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STATUS OF THE WORLD ALUMINIUM INDUSTRY

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Explanatory notes

The following abbreviations are used:

CVG	Corporacion Venezolana de Guajama
EAA	European Aluminium Association
IPAI	International Primary Aluminium Institute
GDP	gross domestic product
NCW	Non-communist world. This is an anachronism but has been retained until political and economic relations between the former Union of Soviet Socialist Republics and eastern Europe and the rest of the world become clearer
OECD	Organisation for Economic Co-operation and Development
USEPA	United States Environmental Protection Agency

Contents

Page

Figures

Tables

Introduction

The history of mankind is often divided into different ages according to the technological level reached. Thus, one speaks of the Stone Age, the Copper Age, the Iron Age etc. Since aluminium was discovered one hundred years ago, it has become a very important metal for the technological advancement of the human race, despite being one of the youngest metals. If these last one hundred years of human history were to be given a name, it would not be an exaggeration to call them the Aluminium Age.

The present report gives an overview of the aluminium industry. Chapter I introduces aluminium as a material for the future. Chapter II reviews the economic aspects of the aluminium industry. Chapter III describes primary aluminium production in different regions of the world. Chapters IV, V and VI deal with the bauxite, alumina and caustic soda industries, respectively, as parts of the aluminium industry. Chapter VII presents an overview of market conditions for the aluminium downstream industry. Chapter VIII, the penultimate chapter, discusses one of the most important aspects of the industry, its environmental aspect. Chapter IX, the last chapter, presents the conclusions of the report.

I. Aluminium

The only metal whose annual production exceeds that of aluminium is iron. Not only is the aluminium industry the largest of the non-ferrous metal industries, it is also the youngest: aluminium smelting began just 100 years ago, by the Hall-Heroult process [1]. Certain properties of this metal, such as its lightness and durability, its corrosion resistance and good electrical and thermal conductivity, have encouraged its use in all sectors of the economy. Its good appearance and recyclability have added to its appeal.

Aluminium is a versatile metal and is employed in a diverse range of applications in a large number of industries. In almost all its uses it is alloyed with other metals to increase its strength and machinability. There are currently over 100 alloys in everyday use, and others continue to be developed as the major producers attempt to increase the metal's acceptability.

The total world output of aluminium has reached 365 million tonnes to date, 70 per cent of which was produced in the 1970s and 1980s. The metal can be cast, rolled or mixed with other metals, such as copper, zinc and magnesium, to obtain additional properties [2].

In its unalloyed form, aluminium is resistant to corrosion and has high electrical and thermal conductivity. Metal with a purity of greater than 99 per cent is mainly used in the electrical and chemical industries. In its chemical uses, it has no real substitute, but in volume terms this use is a minor one. In the electrical sector, it competes head-on with copper.

The addition of copper in small quantities (4.0-6.5%) confers high strength but impairs corrosion resistance. Such alloys, which may also contain minor quantities of manganese, silicon, magnesium, nickel, titanium or vanadium in various permutations, are typically employed in the aircraft and building industries, usually in fairly heavy-duty applications. In these applications the main competition comes from stainless steels and from carbon-dispersion-strengthened alloys and other composite materials.

When manganese is the major additive the result is a moderately strong alloy that is readily workable although non-heat-treatable. Such alloys are used mainly in the construction and automotive sectors. In the latter sector, aluminium is used for truck bodies, where it competes with various coated steels. Silicon-based alloys compete with iron and steel in engine component applications.

The addition of silicon lowers aluminium's melting point without making it brittle, while magnesium imparts very high corrosion resistance. Alloys of aluminium with silicon and magnesium in various quantities are the most widely used aluminium alloys. They are employed in a diverse number of applications in the construction, transport and engineering sectors, where they compete with a wide range of stainless and coated steels, copper, plastics and composites.

The magnesium and manganese alloys of aluminium are widely used in can body stock, which has been a major growth area in recent years. Here, aluminium has made inroads at the expense of tin plate in the beverage can and aerosol sectors. However, it is not having things all its own way and is coming under pressure from other materials. Aluminium/magnesium foil competes with paper and plastics. Other alloys have been developed for special applications. Examples of this include several aluminium-tin alloys, which have very high fatigue strength and are employed in various high-stress engineering applications such as bearings and bushings. In the aerospace industry, aluminium-lithium alloys continue to make inroads, although carbon-reinforced composite materials provide strong competition.

II. Economic aspects of the aluminium industry

A. Historical overview

After the Second World War, demand for aluminium grew at an average rate of 8-9 per cent, inspiring a rapid expansion of primary production capacity that eventually led to supply being in excess of market demand. The energy crisis of 1973 and the international recession that followed exacerbated the situation. Demand for aluminium products collapsed and prices plummeted. Despite new energy price pressures and growing capital costs, however, world demand continued to grow at 4.3 per cent per year, and the production of primary aluminium grew in line with this.

Since the late 1970s, the aluminium industry has gone through three major price cycles, with peaks in 1980, 1983 and 1988 and lows in 1982 and 1985 [3]. Figure I shows the behaviour of the aluminium market from 1980 to 1990.

By the 1980s, a four-year growth-recession cycle had developed. The boom periods of 1980 and 1984 were the result of rapidly increasing demand, spurred by general economic growth. The current boom in aluminium markets, however, seems to have been mainly inspired by the extremely low aluminium prices in 1989 and thereafter. The availability of cheap material has restrained the development of substitutes, while at the same time opening new applications.

The boom periods were usually brought to an end by the excessive reopening of mothballed capacity, generating an imbalance in demand and supply. After a while, the surplus output encouraged the next downturn. The response by the aluminium industry was extensive restructuring, involving capacity trimming, the modernization of existing plants, diversification, forward integration and other shifts in the pattern of production. This restructuring process, which mainly affected the aluminium smelter stage of the industry, entailed large closures of capacity in Japan, the United States of America and Western Europe and the addition of new smelters in Australia, Canada and Latin America.

