Alucam Smelter to the Economy: Past and Projected (FCFA millions)⁴⁵

	Existing Smelter (Average, 2001-2006)	Extended Smelter 304,000 tpy capacity (Ave 2009-2020)
Value added - Direct	24,333	85,833
Value added - Direct and Indirect (percent total VA) ⁴⁶	62,419 (0.74 %) ⁴⁷	206,000 (1.96%)
Local inputs (electricity only)	18,633 (9,000)	NA
Investment (local inputs only)	8,000 (3,167)	179,583 (NA)
Employment – Direct	983	1,786
Total Employment – Direct and Indirect (percent of total industrial employment)	2,359 (4.5%)	4,286 (NA)
Fiscal Revenues – Direct and Indirect (percent of total GOC revenues)	43,169 (2.85%)	87,000 (NA) ⁴⁸
Net Balance of Payments (percent of total imports less Alucam's imports)	24,019 (1.8%)	113,833 (NA)
Training	117	NA
Social Programs (of which housing is the major part)	1,418 (532)	NA

Conclusions

Given the excess demand for power and the age of the plant, the current Alucam smelter does not appear to be viable once its power contract runs out and aluminum prices revert back to normal levels. Moreover, the implicit power subsidy will increase with time as the rest of the economy grows. Of course, if power supply had not been allowed to stagnate for so

⁴⁵ The dollar/FCFA rate fluctuated significantly in this period but 500 FCFA to the dollar can be used as an approximation. Hence, for example, 24,333 million FCFA is approximately US\$ 50 million.

⁴⁶ For the future smelter, this is the percentage of value added in 2007.

⁴⁷ To obtain this figure Prescriptor (2008, 67) uses a multiplier of 2.4 for both scenarios. The methodology that they used to obtain this multiplier is unclear to us, although it does seem a reasonable assumption. The amounts for labor and fiscal revenues use the same multiplier.

⁴⁸ Fiscal revenues are assumed to be twice as high on average, as in the earlier years amortization of the capital investment and will greatly reduce the contribution despite the fact that value added is projected to be 3.5 times higher on average.

long in Cameroon, Alucam may not have been put in this position. Unlike Ghana, discussed below, there were and are several options for low cost power in Cameroon that could have met the demand of both the smelter and all or most of the other consumers.

Nevertheless at the current level of aluminum prices, the smelter is profitable and would be viable at significantly higher power prices. This indicates that if power is to be subsidized in any manner, it may be advisable to link the electricity tariff more directly than is currently the case with the aluminum price once the latter crosses a certain threshold (taking into account the costs of other inputs).

In the medium-run and longer, under reasonable assumptions with respect to the cost of and demand for power and the various economic and social contributions, it is possible to construct a case for the viability of a major extension of Alucam. This case does not depend on developing an integrated aluminum industry. The analysis is far from conclusive, however, and depends on four critical variables on which more information is necessary, including: (i) the WTP of other Cameroonian power consumers for large blocks of power above their projected allocation; (ii) the variation in delivery costs of HV versus MV and LV power; (iii) the projected direct fiscal contribution of Alucam; and (iv) the multiplier effects of Alucam, which should distinguish between employment in the factory, employment to local contractors, and multiplier effects of the expenditures of the first two groups.

Finally, we would like to emphasize three points. First, if the project moves ahead, power contracts should include some safeguards for other consumers and these should increase over time. Second, the hydraulic rent paid by Alucam (and other customers) for water flow from the Lom Pangar Dam (and others) should at a minimum cover the full capital and operating costs of the dam. Over time, this rent should increase and consideration should be given on tying the rent to the price of aluminum (adjusted for prices of other important inputs). Third, it is realistic to plan and implement a series of sources of relatively inexpensive hydropower to be developed in Cameroon, with a new source coming on line about the time that non-smelter demand for power is at a level that the smelter (or smelters) is not needed as a base load for the existing power supply.

The Valco Smelter in Ghana

Scenario Building in Ghana

As discussed earlier, the Valco smelter was closed in 2003, reopened in late 2005 and closed again in early 2007 due to the lack of sufficient low cost power in Ghana given the very large overall shortages. Moreover, there are no obvious possibilities to generate such power in the future. Consequently, scenario building in Ghana is much less complex than in Cameroon. Any

scenario that sees Valco continue as a stand alone operation must focus on the possibilities of an increased availability of power at prices that make it profitable to operate, which in the context of the global aluminum industry normally means in the US 2 to 3 cents per kWh range.⁴⁹

In January 2005 the GOG and Alcoa signed a memorandum of understanding to create an integrated aluminum industry in Ghana. If feasibility studies are positive, the bauxite reserves in Ghana would be exploited, refined into alumina, and smelted at Valco. Accordingly an alternative scenario would be for Valco to receive alumina that is refined in its own 'backyard', which in turn should be less expensive due to the nearby presence of bauxite. Although transport costs in the aluminum industry historically were not very important, they have increased in recent years due to large increases in shipping prices, but these seem to have peaked and are on their way down.

Finally, it is important to analyze the externalities generated by an operating smelter. If a large amount of employment and indirect tax revenues are generated by an operation, it may be justified for a government to provide some subsidies. While it is difficult to estimate these without a full-blown model, the data for which currently does not exist in Ghana, it is possible to obtain some indication by comparing the situation of Valco to Alucam in Cameroon, on which a large study has recently been done. By comparing the employment in Valco and its major linkages with the situation of Alucam, we can obtain a rough estimate of the benefits of the factory by scaling up or down those that we reviewed in the last section on Alucam.

Quantitative Analysis of Aluminum Smelting in Ghana

The analysis begins with a discussion of the reasons for the closure and re-closure of Valco in 2006, despite very high and rising aluminum prices in the latter year. An estimate is made of the implicit subsidy to Valco during a more 'normal' operating year (2002) and its final year of operation (2006). It is then examined whether any of the important characteristics behind this closure have changed substantially in the last two years. We then discuss the 'break-even' electricity price for Valco given its technological structure and trend prices for aluminum and alumina. The break-even price is compared with likely power prices in the medium-run in Ghana. Then the annual power subsidy needed to make Valco viable is estimated, using electricity prices paid by other high voltage users in Ghana.

This is followed by an estimate of the effect of the development of an integrated aluminum industry would have on the break-even electricity price and any power subsidy. Finally, using the Cameroon analysis, we compare the

⁴⁹ Valco have indicated that they could be profitable at as much as 4 US cents per kWh. As detailed data on the firm's cost structure are not available, it is not possible to verify this figure, although it seems doubtful unless aluminum prices remain very high relative to the cost of other inputs such as alumina (and, hence, bauxite) and freight charges.

characteristics of Valco and Alucam in Cameroon and make a rough estimate of linkage effects of Valco, including tax revenue. The amount of tax revenue is subtracted from the power subsidy and divided by the employment associated with the aluminum industry to obtain the subsidy per job created. Other contributions to the economy of the aluminum industry are also discussed.

The Closure of Valco

As noted in section 3.1, Valco was forced to close down in 2003 due to the inability to obtain sufficient power from the Volta River Authority (VRA) at a low enough price to sustain operations. This closure took place at the time when Valco's majority owner, Kaiser Aluminum, was in a situation of generalized bankruptcy, partly due to low aluminum prices.

In some respects, Valco was a victim of Ghana's success. The 4.6 percent annual growth rate in Ghana for 20 years had led to a substantial increase in demand for power, one that the country had not prepared for. Nevertheless, given the lack of new major hydro power alternatives in Ghana, it seems likely that any new power supply would have been priced well out of the range of what Valco needed, particularly in the lengthy period of relatively low aluminum prices, which ended only in 2004. In Table 4.3 the implicit subsidy to Valco in 2002 is calculated in the low and medium case as \$70.1 million and \$138.2 million, respectively. The low case calculation is based on the price paid by other HV users, which could be considered a minimum WTP given the generalized situation of blackouts in Ghana; the medium case subsidy is based on the average price that is paid by all consumers for electricity. The 'high case' scenario was not included since estimates of the true WTP for power in Ghana are not available. The GOG purchased Valco in 2004 and reopened it with the aid of its minority partner, Alcoa. Despite the large increase in real aluminum prices in 2005 (about 20 percent), the aging and inefficient smelter is uncompetitive and requires major refurbishment to become viable. In addition it faced severe power shortages as the booming economy—with annual growth of over 6 percent in 2005-06—was demanding more and more power while supply stagnated. Although only operating at 30 percent of capacity in 2006, it is estimated that Valco received an implicit subsidy of US\$ 35 million. This is equivalent to the subsidy received by the VRA to cover its losses on sales to Valco. If we calculate the subsidy based on the proxy (minimum) WTP in the low case scenario—that is, the price paid by other bulk users—the estimated (minimum) subsidy is US\$ 23.7 million for a plant operating at 30 percent capacity.⁵⁰

⁵⁰ The average price of power for all customers was unavailable so the medium case scenario in 2006 could not be calculated. Databank Research (2007) estimates that the loss to commercial users in Ghana of power cuts in 2006 was about \$744 million, based on their expenditures on the operation of diesel generators. This figure suggests that the WTP of firms in Ghana is far above the current bulk user price.

Table 4.3: Estimates of Implicit Subsidies to Valco

	2002	2006
Aluminum Output (tonnes)	117,000	60,000
Power Used (kWh)	2063m	1030m
Price per kWh	1.1	2.7
Price for other HV Customers (US cents/kWh)	4.5	5.0
(Average price for all customers, 2002; LV and MV prices, 2006)	(7.8)	(13.0, 5.0)
Implicit Subsidy – Low Case (\$US)⁵¹	\$70.1m	\$23.7m
Implicit Subsidy – Medium Case (\$US)	\$138.2m	NA

For Valco to reopen again, it is essential to find a new source of low cost power for which it can provide an anchor. However, it does not seem likely that there will be low cost power available in the foreseeable future in Ghana, whether from thermal plants associated with the WAGP or new hydro developments. Power associated with the WAGP is expected to cost well over 4 US cents per kWh, the maximum that Valco says it can afford to pay. Significant new hydro power is not expected before 2013, when new power should come on line from the Bui Dam project on the Black Volta. While this dam is projected to increase capacity by 400 MW, there are doubts about this claim, and it may end up providing less than half this amount on any sort of sustainable basis and will likely cost more than 4 US cents per kWh. Moreover, the high and growing level of excess demand—both domestically and from neighboring countries—should easily absorb this power (even if it does amount to 400 MW) at prices that are prohibitive for an aluminum smelter. While there is the possibility of importing low cost power through the West African Power Pool (WAPP), such power would certainly have to come from Guinea and the timeframe for development of this power on a large enough scale to be useful for Valco is estimated at about 10 years—which is likely too long-term. Moreover, as discussed further below, the fragmented nature of most of the potential hydro power from Guinea means that it is unlikely to generate a surplus of ‘cheap’ hydro power. Finally, while Valco is contemplating building its own dedicated power plant, the feasibility of it providing power at a cost that makes the smelter viable is questionable.

Break-Even Prices for Valco

Valco is an old smelter, similar to Alucam’s current operation but far less energy efficient. As aluminum prices revert to long-run trends, it seems

⁵¹The implicit subsidy is the price paid by other HV customers minus the price paid by Valco times the number of units of power. Given the generalized power shortages, the price paid by other HV customers can be considered as a floor value of the WTP for power in Ghana.

probable that, energy aside, Valco will be in the same range of the industry cost curve as Alucam. This means that it would need to purchase power in the range of US cents 1.5 to 2.5 per kWh to be viable. Given that Valco is very unlikely to be able to get power for less than US cents 4.0/kWh (and probably significantly higher), the viability of its operations in the long-run are very questionable. Even if an integrated aluminum industry were developed, this would likely only reduce power costs by US cents 0.2 to 0.3/kWh, which does not seem enough to push Valco's costs down sufficiently to be viable in the medium-run.

Benefits to the Ghanaian Economy Generated by Valco

It seems probable that for Valco to reopen, it would need a sizable power subsidy in the medium-run, whether calculated on the cost of supplying the power or the WTP for more power in Ghana. Such a subsidy could only be justified if the other economic benefits are expected to be very large. Given the lack of data on Valco's contribution to the Ghanaian economy, we will make calculations of this contribution partially based on the figures from the Prescriptor (2008) study of Alucam.

Benefits from the smelter include its contributions to value added, investment, local purchases, direct and indirect employment, training, fiscal revenues, the balance of payments, training, and social programs (Table 4.4). From 1995 to 2002, Valco's production was about 60 percent higher than Alucam's (see Table 3.2), so we assume that the same was true for value added and the contribution to the balance of payments in a typical year. Direct employment was 1,200, about 25 percent higher than Alucam. While most output was exported, a significant amount was sold to Aluworks to produce rolled aluminum. Aluworks is about 80 percent the size of Socratal and exported half of its output on average, versus 30 percent for Socratal, suggesting that spinoff employment was more in Cameroon than in Ghana. Moreover, it does not appear that there was any significant investment in Valco in this period, again reducing the impact on employment.

If we assume that the employment multiplier is the same for Valco than Alucam (although the above suggests it was probably somewhat lower), then Valco would have generated 2,880 jobs in a typical year. From 1999-2002, Valco contributed US\$ 500,000 to various social programs. Data on training are not available.

The missing link in the analysis is the fiscal contribution of Valco. When the smelter opened it was given preferential tax treatment, much of which carried on throughout its operating life. Nevertheless, it is not clear what Valco has contributed directly to the fiscal accounts of the GOG. If this fiscal contribution was negligible in our generated average year, then the subsidy per job created was US\$ 2,830 per year—

compared to a per capita GNI of US\$ 520—using a WTP based on the bulk power price, which should be considered a lower bound, and US\$ 5576 using the average price paid for power, which is probably a more realistic figure. In sum, the estimated subsidy per job created per year is between 5 and 10 times the average income in Ghana.