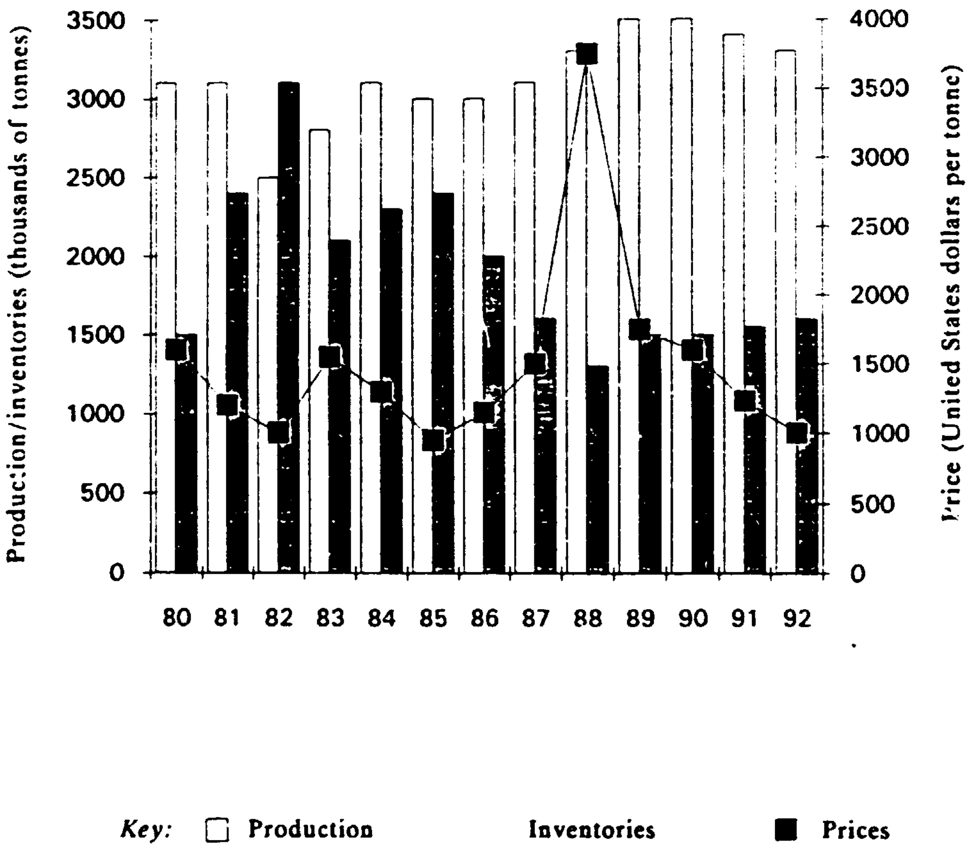
B. Recent trends

In the most recent cycle, the first fruits of these steps were noticeable by 1986. In 1987 aluminium prices recovered, despite the worldwide collapse of the stock market. The upswing continued into 1988, reflected in aluminium production, consumption and trade. Despite the recommissioning of almost all available capacity, demand continued to exceed supply throughout 1988.

Aluminium prices peaked at their historical high in June 1988, the culmination of several years when demand increased more rapidly than supply and inventories were reduced. Since then, prices have declined. However, the markets remain very closely balanced, in spite of the fact that total production is currently 30 per cent higher than in 1982. It is estimated that demand increased 2-3 per cent in 1991 and that it will have increased at a slightly higher rate in 1992. Additional capacity coming on stream during the period should suffice to keep the market in balance, although a slight surplus could develop if recessionary tendencies grow stronger. Aluminium prices are not, however, likely to fall below US$ 1,430-1,650 per tonne for an extended period. As regards alumina, an earlier tight supply situation has eased with increasing production, and prices, particularly on the spot market, are decreasing. Bauxite prices are expected to remain steady [4].

The main factors affecting demand for primary aluminium have been slow economic growth worldwide, the declining importance of manufacturing in gross domestic product (GDP), a slow-down in the process by which aluminium is replacing other materials, reductions in inventories resulting from the introduction of just-in-time delivery and an increase in the rate of recycling

Figure I. Prices, production and inventories of aluminium a/



Sources: International Primary Aluminium Institute (London); United Nations Conference on Trade and Development (UNCTAD), *Monthly Commodity Price Bulletin*.

a/ Prices are year averages of the London Metal Exchange for standard grade (99.5% Al) 1980-1988 and high grade (99.6% Al) 1989-1990.

aluminium scrap. Of these, the slowdown in the process of substituting aluminium for other materials is of special importance. The sectors expected to make the largest contribution to continued growth in demand are transportation and packaging. On the supply side of the industry, the restructuring process, which was brought about by changes in the price of energy, the aluminium pricing system, government policies and corporate strategies, has changed the geographical distribution of production. The industry has as a consequence been transformed from what could be described as an ordered oligopoly into a more complex structure. While it has retained several oligopolistic characteristics, the new structure also exhibits many complicated and multifaceted relationships. Developments in the international trade of bauxite, alumina and aluminium reflect shifts in the distribution of production. This has caused international trade in aluminium to increase more than consumption.

Owing to the supply/demand imbalance for primary aluminium, the market softened during the second half of 1990 and prices declined. Demand was lower than expected because of the recession in the United States and the United Kingdom of Great Britain and Northern Ireland and the many economic and political uncertainties surrounding the Persian Gulf crisis.

The year 1990 was the lowest point of the current economic cycle. One of the main reasons, as was mentioned previously, is that the major economies have not been synchronized in their business cycles. Thus, after the worst of the recession had been seen in the United States, Canada and the United Kingdom, where output fell in 1991, robust growth continued in Germany and Japan. It is likely, therefore, that the expected economic upturn in 1992 will be more subdued than in past cycles.

The end of the Persian Gulf war did not improve the position of the metal since the United States and the United Kingdom were still in recession. Prices remained low (US$ 0.70-0.71 per pound) and were not expected to improve much during 1991 owing to the additions to world smelting capacity. The current cost/price ratio is not very favourable, and costs in major metal-producing countries such as the United States could rise in the near future owing to the strict enforcement of certain environmental regulations. Stocks are being drawn down rapidly. If the economic situation improves, 1992 should be a better year for the industry, but in October 1991 Commodities Research Unit Ltd. reported average prices for 1992 below those for 1991 [5].

The outlook has worsened for three reasons [5]:

(a) The aggregate capacity utilization for 1990 reached 96.1 per cent, higher than in the two previous years. Compared with what is needed to balance the market, the closures at the beginning of the decade represent only a drop in the ocean;

(b) Net exports by eastern Europe during 1991 were around 52,000 tonnes, much higher than had previously been thought. They were a major contributor to the world market surplus of 812,000 tonnes;

(c) The economic recovery in 1991 was weak and erratic, with improvement in the United States being offset by a slowing down in the economies of Japan and Germany. In 1991, the price of aluminium was US$ 1,250-1,300 per tonne. Prices were at a lower level in inflation-adjusted terms than at any time in the 1980s. It is difficult to see why they should recover; unless there are significant cuts in production in the West, there is unlikely to be any price upturn in 1992.

The alumina market is also soft due to an oversupply situation and increasing stocks. Spot prices have declined to US$ 195-200 per tonne and are likely to remain at those levels for the rest of the year. Some improvement in the market is expected by next year as the demand for primary aluminium increases.

The market for traded bauxite is currently in better shape than that for alumina. However, additional output from Brazil, Venezuela and Guyana could cause it to become softer by the end of 1991 and remain in that position during 1992 as well. Substantial improvements are expected in 1993.

C. Future trends

The flow of bad economic news seems to be ending. True, the economic slowdown from August 1990 onwards was severe, and though Japan and Germany were very resilient, the

American and British economies were hard hit, with construction particularly badly affected. But leading indices strongly suggest that the recovery is now starting. And with interest rates falling and inflation low, the rebound could be more vigorous than many expect. Anthony Bird Associates [6] thinks that industrial output in the countries of the Organisation for Economic Co-operation and Development (OECD) should rise by 3.5 per cent in 1992 after a small fall in 1991. From 1993 onwards, growth should reach 4.5 per cent for a while. And signs are that the metal-using industries will do at least as well as the average. But an eye must be kept on the progressive collapse of the economy of the former Union of Soviet Socialist Republics and on oil prices, although neither factor is expected to abort the recovery.

Aluminium consumption held remarkably when the economic situation was at its gloomiest and will even record a small rise in 1991. One reason for this is that consumers stocks are low, thanks to just-in-time delivery, so that the consumer stock cycle does not magnify any economic shocks, as it did 10 years ago. In addition, aluminium's competitive position remains excellent in every market that has been examined. Part of this competitive edge will be eroded when metal prices recover, especially in 1993 and 1994. However, it is expected that from 1992 onwards consumption will grow 4-5 per cent per year.

In spite of this resilience in demand, aluminium stocks have grown. One reason is that the Soviet Union, desperate for foreign exchange, stepped up its exports of the metal (from stock, however, not from current production). Producers in the West have found it difficult to adapt to this by cutting production: the swing plants nowadays are the European plants, which are less flexible than the American plants that occupied the swing position in the last cycle. Some production cuts are now being made, but so far they are merely matching the rate at which new smelters are coming on stream. This situation cannot last. For one thing, at current metal prices, only 5.3 million tonnes of capacity is covering its operating costs.

While demand has been hesitant, supply has been building up, with new smelters coming on stream earlier than expected, and with the net supply from the former Eastern bloc remaining high. Production cutbacks are likely before long, since today's metal prices are lower than the operating costs of many smelters. However, the amount of excess supply is modest, and only modest production cutbacks are called for. According to some estimates, at the end of 1991 the difference between export capacity and the amount of stocks will be very similar to the situation seen in mid-1986, which was soon followed by a period of intense shortage.

As for growth in demand, it can be expected that supply will be adequate in the short term but may not be so in the long term. At present, many companies are planning their new projects, and the smelters plants under construction are based on moderate long-term growth in demand of just over 3 per cent per year. However, many people think that this growth could be over 4 per cent, in which case companies will soon have to revise their investment plans upward. But this will be done only if the price is right. And prices now are very low, indeed dangerously low. At today's metal prices, it is not possible for any new smelter project to cover its operating and capital costs and also earn an acceptable profit.

The world aluminium industry, which for years enjoyed an extremely good market situation, will have to make great efforts to maintain its profitability. T. M. Tschopp, Chairman and Executive Vice-President of the European Aluminium Association (EAA), spoke of ways to cope with current market circumstances:

> "We must optimize and speed up technical development. We must increase the quality of our products, must create more products designed for customers needs, must modernize our plants and intensify the search for new materials. We must optimize the economics of our businesses. We must concentrate our investments accordingly and be prepared for new partnerships that give us strength under new market conditions such as the 'United Europe' [7]."

III. Primary aluminium production

The International Primary Aluminium Institute (IPAI) defines primary aluminium production as the weight of liquid aluminium tapped from the pots, excluding alloying elements, returned scrap or remelted products. The pattern of aluminium production over the last two decades has in many respects been similar to that of most of the other base metals in that there has been a shift away from production in the industrialized countries towards production in the newly industrializing countries.* For aluminium, the prime impetus behind the change has been the availability of cheap power in areas such as the Middle East and Latin America. Although output in these regions has grown rapidly, producers in the industrialized countries still account for the bulk of Western output [8].

In 1965, the dominance of the United States was massive, with that country accounting for about half of the total output. Most of the rest of the world's output came from Europe, where France, The Federal Republic of Germany and Norway were the major producers. Over the next 10 years, primary production grew at an average annual rate of 6.8 per cent. The European producers increased their share as output surged in the Federal Republic of Germany, Norway, Spain, the United Kingdom and Yugoslavia and as production facilities were established in Greece, Iceland and the Netherlands. The most spectacular performance, however, was that of the Japanese industry.

The demise of the Japanese aluminium industry was even more dramatic. Between 1975 and 1980, primary output fluctuated around the 1 million tonne level. The recession of the early 1980s took its toll on the high-cost facilities in Japan, and output fell away to less than 250,000 tonnes in 1985. Output in Europe was remarkably stable in 1975-1985, varying from 3.2 million to 3.7 million tonnes. The share of United States producers fell further as production in 1985 remained essentially unchanged from 10 years earlier, at 3.5 million tonnes (it had reached a high of 4.7 million tonnes in 1980). By 1985, the United States accounted for slightly under 30 per cent of non-communist world (NCW) output. In contrast, Canadian output continued to expand: it exceeded 1 million tonnes for the first time in 1978, and by the 1980s the Canadian share was about 8.5 per cent.

Between 1975 and 1985, a number of countries established a significant presence in the industry. Most notable was the expansion that took place in Australia and Venezuela. In Australia, the Tomago and Boyne smelters came on stream in the early 1980s, while both CRA Ltd. and Alcoa expanded existing facilities. The country's output increased fourfold, to around 850,000 tonnes, by 1985. From a lower base, Venezuelan production increased 800 per cent, to 400,000 tonnes, as first the Alcasa project was expanded and then the Venalum smelter was set up. Latin American production was also boosted by the development of the industry in Brazil, where by 1985, production exceeded 500,000 tonnes, compared with just over 100,000 tonnes 10 years earlier. The other area of expansion was the Middle East, where the availability of cheap power encouraged the development of aluminium production in Bahrain, Egypt and the United Arab Emirates. By 1985 the three countries were producing about 500,000 tonnes per year between them.

These changes in the geographical distribution of primary production between 1965 and 1985 show how the share of Latin American producers has grown at the expense of North American producers. They also show the significant growth of Australasian output. Expansion in some of the Asian countries is masked by the demise of the Japanese industry, which caused the region's share of total output to fall from 14 per cent to 10 per cent between 1975 and 1985.

*The term "newly industrializing countries" is used extensively to describe developing economies, be they countries, provinces or areas, where there has been particularly rapid industrial growth. It does not imply any political division within the ranks of developing countries and is not officially endorsed by UNIDO.

World production of primary aluminium increased by nearly 4.7 per cent in 1987 over the previous year, reaching 16.2 million tonnes. The figure is slightly higher than that for 1980, indicating a steady recovery by the aluminium industry from the slump in the early 1980s. Table 1 shows the major primary-aluminium-producing countries in the world. As is clear from the table, the recovery has been more pronounced in developed countries, where producers have cautiously begun reopening mothballed plants. However, the combined output of developed countries in 1987 was still more than 10 per cent less than in 1980. The slump was most dramatic in Japan, which had been the world's third largest producer in 1980. Since then, Japanese production capacity has been severely cut back, and the output of primary aluminium fell by 96 per cent to less than 41,000 tonnes, between 1980 and 1987.