Table 4.4: Simulated Contribution of the Valco Smelter to the Ghanaian Economy (\$US)

	Valco (Simulated Ave year if operating 2001-2006)	Alucam (Average 2001- 2006)
Aluminum Production	136,000	85,000
Power Subsidy (Low case/Medium case)	\$81.5m/\$160.6m ⁵²	Not calculated
Value added – Direct	\$78m	\$49m
Value added - Direct and Indirect	\$187m	\$117m
Investment	negligible	\$1.6m
Employment – Direct	1,200	983
Total Employment – Direct & Indirect	2,880	2,359
Fiscal Revenues – Direct	NA	36
Net Balance of Payments	\$77	\$48
Social Programs	0.5	2.8
Simulated Subsidy per Job Created (Fiscal Revenues = 0) (Low case/Medium case)	\$2830/\$5576	Not calculated
Per capita GNI of Ghana (2006)		\$520

Note: See text above for explanation of variables and calculations.

Conclusions

In conclusion, Valco played an important role in the development of the power sector of the Ghanaian economy. However, as the economy grew, the power sector was left to stagnate. By the late 1990s, not only was Valco no longer needed as a base load power customer, it was consuming large amounts of power for which other customers would have been willing to pay a much higher price. While proper attention to the development of the power sector may have extended Valco's operating life for several years, the reality is that after the Volta River, there are no other sources of cheap power in Ghana. Accordingly, it would likely have eventually met the same fate.

⁵² These figures are calculated assuming that the subsidy is US cents 3.4 and 6.7 per kWh, respectively. See the discussion on Table 4.3.

Nevertheless, Valco has made important contributions to the Ghanaian economy. Whether Valco would justify a subsidy in the future depends on a number of variables, three of which are particularly critical: (a) fiscal contribution, (b) indirect effect on employment, and (c) the opportunity cost of power. In the calculations above, it is likely that the fiscal contribution was underestimated, although it is unclear whether this is significant or not. It is also likely that the employment effects are overestimated and the opportunity cost of power (used to determine the power subsidy) is underestimated. Given the very strong long-run growth in Ghana, it is not likely that individuals who are not employed directly or indirectly by the smelter would become unemployed, which is the underlying assumption. Similarly, the opportunity cost of power measured by the 'true' WTP, even adjusted for the extra costs associated with the distribution of MV and LV power, may well be two or three times the bulk rate of power.

Other Potential Aluminum Smelters in West and Central Africa

Ghana and Cameroon are not the only countries in the two regions in which there has been considerable discussion or movement on aluminum smelters. In Nigeria, they have been viewed as a way of economically using the considerable amounts of flared gas associated with the large oil operations. Given its abundant bauxite and hydroelectric potential, an integrated aluminum industry has long been discussed as a way to kickstart the industrialization process in the Republic of Guinea. If the Democratic Republic of Congo is to develop the enormous hydroelectric potential of the Congo River, it will need large base load customers, of which aluminum smelting is often viewed as a possibility. Nevertheless, there are obstacles to overcome and pluses and minuses for the construction of aluminum smelters in all three countries, as discussed below.

Nigeria

The long-term future of aluminum smelting in Nigeria largely depends on whether it is economical to capture and sell gas that would have been flared to provide the power to operate the smelter. The most immediate issue is the pricing of the gas at a rate that is acceptable to its producers, which is currently not the case, although the experience in the Middle East suggests that it should be well within the range typically needed for profitable aluminum smelting. Moreover, the amount of "associated gas," little of which is currently used in Nigeria, is such that it could provide electricity to all of Sub-Saharan Africa less South Africa (World Bank, 2005).³³ However, natural gas transportation is much costlier than oil, so costs rise quite quickly when it has to be moved via a network. Hence, it can be more

³³ Associated gas is gas that is a residual of oil production. About 75% of Nigeria's gas reserves are associated gas.

profitable to sell it to a local producer (such as an aluminum plant) rather than transport it to a large consumer market for electricity.

The main use for captured associated gas is to run thermal power plants. This electricity can be used for large industrial complexes like smelters, the domestic market or export. The most important consideration is that it is not sold at a subsidized price.⁵⁴ The second is that the gas is receiving its opportunity cost, taking into account both positive and negative externalities associated with its use. Of course, given the delivery costs associated with natural gas and the general complex situation of the Nigerian power market, it could well make sense to provide gas at a lower price to the power plant associated with the Alcon smelter than to less conveniently located power stations.

Guinea

At first glance, Guinea seems the most likely place to locate an aluminum smelter in West and Central Africa, if not all of Africa; it has large bauxite reserves, considerable hydroelectric potential with limited domestic demand, and one alumina refinery with another larger one under construction. Moreover, much of the transport infrastructure is already being developed in the context of the new alumina refinery, which would greatly reduce the capital costs of a new smelter. Nevertheless, despite the fact that Rusal stated in September 2006 that it was considering building an aluminum smelter in Guinea, the company announced in February 2008 that, with China Power Investment Corporation as its partner, it was developing an “integrated” aluminum industry—with the bauxite and alumina coming from Guinea and the aluminum being smelted in China!⁵⁵

However, much of the hydroelectric potential of Guinea is scattered around the country in small projects, with over 2/3 of the reported 6,000 MW being associated with installations of less than 200 MW, many of which would not be viable in the 8 month dry season. Moreover, given the very strong seasonality of rain in Guinea, large reservoirs would have to be maintained for most hydro projects, significantly increasing the costs. In a recent study of the Konkoure River Basin, the country’s most important for hydro purposes, it is estimated that only 725 MW of power could be developed at less than 35 cents/kWh (Amissah-Arthur, 2007: 33).⁵⁶ It seems likely that production costs in most other sites in other river basins would be higher.

In addition, although total domestic demand for power in Guinea is estimated to be only about three times the capacity of the existing 200 MW

⁵⁴ There are reports that the gas price being charged to Rusal would amount to a subsidy of about US\$ 12 million per year, although the price is now being reviewed (Helmer, 2008).

⁵⁵ See Rusmet (2006) and Azom.com (2008) for reports on the two announcements.

⁵⁶ The sites are Kalete (210 MW) at a production cost of 1.84 cents/kWh, and Suoapiti (515 MW) at 3.21 cents/kWh. The Kalete project is dependent on Suoapiti being undertaken first.

system (Amissah-Arthur, 2007: 40), much of the hydro power is compromised as it is being developed under international agreements. Senegal is a joint partner in the development of the Konkoure River Basin, the only one entirely in Guinea, so would be entitled to part of its output. Power developments on all other river basins would fall under agreements for regional power sharing in the West African Power Pool.

In sum, for aluminum smelting in Guinea to be a viable proposition, it would need to be shown that: (a) there is a greater potential for low cost hydroelectric power than what currently seems to be the case; and (b) if so, that there would be sufficient surplus power after increased domestic demand and export obligations to Senegal and WAPP are met. Of course, even if both of these conditions are met, there are many other considerations, including the social and environmental impacts of associated dams and the opportunity cost of the hydro power.