Table 1. World production of primary aluminium in the 25 largest producing countries and in various regions of the world, 1987

Country, region or economic group	*Production (thousands of tonnes)*	*Change 1980-1987 (%)*
United States	3 342.9	-28.17
USSR	2 354.8	-1.88
Canada	1 548.4	44.1
Australia	1 024.2	237.46
Brazil	843.5	223.68
Norway	797.8	20.57
Federal Republic of Germany	737.7	0.96
Venezuela	439.6	35.18
China	420	17.32
Spain	341	-11.77
France	322.5	-25.33
United Kingdom	294.4	-21.37
Netherlands	268.7	4.07
India	265.3	43.48
New Zealand	249	59.41
Yugoslavia	245.9	52.35
Italy	232.6	-14.23
Indonesia	201.4	201.4
Bahrain	180.3	43.1
Egypt	179.2	49.33
South Africa	170.6	97
United Arab Emirates	155.9	345.43
Argentina	155.1	16.53
Ghana	150.3	-19.93
Cameroon	71.5	66.26
North America	4 891.3	14.61
Western Europe	3 453.7	-3.93
Latin America	1 500.3	83.77
Other developed	1 484.4	-9.37
Asia (excluding China)	901.4	89.49

continued

Table 1 (*continued*)

Country, region or economic group	Production (thousands of tonnes)	Change 1980-1987 (%)
Africa	401	14.34
Total world	16 240 a/	1.29

Source: *Industry and Development: Global Report 1990/91* (UNIDO publication, Sales No. E.90.III.E.12).

a/ This total includes estimates of production in the USSR, Eastern Europe and China.

In the United States, the world's largest producer, output dropped by 34.7 per cent between 1980 and 1986. In 1987, however, production increased 10 per cent, reflecting the upswing in the industry. In Western Europe, the decline from 1980 to 1986 was not so pronounced (5.4%) owing to the sharp rise in Norwegian production (10.2%) and the more moderate increase in the Federal Republic of Germany (4.5%). Norway became the biggest producer in Western Europe in 1987, ahead of the Federal Republic of Germany. But the output of all other major Western European producers fell considerably. Slumps of 26.3 per cent in the United Kingdom, 25.5 per cent in France, 10.5 per cent in Italy and 8.2 per cent in Spain were recorded during the period 1980-1986.

In other developed countries, there were remarkable upturns. Between 1980 and 1987, South Africa and New Zealand increased production by 97 per cent and 60 per cent, respectively. Growth was pronounced in Australia, where output rose 237 per cent, representing the second largest growth rate during the period. In 1987 the United States was the largest producer, with almost 21 per cent of the total world output, ahead of the Soviet Union (15%), Canada (9.5%), Australia (6.3%), Brazil (5.25%) and Norway (4.9%).

Of the developing regions, Latin America was the largest producer of primary aluminium in 1986, with a 9 per cent share of production, ahead of Asia (6%) and Africa (2.5%).

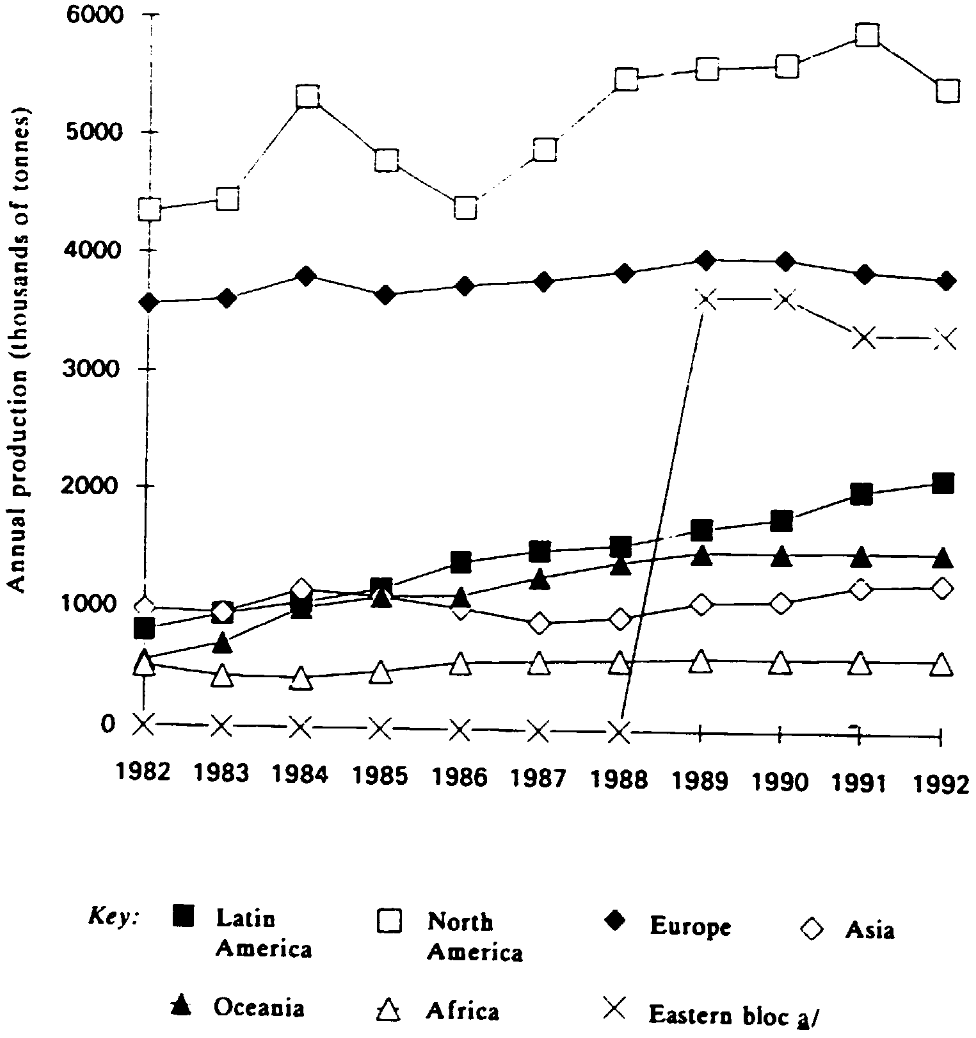
On a country-by-country basis, Brazil, the top producer among developing countries, experienced growth of 11.4 per cent between 1986 and 1987; its output exceeded that of any West European producer and put it in fifth place in 1987. The Brazilian Aluminium Producers' Association estimated that the country's output should reach 871,000 tonnes in 1988. The second largest manufacturer among developing countries was Venezuela, which had half as much output as Brazil in 1987. It was followed by India, Indonesia, Bahrain and Egypt. The United Arab Emirates, Brazil, Indonesia and the Islamic Republic of Iran experienced the highest growth rates (345%, 224%, 201% and 152%, respectively) between 1980 and 1987. The only major producer country in the developing world where output declined was Ghana, which produced nearly 34 per cent less in 1986 than in 1980, with production recovering by about 21 per cent between 1986 and 1987. This recovery represented the second largest growth rate in 1987, outstripped only by that of Mexico, which increased production by 63 per cent. Other developing countries in which output declined in 1987 from the preceding year were Turkey, which experienced a fall of over 30 per cent; China, with a 14 per cent decline; Cameroon, down by 12 per cent; and Indonesia, down by 8 per cent.

Despite the smelting boom in developing countries in the 1980s, developed countries still dominate world production. Their combined share amounts to almost 80 per cent, mainly owing to high levels of production in the traditional producer countries and sharp rises in Australia, Canada and Norway. Figure II and table 2 show world aluminium production from 1982 to 1992.