Democratic Republic of Congo

From the perspective of a primary aluminum producer, the DRC is likely the most intriguing prospect in all of Africa. Its untapped hydro potential is estimated at around 100,000 MW, of which 40,000 MW is associated with the Inga Rapids on the Congo River. Inga has already been developed to some extent with two power stations, both of which currently are being rehabilitated with a US\$ 300 million grant from the World Bank. When completed, Inga I and II will see combined capacity increase from 700 MW to 1300 MW of reliable production (out of a potential of 1700 MW). Various schemes for a much larger Inga III have been considered for a number of years. Accordingly, it is not surprising that in October 2007 BHP Billiton signed an agreement with the Government of the DRC to fund a feasibility study for an Inga III hydro power project (Sguazzin, 2007). The feasibility study will be done along with the development of plans for an 800,000 tpy aluminum smelter in the Bas Congo region, not far from Kinshasa. The US\$ 3 billion smelter would have a power requirement of 2000 MW. While the total amount of new hydro would be determined in the study, past discussions of Inga III have mentioned the possibility of 3500 MW.

The development of Inga on a large scale is dependent on finding a large base load customer, at least in the short-run and medium-run. In the long-run, there is the possibility of DRC becoming a major exporter of power, to both Southern Africa and Western Africa, particularly Nigeria.⁵⁷ If the political, environmental and social risks can be managed satisfactorily, it is possible to envisage the amount of hydro power in DRC being expanded over time, at first relying mostly on base load customers such as smelters, but in the longer run absorbing more power domestically and moving to more lucrative power exports.

⁵⁷ The existing transmission corridor from Inga to the SAPP is limited to 1000 MW, although the strengthening of this corridor is currently under study.

Developments in and Lessons From Southeast Africa

An Overview of the Aluminum Industry in Southeast Africa

South Africa has benefited from abundant and cheap supply of electricity ever since the state owned Electricity Supply Commission (Eskom) was established in 1928. Artificially low costs of capital and labor costs during the “apartheid” years, combined with large shallow reserves of reasonable quality thermal coal, enabled Eskom to stimulate industrial development and become a surplus producer, exporting electricity to neighboring countries. The low cost of energy prevented foreign power companies from entering the market allowing Eskom to maintain its monopoly control and supply 95 percent of the country’s power. However, with increasing opposition to apartheid, priority was given to energy self sufficiency, particularly thermal power generation. This resulted in a significant oversupply of power and the mothballing of certain power stations once the oil embargo and growing sanctions began to negatively impact growth from the mid 1970s. Since 1994 the new majority government expanded public access to energy and provided services to rural areas and townships and successfully promoted FDI to encourage the rapid increase in GDP growth. Demand, nonetheless, remained well below supply until around 2004.

The boom in aluminum production in Southeast Africa is largely due to the excess power capacity that Eskom built in the 1980s, when it overestimated demand for electricity. Its establishment in the region was pioneered by the state owned Industrial Development Corporation (IDC) in 1971 to exploit the abundant low cost thermal power with the development of the Bayside aluminum smelter in Richards Bay.⁵⁸ Although the existence of Richards Bay deep sea port and good port facilities (with some upgrading) at Maputo were important, it was the availability of a long-term, low cost power contract that motivated BHP Billiton to expand capacity and build the Hillside Smelter in 1996 and the Mozal Smelter in 2000. It is also important to note that Mozambique has a large surplus of electricity, primarily due to the hydropower plant at Cahora Bassa Dam, 60 percent of

⁵⁸ A controlling interest in Bayside was acquired in 1989 by General Mining and Finance Corporation of South Africa, who in turn was subsequently merged with BHP in 2001.

whose output it exports to Eskom through the South Africa Power Pool, which then, in effect, resells a significant part of it back to Mozal (USITC, 2007: 3-60).

A high capacity rail line, port, and coal handling plant (Richards Bay Coal Terminal) in Richards Bay were first developed to transport thermal coal from the Witbank region of South Africa to the coast for export. At the same time there was an abundance of inexpensive coal for use in thermal power plants, which eventually led to a surplus power situation (ECA, 2004: 93).

There are currently two aluminum smelters in Richards Bay in South Africa—Hillside and Bayside—and one in Mozambique—Mozal in Maputo.⁵⁹ The operator of all three smelters is BHP Billiton, which owns 100 percent of Hillside and Bayside and 47.1 percent of Mozal. The other owners of Mozal are Mitsubishi (25 percent), the Industrial Development Corporation (in South Africa) (24 percent), and the Government of Mozambique (39 percent). Rio Tinto (through its acquisition of Alcan in 2007) has a firm commitment to build a fourth smelter, Coega, in Port Elizabeth, South Africa. A power deal had already been worked out with Eskom for Coega, but electricity constraints have caused Rio Tinto to review the timing of the project and delay its development until 2012. The project was originally scheduled to be developed in two phases in 2010 and 2012.

The Hillside, Mozal, and proposed Coega smelters are all large smelters with capacities of 685,000, 550,000, and 720,000 tpy, respectively. Hillside and Mozal are relatively new smelters, having begun production in 1996 and 2000, respectively. Bayside is an older relatively small smelter with a capacity of 200,000 tpy. In 2006 the three operating smelters produced 850,000 tpy or 4.4 percent of the world's primary aluminum. If and when Coega is commissioned, about 7 percent of the global aluminum supply would be provided from Southeast Africa⁶⁰, requiring some 2,500 MW of power or 6.3 percent of South Africa's current installed capacity of 40,500MW.

In 2004 the United Nations Economic Commission for Africa (ECA, 2004) undertook an in-depth analysis of the impacts of the Hillside, Bayside (to a lesser extent), and Mozal smelters as part of its study "Minerals Cluster Policy Study in Africa: Pilot Studies of South Africa and Mozambique."⁶¹ The analysis looks at the direct, upstream, downstream, and outsourcing (called 'sidestream' in the paper) benefits of the smelters in the

⁵⁹ Sometimes Mozal is referred to as Mozal I and Mozal II; the second is on the same site and is an expansion of the first. If no distinction is made, the text refers to the entire operation.

⁶⁰ There have also been talks and preliminary plans to build an aluminum smelter in Beira, Mozambique, but to date nothing has come to fruition.

⁶¹ As the title suggests, this analysis was undertaken in an economic cluster framework and, accordingly, focuses on economic and social impacts, including employment, and does not evaluate cultural or environmental impacts. At times in the Bayside smelter is included in data on the South African aluminum industry.

two countries. In the case of Hillside and Bayside in Richards Bay, the socioeconomic benefits included (ECA, 2004: 80-89).⁶²

- The creation of 57,355 jobs in 2000, of which 2,750 were direct employment in the smelters; 5,201 were through backward linkages, including outsourcing; 17,397 were through forward linkages; and 32,007 were induced through multiplier effects;
- Over R7 billion in contribution to GDP in 2000, 0.9 percent of total GDP;
- In 1999, 61 percent of Hillside's 1,231 vendors were from South Africa and 32 percent were from Richards Bay;
- As of 1999, Hillside had accredited 45 SMEs as vendors through its development program (discussed further in the next sub-section);
- By 1999 Hillside had provided 50,000 days of training;
- Downstream aluminum pilot project (DAPP);
- Billiton paid R156 million in direct taxes in 1999, which doesn't include employees' income taxes;
- Billiton invested R8,346,364 in community development activities in 1999;
- Large increase in commercial and tourist enterprises in Richards Bay, including over 1,000 new hotel rooms and 24 new restaurants from 1995-2002;
- Hulamin Limited, South Africa's largest fabricator of aluminum semis, proceeded with a R2.4 billion upgrade of its facilities in Pietermaritzburg largely due to the availability of primary aluminum from Hillside and Bayside—this meant an increase in capacity from 50,000 to 185,000 tpy, which fostered an estimated 31,000 jobs throughout South Africa, largely in aluminum finished products;
- Large expansion in infrastructure, which in turn has likely resulted in the decision for other large firms to locate in the area

In the case of Mozal, near Maputo, the socioeconomic benefits included (ECA, 2004: 116-20):

- At the peak of employment, 9,000 jobs were created during the construction of Mozal I and 6,000 jobs for Mozal II;
- In total Mozal has over 11,000 permanent jobs, while Mozal I through linkages has created another 2,500 jobs (IFC, 2004);
- BHP-Billiton spends US\$ 35-40 million per year on purchases from local Mozambican companies, and at any point in time they usually have between 200 and 250 contracts with local suppliers;
- US\$ 330 million contribution to GDP in 2004 (10 percent) and a more than tripling of export earnings—however net exports are likely to be

⁶² These figures relate to the period prior to a major expansion in Hillside in 2003 so probably underestimate the benefits by about 15 percent to 25 percent

lower as Mozambique imports both power and raw materials, so large increase in imports are likely to offset a large part of exports of aluminum;

- Over US\$ 8 million were paid in taxes by Mozal in 2004;
- Through the Mozal Community Development Trust, BHP-Billiton spends about 1 percent of pre-tax profits on community initiatives, US\$ 2 million in 2002;
- Over 8000 students have benefited from educational upgrades, including 40 new classrooms and a new secondary school;
- Through Small and Medium Enterprise and Empowerment Program, between 2001 and 2003, 28 companies benefited from over US\$ 5 million in contracts with Mozal; and
- Big increase in quality and quantity of infrastructure, particularly in Beluzone Industrial Park.

Lessons for West and Central Africa from Southeast Africa

The overarching rationale for a government of a low-income country to support the installation of an aluminum smelter is for the contribution it can make to the long-run sustainable development of the country. This contribution can be realized through three non-exclusive mechanisms comprising:

- The first, and historically most common, is that the smelter serves as a base load anchor for a power generation facility that would otherwise be unviable due to lack of economies of scale;
- second, the smelter provides a strong balance sheet to promote and support a large number of externalities due to the infrastructure associated with its construction and operation, such as roads, rail, port facilities, and of course power. This encourages other businesses to be developed; and
- third, the smelter has a strong multiplier effect on employment and GDP due to backward and forward linkages and out-sourcing activities. In particular, the existence of the smelter leads directly to the development of a large amount of human capital, including entrepreneurship, which is essential for the long-run sustainable development of the country. The second and, especially, the third mechanisms imply that the aluminum smelter does not become an enclave where the only individuals to receive substantial direct benefits are its employees and shareholders.

However, as discussed in section 1 and emphasized in section 3.1 on Ghana, if a smelter operation outgrows its role as a base load anchor and becomes a fiscal drag on the country, its contribution to the second and

third mechanisms of sustainable development become compromised. In South Africa power demand has caught up with supply due to a combination of rapid economic growth, increased rural access and limited investment in new generation. Systematic load-shedding since 2007 was insufficient to prevent the complete closure of the important mining sector in January 2008, leading to the delay (suspension) of the Coega aluminum project and cut backs of about 120,000 tonnes by BHP-Billiton.

It is important, therefore to make realistic predictions of the supply and demand for power in the host country (or region) over the medium-run and long-run. Most smelters will need about 20 to 25 years operating life to make a reasonable return on the investment; hence, some degree of certainty that there will be low cost surplus power for that length of time is necessary. Nevertheless, the owners of the smelter cannot expect a 'free ride' on power, and it is therefore important to incorporate automatic increases in power prices that reflect its opportunity cost. In fact, given the high degree of uncertainty associated with such estimates, it may be desirable from a contractual point of view to ensure power prices reflect production costs after a certain length of time and opportunity costs thereafter.

Consequently, in drawing lessons for West Africa from the southern African experience, in addition to the availability of abundant low cost power, two main issues arise:

- How can economies of scale or scope be exploited with respect to infrastructure development; and
- how can backward and forward linkages be enhanced, including the use of a significant and increasing amount of domestic outsourcing by the aluminum smelting company, all of which contribute to local community and regional development and the eventual development of an industry cluster.

Infrastructure Development

In the case of South Africa it is difficult to attribute infrastructure development directly to the aluminum smelters. Nevertheless, it was the development of the Richards Bay deep sea port and coal terminal and other regional infrastructure coupled with cheap power that motivated BHP Billiton to build the Hillside smelter. In turn, the existence of Hillside and the older Bayside smelter were important catalysts for the development of a wide network of local and regional infrastructure, which has attracted other large industries to the area. In sum, there has been a virtuous circle of infrastructure (as well as human capital) development associated with the smelters and other industries in the region.

Mozal in Mozambique is a clearer cut case of the aluminum smelter

leading to a large increase in infrastructure. Mozal was the first client to be based in a large industrial park, Beluzone, 16 kilometers outside of Maputo. It is the key anchor project of the Maputo Development Corridor, which links Maputo and its port with major South African cities along the N12 highway and with the South Africa rail utility, Spoornet (ECA, 2004: 115). In order for Mozal to operate it was necessary to reactivate two idle power stations and bring in 400 KVA high tension power lines from South Africa, from which other consumers in Maputo also benefit. Moreover, in addition to the port and industrial park, the local infrastructure had to be vastly improved. An additional indirect impact of Mozal has been the construction of local public infrastructure including a residential complex, landfill site, access roads, water supply and telecommunications systems. From its opening in 2002 to January 2006, the Beluzone Industrial Park has attracted 15 other firms.

The situations in South Africa and Mozambique are quite different with respect to infrastructure development. In the former a strong infrastructure network attracted industries to the area; in the latter, a very large investment project was the incentive to develop or greatly improve infrastructure. In neither case did the aluminum smelter play an important anchor role for the development of electric power, although in both cases surplus power was available and sold to the companies, a situation that has only recently come to an end.