A. Africa

Africa remains a minor producer of aluminium. Operations are located in just four countries: Cameroon, Egypt, Ghana and South Africa. Output has increased steadily in recent years, largely

Figure II. World aluminium production



a/ Former Soviet Union and Eastern Europe; no data were available for these countries from 1982 to 1988.

Table 2. Annual primary aluminium production by region
(Thousands of tonnes)

Region	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
Africa	501.2	421.4	413	473.2	552.2	571.6	582	604	602	609	610
Asia and the Middle East a/	977.8	953.1	1 147	1 098	1 006	893.3	942	1 073	1 090	1 217	1 241
Eastern bloc b/	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	3 650	3 654	3 352	3 352
Latin America	799	940.9	1 042	1 164	1 397	1 500	1 552	1 698	1 789	2 030	2 127
North America	4 344	4 444	5 321	4 782	4 392	4 883	5 494	5 585	5 616	5 890	5 430
Oceania	547.6	695.2	997.7	1 095	1 111	1 276	1 410	1 501	1 498	1 503	1 503
Western Europe	3 563	3 611	3 807	3 653	3 734	3 777	3 857	3 977	3 975	3 877	3 834
Total world	10 733	11 066	12 727	12 265	12 192	12 902	13 837	18 088	18 224	18 478	18 097

Sources: James F. King (consultants), *World Capacity and Market Report* (Newcastle upon Tyne, August 1991); Shearson Lehman Hutton, *Annual Review of the World Aluminium Industry* (1989).

Note: N.A.: not available.

a/ Excluding China.

b/ Including eastern Europe, China and the Democratic People's Republic of Korea.

reflecting the restart-up of Volta Aluminium in Ghana following the drought-inspired production shut-down in 1984. The latest statistics suggest that African output was 609,000 tonnes in 1991,and the absence of any developments in the region implies that production should be similar in the coming years. Table 3 shows the total output of primary aluminium in Africa.

Table 3. Annual primary aluminium production in Africa
(Thousands of tonnes)

Country	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
Cameroon	78.9	77.4	73.1	81.6	81.1	71.5	72	87	88	87	85
Egypt	141.0	140.2	172.5	178.5	176.9	179.2	180	180	180	178	180
Ghana	174.2	42.5	N.A.	48.5	124.6	150.3	160	169	174	176	175
South Africa	107.1	161.3	167.4	164.6	169.6	170.6	170	168	160	168	170
Total	501.2	421.4	413	473.2	552.2	571.6	582	604	602	609	610

Sources: James F. King (consultants). *World Capacity and Market Report* (August 1991); Shearson Lehman Hutton. *Annual Review of the World Aluminium Industry* (1989).

1. Cameroon

Cameroon's sole producer of aluminium is the Alicam joint venture between Pechiney and the State. The smelter has a capacity of 94,000 tonnes per year. Output in 1988 was slightly under this figure, but in 1991 it was operating at full capacity.

2. Egypt

Production capacity at the Aluminium Company of Egypt was increased steadily in the early 1980s to the current level of 180,000 tonnes per year. Output has fluctuated around this level since 1985 and there is no reason for this to change.

3. Ghana

Ghanaian production stems from the Kaiser (90%)/Reynolds (10%) joint venture, Volta Aluminium. As mentioned above, output has been hindered by power shortages associated with the drought in the country. Seemingly these problems are now over. Output has expanded rapidly since the plant was shut down for the whole of 1984. Output in 1991 was 176,000 tonnes, a level that should have been reached in 1990.

4. South Africa

South African production is in the hands of Alusaf. The 170,000 tonnes per year plant has operated at full capacity in recent years and should continue to do so.

B. Asia and the Middle East

Trends in Asian primary aluminium output have been dominated in recent years by the decimation of the Japanese industry. During the 1980s, the country's production fell from more than 1 million tonnes in 1980 to 36,000 tonnes in 1991. The demise of the Japanese producers overshadowed developments that were taking place elsewhere in the region: an aluminium smelter was set up in Indonesia (the Ashan joint venture), while expansions took place in the United Arab Emirates and Bahrain. The region's share of total output has, however, dwindled overall. At the beginning of the decade Asian production accounted for 14 per cent of NSW output; but at the end of the 1980s it had dropped to 7 per cent of NCW output.

As the potential for further declines in Japanese output is now limited, Asian output should start to increase as a result of capacity expansions in the United Arab Emirates and India. Looking slightly further ahead, projects are being planned in Saudi Arabia. Table 4 shows the output of primary aluminium in Asia and the Middle East.

1. Asia

(a) India

India possesses the largest smelting capacity in Asia. Its production facilities are rather fragmented, however, in that there are six smelters, four of which are under 100,000 tonnes. The largest existing plant is Hindalco's 150,000 tonnes per year smelter at Renukoor. This plant will soon be surpassed by the recently commissioned Nalco smelter in Oris state. The first phase (54,000 tonnes per year) came on stream in 1987. Technical problems restricted output in that year to under 30,000 tonnes, well below projected levels. Output should continue to expand, because capacity is scheduled to have doubled by the end of the decade, to over 200,000 tonnes.

The remaining facilities include three smelters owned by Indalco in which Alcan has a 39 per cent stake, with a combined capacity slightly in excess of 100,000 tonnes per year, and two smelters under State control: Balco (100,000 tonnes per year) and Malco (25,000 tonnes per year). It appears that the future of the Malco plant is in some doubt following the refusal of the local government to increase power supplies to the plant.

Power supply problems have plagued the Indian aluminium industry for many years and largely explain its inability to operate at anything like full capacity. Indeed, all six smelters that operated in 1987 had their output constrained by power shortages, to the extent that total supply in that year was only 253,000 tonnes, compared with nameplate capacity of over 400,000 tonnes. In fact, that was a marked improvement on the production levels recorded in the early 1980s, and to some degree the problems have been alleviated by the commissioning of new capacity with dedicated power as well as some new power plants for existing facilities.

Now, 75 per cent of the industry's energy requirements are met by dedicated power units, which, combined with the expansion at Nalco, should enable primary output to climb steadily over the next few years. Total output in India at the end of the 1980s was over 500,000 tonnes.

(b) Indonesia

The Asahan smelter in Indonesia was originally set up by a consortium of five Japanese enterprises and the Overseas Economic Coordination Fund Bank (75%) and the Government of Indonesia (25%). It was opened in three stages between 1982 and 1984. Output rose every year between 1982 and 1986, when the smelter almost achieved its full rated capacity. However, power shortages constrained production in 1987 to 201,000 tonnes, compared with almost 219,000 tonnes in 1986. In 1985, a study was undertaken that considered the possibility of raising the smelter's capacity to 400,000 tonnes per year by 1990, but financial constraints make it unlikely that this will be achieved by then.

In 1987, the Indonesian Government raised its stake to 41 per cent. This move prompted a dispute between the State and its Japanese partners (Nippon Asahan Aluminium Corporation). The Indonesian interpretation of the joint-venture agreement was that the Government could take 41 per cent of output after the domestic market (75,000 tonnes per year) had been supplied; the Japanese laid claim to all of the aluminium after the local requirements had been met. The protracted dispute should not, however, affect production at the plant. The worst of the power shortages now appear to be behind the company; after some disruption in the first quarter of 1991,

Table 4. Annual primary aluminium production in Asia and the Middle East
(Thousands of tonnes)

Country	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
Bahrain	171	171.7	177.3	174.8	178.2	180.3	182	187	212	228	230
India	216.7	207.7	268.5	266.2	257.1	253.4	320	423	433	499	506
Indonesia	30.5	114.8	199	216.8	218.8	201.4	190	197	192	179	185
Iran (Islamic Republic of)	45	39.2	42.4	43	40	40	40	45	40	43	45
Japan	350.7	255.9	266.7	226.5	140.2	40.6	35	35	34	36	35
Republic of Korea	15.2	12.6	17.2	17.7	17.3	21.7	20	17	4	0	0
United Arab Emirates	148.7	151.2	155.4	153.2	154.8	155.9	155	168	174	233	233
Total	977.8	953.1	1 147	1 098	1 006	893.3	942	1 073	1 090	1 217	1 241

Sources: James F. King (consultants), *World Capacity and Market Report* (August 1991); Shearson Lehman Hutton, *Annual Review of the World Aluminium Industry* (1989).

the plant is now operating at full capacity. For 1991 a full capacity production of 220,000 tonnes had been projected, but total output was only 179,000 tonnes.

(c) Japan

The dramatic fall in Japanese output has been discussed elsewhere. Rationalization of the industry was so severe that only one producer remains: Nippon Light Metal (50% Alcan) still operates a 64,000 tonnes per year smelter. Output in 1991 was just over 36,000 tonnes. In spite of this, Japan has considerable secondary production and also consumption. Japan has a good downstream industry. Hokkai Can is building an aluminium can factory at Shiga that will come on stream in May 1993. Kobe Steel is building an aluminium smelter for aluminium-magnesium alloys that will be ready at the end of 1995 [9].

(d) Republic of Korea

Koralu was the sole producer in the Republic of Korea, with a 180,000 tonnes per year smelter. The plant operated at capacity until 1988, then closed down in 1990.

2. Middle East

Many significant changes are taking place in the Middle East. Already there are two medium-sized producers, Bahrain and the United Arab Emirates. In Bahrain, Aluminium Bahrain has the rated capacity to produce 170,000 tonnes per year, although output exceeded that level in 1989. The plant's annual capacity increased to 220,000 tonnes in the early 1990s; there was, moveover, the possibility of further expansion to 400,000 tonnes at some stage. In Dubai, United Arab Emirates, Bubal raised its capacity to 155,000 tonnes per year from 135,000 tonnes per year; in 1991, it reached a total output of 233,000 tonnes.

In 1987 it was decided to construct a 240,000 tonnes per year smelter in the United Arab Emirates. It would be built and operated by Doha Aluminium, a joint-venture company set up by Amari (15%); United Aluminium Fabricators (30%), a group of United States-based fabricators; International Engineering Consultants (30%); the China National Metals and Mineral Import and Export Corporation (10%); and private Arab interests (15%). Construction of the plant started in the middle of 1988, and the first metal was produced two years later, in 1990. Power requirements for the smelter were met by the nation's huge reserves of natural gas; this will ensure that the plant is a low-cost one.

The Saudi Arabian Government has given the go-ahead for a 200,000 tonnes per year plant at Yanbu, which could be on stream in 1992; plans for smelting capacities in Kuwait and Qatar are vaguer.

The only other smelter operating in the region is in the Islamic Republic of Iran. Iralco has a 50,000 tonnes per year smelter at Arāk. Production in 1991 was 43,000 tonnes. The Islamic Republic of Iran and Bahrain are jointly building an aluminium plant in the Persian Gulf region, with a projected production over 220,000 tonnes per year [9].

C. Eastern Europe, China and the Democratic People's Republic of Korea

1. Overview

Recent political upheavals in the former Soviet Union are likely to have an important bearing on the economic fortunes of the whole of eastern Europe. The loose federation of republics that was once the USSR has put aside slow, hesitant reform policies and has committed itself to fast trade reforms. However, the situation there remains uncertain as long as the question of the ownership rights within the individual republics remains unresolved. Consumption in eastern Europe shows overall strength, and some key sectors, such as transport and construction, are showing signs of stabilizing. For the former Soviet Union, any hopes for a medium-term recovery in primary metals consumption depend on how much foreign financial assistance will be made available in return for the pursuit of free market policies.

2. *Consumption*

The consumption of primary aluminium in eastern Europe continues to be adversely affected by the recession in the region and by the decrease in purchasing power caused by economic restructuring in most of the countries. Overall consumption in the region is expected to fall by almost 8 per cent between 1990 and 1993. In spite of this, the countries of eastern Europe have the longer-term potential to expand their aluminium consumption as their economies are restructured.

3. *Production*

The total amount of primary aluminium production increased significantly in the last months of 1991, and as a result the utilization rate for the Eastern bloc is now much higher. The utilization rate has been raised further by the complete closure of primary production capacity in Hungary between 1991 and 1993 and announcements of closures in Romania. Production in the former Soviet Union has been higher than it was before that country broke up.

4. *China*

Of the developing countries, China, with an estimated output of 420,000 tonnes of primary aluminium in 1987, was the third largest producer, just behind Venezuela; in 1991, with a total output of 837,000, it was becoming the second largest producer. The Qinghai smelter, having an annual capacity of some 100,000 tonnes, started production at the beginning of 1988 and is part of a larger plan to make China self-sufficient in aluminium by the early 1990s. A number of power stations and new projects at Guizhou, Guanchi and Yunna are under construction. These three regions all contain primary smelting facilities, and they expect that the power stations being built will satisfy their power needs. Table 5 shows the total production of the Eastern countries from 1989 to 1991 and the forecast for 1992.

Table 5. Annual primary aluminium production in eastern Europe, China and the Democratic People's Republic of Korea a/
(Thousands of tonnes)

Country	*1989*	*1990*	*1991*	*1992*
China	744	827	837	827
Czechoslovakia	69	65	60	60
Democratic People's Republic of Korea	10	10	10	10
German Democratic Republic b/	54	45	45	45
Hungary	75	75	76	76
Poland	48	46	48	48
Romania	269	179	170	170

continued

Table 5 (*continued*)

Country	*1989*	*1990*	*1991*	*1992*
USSR c/	2 380	2 407	2 106	2 106
Total	3 650	3 654	3 352	3 352

Sources: James F. King (consultants), *World Capacity and Market Report* (August 1991); Shearson Lehman Hutton, *Annual Review of the World Aluminium Industry* (1989).

a/ No data available for the years before 1989.
b/ After 3 October 1989, part of Germany.
c/ At the end of December 1991, the USSR became the Commonwealth of Independent States.