The main lesson to be drawn by countries in West and Central Africa is not that a country should develop its infrastructure to attract an aluminum smelter. Rather, it is that if a company is considering an investment in an aluminum smelter in a country, strong attention must be paid to infrastructure considerations or the smelter will be operated in an enclave matter. Accordingly, if the reason for promoting investment in an aluminum smelter goes beyond using it as an anchor for a large (hydro) power project, it is essential that the infrastructure is (or will be) in place to allow for the development of upstream and downstream linkages as well as to attract other large-scale investments. This does not imply that good infrastructure will guarantee that the smelter makes a substantial contribution to sustainable development. In the next sub-section other initiatives to cultivate these important linkages in Southeastern Africa will be discussed.

Linkages and Outsourcing

Although Bayside was the one of first large industries in the Richards Bay area, the Hillside Aluminum Smelter was part of an ongoing initiative between government and the private sector to transform the Richards Bay area into an important industrial cluster, of which the aluminum industry is the key but far from only part. In addition to prudent macroeconomic

management, the GORSA's role has been to provide the national and regional infrastructure, incentives for research and development, and assist in developing the human capital, either directly or through incentives for company run training programs. Richards Bay is now one of the most dynamic areas of Southern Africa and the recent construction in the area by Ticor, Australia of a large illmenite smelter is another indication of the attractiveness of the region for investors.

By themselves, the two aluminum smelters have played a very important role in the region with respect to job creation and the development of human capacity. Hillside, itself, had contracts with 395 local vendors and 756 South African vendors in 1999, even before the expansion of 2002. ECA (2004: 86) estimates that the two smelters created 5,200 jobs in South Africa through domestic outsourcing in 2000, not including multiplier effects. While Hillside exports most of its product, Bayside sells 65 percent of its output nationally, either in the form of slightly processed primary aluminum or semis. ECA (2004: 86) estimates that over 17,000 jobs were created in South Africa in 2000 through forward linkages, again not including multiplier effects.

Of particular importance is Hulamin—called Hulett Aluminium until March 2007—in nearby Pietermaritzburg. Hulamin is the most important producer of aluminum semis in Sub-Saharan Africa and supplies metal to general engineering, building, transport, cookware and electrical firms. After a major expansion in 2000, its capacity increased from 50,000 to 200,000 tonnes per annum, and an ongoing expansion will increase it to 250,000 tonnes. In addition to the more than 2,000 Hulamin employees, ECA estimate that it fosters more than 31,000 jobs throughout South Africa (2004: 84).

In addition to contributing to the industrial cluster in the Richards Bay and Pietermaritzburg region, the two aluminum smelters and Hulamin are all actively involved in fostering more linkages to SMEs and specific training for employment and advancement in their facilities. Hillside and Bayside Aluminium directly support and incorporate SMEs into their activities. According to ECA (2004: 81):

“[As of 2002] Hillside Aluminium had 45 accredited SME companies on their database. In order for an enterprise to be registered as an SME, two requirements have to be fulfilled. Firstly, at least 55 percent of the equity has to be owned by someone from a previously disadvantaged economic background. Secondly, the enterprise must be willing to enter partnerships with larger vendors in order to facilitate a transfer of skills and technology in order to provide a base for the future growth of the business.”

Note that both companies (and other large businesses in Richards Bay) undertake vendor evaluations in order to determine the assistance that will

be necessary to ensure quality and competitiveness and help SMES access resources such as finance, technology, and business development information. In addition, as part of the BHP Billiton Development Trust, the smelters are involved in the Downstream Aluminum Pilot Project, which will assist potential entrepreneurs from local communities with the establishment and management of their own downstream aluminum manufacturing enterprises from infancy through to independence.

Finally, the smelters place considerable emphasis on employee training and skill development. Before Hillside began operation, for example, approximately US\$ 4 million and 50,000 days of training were invested to ensure that all employees were well-equipped to operate and manage the technology and equipment (ECA, 2004: 82). In addition, Hillside has an Accelerated Development Program, where highly skilled employees acquire in-depth training to enable them to use their equipment more effectively.

Although not of the same magnitude, in some ways the situation in Mozambique is more dramatic than South Africa, given the state of the economy of the former at the time of Mozal's construction. In addition to the infrastructure discussed above, the smelter has had a large impact on job creation in the Maputo area. According to IFC (2004), by mid-2004, Mozal created over 1100 full-time jobs, 89 percent of which were Mozambican, and Mozal I alone had created 2,500 indirect jobs through linkages with the rest of the economy. On average Mozal has between 200 and 250 ongoing contracts with local firms (ECA, 2004: 116). Over 60 local companies received contracts during the construction of Mozal II. As noted above, the creation of the Beluzone industrial park means that local firms can get access to high quality facilities.

During construction of Mozal II, the company ran a program targeting SMEs, called the SME Empowerment Linkages Program (SMEELP). SMEELP enabled 15 local SMEs to win and deliver contracts valued at over US\$ 5 million to this project. The entire Mozal operation currently supports Mozlink, which assists SMEs in winning and delivering contracts to its operations. By late 2005, Mozlink had already successfully supported SMEs in winning a total of US\$11 million in contracts (Thomas, 2005). Additionally, Mozal established the Mozal Community Development Trust (MCDT) with an annual budget of US\$ 2 million in support of the local community. The MCDT supports small business development, education and training, health and environment, sports and culture, and community infrastructure for the communities within a 10 kilometer radius of Mozal (Thomas, 2005).

It is important to highlight that success with SMEs mostly came with Mozal II, as Mozal I had failed to develop effective linkages to the local Mozambican economy. The main reasons for this failure were that: (i)

Contracts were 'bundled', including several components that local SMEs could not fulfill; and (ii) contracts were in English. With SMEELP (and later Mozlink), Mozal II developed a specialized program that identified contracts that could be sourced locally, trained local entrepreneurs on tendering, and provided training and mentoring to SMEs that won contracts (Thomas, 2005: 11).

Despite the very different situations with respect to infrastructure and human capital, the aluminum smelters have had strong impacts on their local areas with respect to creating linkages. In the case of Mozal, this has been largely through outsourcing or backward linkages, including assistance to SMEs and training in general. In the region of Richards Bay (and South Africa more generally), there have also been extensive downstream linkages through the processing of primary aluminum into semis and then further into manufactured final products.

With the exception of Nigeria—which is probably somewhere in between—the situation of West and Central African countries is more akin to Mozambique than South Africa, so there may be more lessons to be garnered from the former than the latter. Nevertheless, South Africa's aluminum industry cluster does illustrate what can be achieved over time with strong and persistent government policies and public-private initiatives and partnerships.

The case of Mozal shows that there can be substantial indirect benefits generated by a highly capital intensive industry such as an aluminum smelter. It is important for national and local governments to work closely with the owner of the smelter to identify possibilities, including human capital shortages and related training needs. It is particularly important for the company to have an active involvement with SMEs in order that they deliver the high quality inputs required by the smelter's operations. At the same time, if local infrastructure is only dedicated to the smelter, it will be difficult for SMEs to have the required efficiency.