D. Latin America

The region's production of aluminium rose steadily during the 1980s, from 816,400 tonnes at the beginning of the decade to 1,500,000 tonnes in 1987 and over 2,030,000 tonnes in 1991. The bulk of the increase has taken place in Brazil, where output more than tripled in the period, to 1,140,000 tonnes in 1991. Over the next few years Venezuela should prove to be the main driving force. Expansion plans already in place suggest that output there will be over 650,000 tonnes by 1992 compared to the 1991 level of just over 450,000 tonnes. The more immediate impact of the development of the Venezuelan industry, however, will be less dramatic. In 1989, output reached only 546,000 tonnes. When the expansion underway in Brazil is taken into account, 7.9 per cent growth in Latin American output is projected for 1992, when production is expected to exceed 2,130,000 tonnes. Table 6 shows the output of primary aluminium in Latin America.

1. Argentina

The only smelter in the country is that of Alur, a joint venture between Alcan, Pechiney, Kaiser and the State. A programme of modernization and expansion increased its output from 155,000 tonnes per year in 1986 to 166,000 tonnes per year in 1991, but no future development projects are foreseen.

2. Brazil

Although most of the industry's attention has focused on developments in neighbouring Venezuela, output during the 1980s grew considerably faster in Brazil than in Venezuela. From a lower base in 1980, Brazilian output in 1987, estimated at 860,000 tonnes, is double Venezuelan output, which makes it the fifth largest aluminium producer in the world behind the United States, the former Soviet Union, Canada and Australia; it stands fourth in world exports of unwrought aluminium. That makes it the biggest developing country producer and exporter of this metal. Backed up by 20 per cent of the world's bauxite reserves, Brazil has expansion plans similar to those of Venezuela, namely, increasing primary smelting capacity and strengthening the vertical integration of the aluminium industry.

Until 1990, when it reached 930,000 tonnes per year, primary production capacity had been increased only moderately, but in 1991 it was increased considerably, reaching over 1,140,000 tonnes per year. By the year 2000, primary smelting capacity is forecast to reach 1,430,000 tonnes per year, some 600,000 tonnes less than that of Venezuela.

In contrast to the Venezuelan industry, Brazil's aluminium industry is not dominated by government interests. However, State officials strictly control domestic prices, which are kept below world market prices.

Table 6. Annual primary aluminium production in Latin America
(Thousands of tonnes)

Country	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
Argentina	140.5	136.4	133.7	139.9	150.6	155.1	155	164	166	166	165
Brazil	299.1	400.7	455	549.2	757.4	843.5	860	888	931	1 140	1 210
Mexico	43.3	39.7	44	42.7	37	60.2	60	72	68	70	72
Suriname	42.5	28.9	23	28.8	28.7	1.9	22	28	31	29	30
Venezuela	273.6	335.2	386	403.1	423	439.6	455	546	594	625	650
Total	799	940.9	1 042	1 164	1 397	1 500	1 552	1 698	1 789	2 030	2 127

Sources: James F. King (consultants), *World Capacity and Market Report* (August 1991); Shearson Lehman Hutton, *Annual Review of the World Aluminium Industry* (1989).

The most ambitious Brazilian project under construction is the Albras primary smelter. Phase I currently allows production of 166,000 tonnes per year, but when phase II is finished, in 1991, capacity will amount to 340,000 tonnes per year. Brazil's State mining concern at present sells its metal take of 51 per cent mainly to Japan but also to the European Community.

As in Venezuela, efforts are being made to erect downstream facilities. Reynolds Internacional do Brasil constructed a plant that produces 700 million aluminium cans per year, which came on stream in late 1989.

3. Mexico

Primary aluminium production is in the hands of Aluminio S.A. [8], in which Alcoa has a stake. Capacity was raised from 66,000 tonnes in 1986 to 70,000 tonnes in 1991. More than 2,000 tonnes of increase are expected in 1992.

4. Suriname

Despite being a major producer of bauxite, Suriname produces only a smali quantity of aluminium. The country has just one smelter, Suralco's 60,000 tonnes per year plant at Paranam, which is working at 50 per cent of capacity. In 1987 operations were almost completely halted by a series of guerrilla attacks on power lines to the plant, which restricted production to just 2,000 tonnes in that year. Output in 1991 was over 29,000 tonnes.

5. Venezuela

Venezuela is in a fortuitous position because it has an abundance of the requirements for the efficient production of aluminium. The country possesses huge bauxite reserves and ample hydroelectric power, concentrated in Guayana Province. These advantages are supplemented by a good infrastructure and cheap labour. A report by Anthony Bird Associates in 1988 put Venezuela at the bottom of the cost curve. At the time, the country had an average cost of US$ 0.38 per pound compared to US$ 0.60 in the United States and in 1991 was operating at a marginal profit.

Venezuela has very ambitious plans for the construction and expansion of aluminium plants to permit it to replace Brazil as the region's largest aluminium producer by the early 1990s. If the plans are fully implemented, output should reach almost 1.5 million tonnes in 1992; for 1996, the goal was 2 million tonnes. However, many of the projects have been delayed for political and economic reasons. Table 7 lists these projects.

Table 7. Projected Venezuelan smelter capacity, 1988-1997
(Thousands of tonnes)

Company	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*
Alcasa	120	210	210	400	400	400	400	400	400	400
Venalum	400	460	460	460	460	460	460	460	460	460
Alisa				40	80	120	120	120	240	240
Aldanca										190
Alusur					120	120	120	120	120	120
Alamsa					180	180	180	180	180	180
Aluguay						180	180	180	180	180
Aluyana									180	180

continued

Table 4 (*continued*)

Company	*1988*	*1989*	*1990*	*1991*	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*
Vexal										180
Total	520	670	670	900	1 240	1 640	1 640	1 640	1 760	2 130

Source: Venalum, *Annual Report* (1988).

The development of this industry so far has been carried out under the umbrella of Corporacion Venezolana de Guajama (CVG), the regional development authority. As the major part of the aluminium industry is owned by the State, the Government lays down guidelines for the whole industry. The priority is to achieve vertical integration, and Venezuela has the right resources to do it. Thus, investments are not only made in the construction and expansion of primary smelter capacity but also in upstream facilities for bauxite mining and the production of alumina. For instance, Bauxiven, the State-owned bauxite producer, is planning to invest US$ 195 million in the Los Pijiguaos mine, where large deposits of high-grade ore have been found. With a production of 2 million tonnes per year and an installed capacity of 2.2 million tonnes per year at the middle of the 1990s, production is projected to reach 6 million tonnes per year [4].

E. North America

The output in North America increased greatly in recent years as idled capacity was reactivated in the United States and as output was built up at the newly opened Becancour smelter in Canada. Table 8 shows the output of primary aluminium in North America.

Table 8. Annual primary aluminium production in North America
(Thousands of tonnes)

Country	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
Canada	1 070	1 091	1 222	1 282	1 355	1 540	1 550	1 555	1 567	1 796	1 899
United States	3 274	3 353	4 099	3 500	3 037	3 343	3 944	4 030	4 048	4 095	4 031
Total	4 344	4 444	5 321	4 782	4 392	4 883	5 494	5 585	5 616	5 890	5 430

Sources: James F. King (consultants), *World Capacity and Market Report* (August 1991); Shearson Lehman Hutton, *Annual Review of the World Aluminium Industry* (1989).