In the last five years Mozal has spent considerable funds on local community development. It is important that projects funded in these types of umbrellas have a heavy focus on developing skills that are required by the smelter or related industries, whether upstream or downstream. There is a substantial and increasing literature on how trust funds or foundations can have the largest contribution to local and regional sustainable development. It is too early to tell how well Mozal has learned from this global experience, but the evidence given by the vastly improved performance from Mozal I to Mozal II is encouraging.⁶³

⁶³ Note that the South African Development Community's Development Finance Resource Center announced intentions to finance research on Mozal and the Maputo Development Corridor, the results of which should provide valuable lessons to other countries in Africa (Thomas, 2005).

Conclusions and Recommendations

This section begins with general conclusions and recommendations with respect to the aluminum industry in West and Central Africa, most of which should be relevant for any developing country. These are followed by conclusions and recommendations that are specific to the current situation and potential developments in West and Central African countries. The focus is on the aluminum smelting stage, although some remarks are also directed to the development of an integrated aluminum industry.

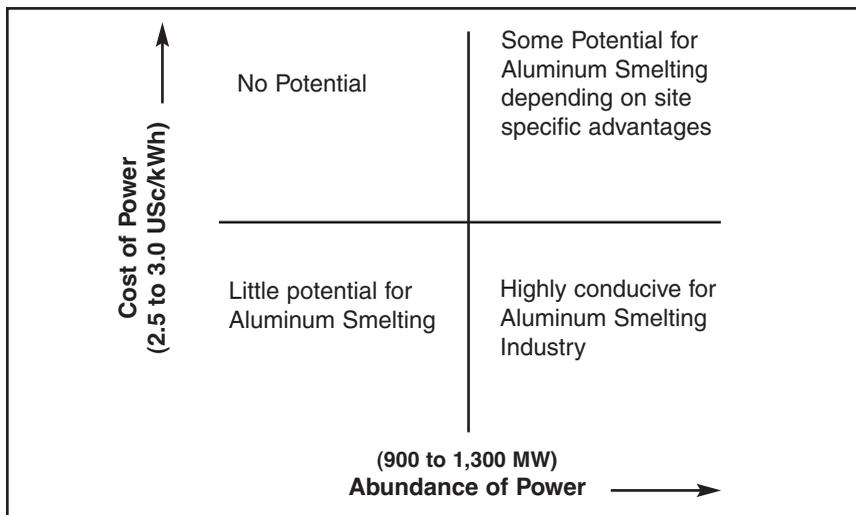
Since power is the main variable conversion cost in the smelting process and the costs of other inputs vary in a much narrower range than the cost of power around the world, the key determinant in situating an aluminum smelter will be the availability of a large, low cost source of power. Consequently, it is unlikely that a company on its own can undertake an independent analysis of the viability of a smelter and then make its decision. Given the importance of energy in any economy, the government and power companies (private or public) must, of necessity, be heavily involved in most cases in the decision making process. Hence, it is more accurate to say that an aluminum company and the government of a country must jointly decide on whether or not to open a smelter, even in an economy that is market oriented.

It is essential that 'surplus' power be available over an extended period. If this power is likely to be in demand by other customers with a higher willingness to pay in the short-run or even medium-run, then the smelter will be competing for this power and be viewed as an albatross rather than a boon for the economic development of the country. The amount of surplus power required to enable a potential smelter to fully contribute to a country's economic development can be defined as not only meeting the power needs of the smelter considered (for a typical modern greenfield smelter of 500,000 to 700,000 tons this would require an installed generation capacity of between 900 and 1300 MW AC.) plus the projected increase in power consumption by other users/consumers over the next 20 to 25 years.

Figure 6.1 shows four combinations of the availability and cost of power.

Clearly, if a country is in the lower or upper left side quadrant with limited or no power surplus, an aluminum smelter is not viable. Moreover, even if there is an abundance of power but its cost is relatively high—more than 2.5 to 3.0 US cents/kWh, the upper right side quadrant, a smelter will not be viable based on long-term aluminum price trends (see para 2.9). Only in the lower right side quadrant is there a potential for an aluminum smelter.

Figure 6.1: Country Options Regarding Availability of Low Cost Power



One of the main inputs in aluminum smelting is alumina, which in turn depends on bauxite ore as a critical input. Accordingly, many countries with bauxite deposits are tempted to develop an ‘integrated aluminum industry’. Given that these are globally traded commodities with international prices, each of these (stages) investments must be evaluated on its own merits. Moreover, in contrast to an aluminum smelter, the decision to invest in either a bauxite mine or alumina refinery is not dependent on the availability of low-cost power. In a developing country with few major industries, it is often argued that a government should subsidize a select number of industries, partially to offset the other disadvantages to locating in their country (e.g., poor infrastructure, small local markets). Nevertheless, such a subsidy is always at the expense of other industries and tax paying consumers. There are job creation and related benefits to having a mine, a refinery or a smelter located in the country—mostly from outsourcing the provision of goods and services—but the backward and forward linkages are generally relatively weak. The former have already been discussed while the latter are dependent on having fairly large local markets

On the basis of these conclusions it is recommended that:

Recommendation 1: Only if there is an abundance of power that has both a low production cost and a low opportunity cost for at least 20 years is a government in a position to consider entering into a long-term power contract with an aluminum smelting company—either directly or through a regulated utility.

Moreover, given that the operation of the smelter will be highly dependent on the country's natural resources, the government should ensure that it obtains its fair share of the resource rents.

Recommendation 2: Regardless of the site specific conditions, the power tariff to an aluminum smelter should be based on the long-run marginal cost of supply since the linkage effects will not normally justify significant power or tax subsidies for a bauxite, refinery or aluminum development.

Recommendation 3: A government keen to attract investment in smelting to exploit its hydro-potential should consider the introduction of a risk-sharing long-term bulk supply agreement where the power-tariff is linked to the aluminum price. Such a contract would typically have a floor to the power-price, designed to ensure full cost-recovery of the cost of power up to a certain aluminum-price. Thereafter the tariff would increase in line with metal-prices, without a ceiling, enabling the power company and/or the Government to capture part of the upside. The Government could consider applying the same structure/arrangement to the hydraulic resource rent collected by the Government.

Recommendation 4: Cameroon, Ghana and Guinea have all indicated strong interest in developing integrated aluminum industries. While there are cost advantages to having a nearby source of bauxite for alumina refining this is much less the case for the co-location of a nearby source of alumina for aluminum smelting, accordingly, the decision to invest in one stage of the industry is taken largely independently of decisions to invest in other stages.

These recommendations lead directly to specific recommendations on the aluminum industry in West and Central Africa.

Recommendation 5: In the absence of a new source of low cost power, the reopening of the Valco smelter in Ghana would require substantial state subsidies and should remain closed.

Recommendation 6: The continuation of the current Alucam smelter in Cameroon without a major extension and hydropower development is questionable. However, studies indicate that a major extension could be

feasible as Cameroon has the hydro-power capacity potential to supply low cost power. Nevertheless, it is not clear that the planned expansion in power in Cameroon—both hydro and thermal power—will result in a surplus for a period long enough to ensure the viability of the smelter. Consequently additional information should be developed on several critical variables, including the WTP of other Cameroonian power consumers for additional large blocks of power; delivery costs of HV versus MV and LV power; and the potential fiscal contribution and the multiplier effects of Alucam. The issues of the allocation of the power sites (Nachtigal, Song Mbengue) and the hydraulic rent to be paid by Alucam to the GOC should also be addressed.

Recommendation 7: The viability of the Alscon smelter in Nigeria depends heavily on the availability of power from a natural gas powered thermal plant. It is essential to determine whether this gas, including associated infrastructure, can be provided at a price that covers full cost but is low enough to make the smelter viable.

Recommendation 8: Given the small size and seasonality of most potential hydro power sites in Guinea, it is questionable whether the country can provide enough low cost power to justify the construction of an aluminum smelter.

Recommendation 9: A country in the region that does have the potential for abundant low cost power over a long time horizon is the DRC at the Inga Rapids on the Congo River. The studies, which are currently underway, aim to demonstrate the viability of using an aluminum smelter as a base load customer to support the further development of this power source. In the long-run, after the development of extensive infrastructure, this power could be a vital resource for economic development throughout Sub-Saharan Africa.

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Annex 1 An Economic Model of the Aluminum Industry in Cameroon

- 1a. $P_A \geq AC_A(P_E, P_{AA}, X)$ is required for profitable production⁶⁴
 1b. $LRP_A \geq LRAC_A(LRP_E, LRP_{AA}, LRX)$ is required for production

P_A = Price of aluminum

AC_A = Average Cost of Aluminum

P_E = Price of Electricity (WTP for large block of electricity by other consumers; in the calculations, the current price paid by bulk consumers in Cameroon is sometimes used as a proxy for a minimum WTP)

P_{AA} = Price of Alumina

X = All other costs

LR in front of a variable signifies in the long-run; for the purpose of this study that means when aluminum and alumina prices revert back to trend around 2012; for the rest of this section the LR equations will not be written out explicitly; however, in the calculations, several of the variables are determined in both the short-run and medium-run to long-run.

2. Determine P_E^* , where $P_A = AC_A$; this is the key relationship, where the price of electricity would be such that the plant would not make a loss taking all other factors as given.

P_E^* = Break-even price of electricity for aluminum smelting.

$$3. S = (P_E - P_{E,ALU})Q_E$$

S = Actual Annual Power Subsidy to Alucam

$P_{E,ALU}$ = Historic or contracted price for electricity paid by Alucam

Q_E = Annual Quantity of Electricity used by Alucam

$$4. S_{MIN} = (P_E - P_E^*)Q_E$$

S_{MIN} = Minimum annual power subsidy need to keep Alucam operating at current levels of production.

⁶⁴Unless stated otherwise all variables refer to the price per unit or the amount per year.

Major Extension

$$5. P_{E,N} = AC_{E,N-W} + P_{W,ALU}$$

$$6. P_{E,N} \leq PE^* \text{ for Alucam to operate}$$

$P_{E,N}$ = Implicit price of power produced in Nachtigal

$AC_{E,N-W}$ = Average cost of units of power from Nachtigal excluding water flow charges

$P_{W,ALU}$ = Price for water flow needed to produce one unit of electricity (one water flow unit) that is charged to Alucam by GOC

$$7. AC_W = AVC_W + AFC_W$$

AC_W = Average cost of one water flow unit

AVC_W = Average variable cost per water flow unit

AFC_W = Average fixed cost per water flow unit

$$8. AFC_W = TFC_W / (n * Q_W)$$

TFC_W = Total cost of building the LP dam

n = the number of years over which it is expected to recover the cost of the dam

Q_W = Quantity of water flow per year

It is assumed here that the cost of building the LP dam is amortized over n years. Normally it would be necessary to bring in the interest rate but as we are only trying to obtain a rough figure for a typical year, we omit this.

$$9. SUB = (AC_W - P_{W,ALU}) Q_{W,ALU}$$

SUB = Annual subsidy to Alucam for water use⁶⁵

$Q_{W,ALU}$ = Annual number of water flow units used by Alucam

This would be the annual subsidy to Alucam. Unless there were externalities (tax revenues, employment generation, net foreign currency contribution, etc), that more than offset this subsidy plus any other losses due to the creation of the dam (environment, habitat, livelihood) and power plant (environment), then it would not be recommended to construct the LPD.

$$10. P_A \geq AC(P_E, P_{AA}, X) \text{ is required for production.}$$

⁶⁵ It is assumed here that in the short-run and medium-run, there are no other significant customers that would drive the market price of the water flow above the average cost of the water flow.

AC' = Average cost of aluminum with local alumina supply

P_{AA}' = Price of alumina with no shipping costs

X = All other costs

11. Determine P_E' where $P_A = AC'$, $P_E' > P_E^*$ (from (2))

P_E' = Break-even price of electricity when there is a local alumina supply;
this would be higher than the break-even price with imported alumina

11. $TFR = TAX_{ALU} + TAX_{ALF} + TAX_{LINKS} + TAX_{LINKS,LF}$

TFR = Total fiscal revenue generated directly or indirectly by Alucam
(excluding multiplier effects)

TAX_{ALU} = Taxes paid by Alucam

TAX_{ALF} = Taxes paid by Alucam labor force

TAX_{LINKS} = Taxes paid by companies with strong upstream and downstream
linkages to Alucam (including outsourcing)

$TAX_{LINKS,LF}$ = Taxes paid by labor force of linkage companies to Alucam

This amount does not include the taxes generated indirectly due to multiplier effects of expenditure of Alucam and linkage companies or the employess of Alucam and linkage companies. However, it overestimates the amount of tax revenue generated by companies that have downstream and upstream linkages with Alucam as it assumes either that they would not exist otherwise or that the entrepreneurs would not have created other companies. In sum, the total should be a good rough approximation. Note that in practice, the tax revenue paid directly by Alucam is multiplied by the GDP multiplier to get the total figure.

12. $TAX_{ALU} = PRT_{ALU} + INCT_{ALU} + EXT_{ALU} + IMD_{ALU}$

PRT_{ALU} = Profit Tax paid by Alucam

$INCT_{ALU}$ = Income (corporate) tax paid by Alucam

EXT_{ALU} = Export tax paid by Alucam

IMD_{ALU} = Import duties paid by Alucam

13. $SUBJOB = (S - TFR) / (ALF + LF_{LINKS})$ or $SUBJOB = (SUB - TFR) / (ALF + LF_{LINKS})$

SUBJOB = Average power (S) or water (SUB) subsidy per job created directly and indirectly by Alucam

This figure gives a rough estimation of the subsidy per job under different scenarios with respect to the availability and price of power.

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Notes

Notes

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