1. Canada

While the focus in the United States has been on the reactivation of previously idled capacity, the focus in Canada has been on expanding capacity. The expansion under way at Becancour and at greenfield projects such as Aloutte will eventually boost the country's capacity to close to 2 million tonnes. The Canadian primary smelting industry is dominated by Alcan, which owns six of the country's eight smelters. These six have a combined capacity in excess of 1 million tonnes. A major investment programme is under way at the company. It plans to replace the old Soderberg lines at the huge Arvida complex as well as some lines at Isle Maligne, Beauharnois and

Shawinigan. In 1983 the company pledged to replace the Soderberg technology with new pre-baked anode plants such as that at Grand Bay. The new facilities are required to meet pollution standards and to be more energy-efficient. The total output of primary aluminium in 1991 was 1,899,000 tonnes.

2. *United States*

Of the established producers, the United States industry has been one of the major beneficiaries of the revival in the aluminium market at the end of the 1980s. Having borne the brunt of the recession in the early 1980s, producers in recent years have restarted many of the facilities idled at that time. The combination of higher operating rates at existing facilities and the reactivation of idled capacity has boosted the country's primary aluminium output from 3,040,000 tonnes in 1986 to 4,100,000 tonnes in 1991. Indeed, although United States output increased in 1987, accounting for approximately 55 per cent of the increase in total NSW production, its share of market was only about 22 per cent less.

F. Oceania

Output in Oceania has risen in each year since 1985, and in 1991 output reached 1.5 million tonnes, which represents over 10 per cent of total NCW primary production. The increase largely reflects expansion in Australia, where two major projects were set up in the early 1980s, at Tomago and Boyne, as well as expansions to existing facilities. Further expansions to the region's output are expected. Table 9 shows the output of primary aluminium in Oceania.

Table 9. Annual primary aluminium production in Oceania
(Thousands of tonnes)

Country	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Australia	380.8	475.1	754.8	851.7	875	1 024	1 160	1 242	1 233	1 245	1 245
New Zealand	166.8	220.1	242.9	243.5	236.2	252	250	259	265	258	258
Total	547.6	695.2	997.7	1 095	1 111	1 276	1 410	1 501	1 498	1 503	1 503

Sources: James F. King (consultants). *World Capacity and Market Report* (August 1991); Shearson Lehman Hutton. *Annual Review of the World Aluminum Industry* (1989).

1. *Australia*

Two of the major North American producers have a presence in Australia. Alcan owns 73 per cent of Alcan Australia Limited, which operates the 150,000 tonnes per year Kurri Kurri smelter. As late as 1991 the plant was operating at full capacity. Alcoa recently expanded its activities in the country with the Portland joint venture with the government of Victoria (45% Alcoa). The first 150,000 tonnes per year pot-line came on stream at the end of 1986. The second 150,000 tonnes per year pot-line was commissioned in March 1988 and reached capacity in October of that year. The company's other operation is the 170,000 tonnes per year Point Henry smelter, in which it has a 51 per cent stake.

CRA's interest in primary aluminium is through its 67 per cent stake in Comalco. It wholly owns the 128,000 tonnes per year Bell Bay smelter. Output in 1987 and 1988 was just under rated capacity, 124,500 tonnes and 126,000 tonnes, respectively. Output at the 208,000 tonnes per year Boyne smelter, in which Comalco is the largest shareholder (30%), was approximately the capacity of the plant. It can be expected that this performance will be maintained. Kaiser, the United

States producer, owns 20 per cent of the project; the remainder is in Japanese hands.

The remaining smelting facility is located at Tomago in New South Wales. The 240,000 tonnes per year Tomago plant is a joint venture between Gove Aluminium (35%) and Pechiney (35%). Along with most of the rest of the production in Australia in recent years, the smelter has operated at full capacity. Total output in 1991 was over 1,245,000 tonnes.

2. *New Zealand*

Comalco has a 79.5 per cent stake in New Zealand's only smelter, the 244,000 tonnes per year plant at Tiwai Point on South Island. The vast majority of the smelter's output is exported, most of it to Japan (indeed, Sumitomo owns the remaining 20.5% of the plant). Power charges have risen in recent years, and in 1986 the reconstruction of failed pots was suspended to contain costs. The smelter, which had operated at nearly full capacity in 1984 and 1985, thus lost output in 1986. In 1987, there was a return to full capacity, and output totalled 238,500 tonnes. Production in 1991, 258,000 tonnes, exceeded rated capacity.

G. Western Europe

Output in Western Europe has been remarkably stable, with production fluctuating around 3.9 million tonnes. As discussed elsewhere in this report, most of the changes in the industry are taking place in the western hemisphere, principally in Latin America, and to a lesser extent in the Middle East. Table 10 shows the output of primary aluminium in Western Europe.

1. *Austria*

Although Austrian annual output is below 100,000 tonnes per year, there are two smelters in the country. Austria Metall operated an 83,000 tonnes per year facility in Ranshofen. Alusuisse runs a 120,000 tonnes per year plant at Lend. Apart from being one of the smallest smelters in the world, the main claim to fame of the smelter at Lend is that it is the world's second oldest operating smelter. Both plants operated at about capacity, producing 94,000 tonnes during 1988. From that time on, output decreased drastically, reaching 64,000 tonnes in 1991; in 1992, output will probably be about 11,000 tonnes.

2. *France*

French production lies in the hands of Pechiney, the State-owned producer. A consolidation programme instituted in 1986 has reduced capacity from 375,000 tonnes to 332,000 tonnes, and from 1989 to 1990 capacity was around 320,000 tonnes per year, where it is expected to remain through the forecast period. Pechiney has constructed a 200,000 tonnes per year smelter at Dunkirk in conjunction with Electricité de France, the State-owned electricity supplier. This certainly went against the trend elsewhere in the world, where new smelters have tended to be established in areas enjoying low power costs.

3. *Germany*

Output in the Federal Republic of Germany suffered in 1987, largely as a result of the closure of Alcan's Ludwigshafen smelter in March of that year. Total output amounted to an estimated 738,000 tonnes, some 3.4 per cent below the 1986 level. Capacity and production were also reduced at Alusuisse's Rheinfelden plant, which is the oldest operating smelter in the world. Although output recovered in 1989 to 742,000 tonnes, given the possible closure of the Vereinigte

Table 10. Annual primary aluminium production in Western Europe
(Thousands of tonnes)

Country	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
Austria	93.9	94.2	95.8	94.1	92.5	93.4	94	93	90	64	11
France	390.4	360.8	341.5	293.2	321.8	322.5	320	335	326	296	349
Germany, Federal Republic of a/	722.8	743.3	777.2	745.4	763.7	737.7	740	742	720	680	680
Greece	134.9	136.2	136.2	123.4	124.4	126.1	140	148	155	153	150
Iceland	77	77	82.4	76.8	80	84.6	80	89	88	88	88
Italy	232.9	195.7	230.2	224.1	242.6	232.6	235	220	232	222	195
Netherlands	248.2	236.3	247.3	244.6	258	268.7	270	274	270	268	272
Norway	645.1	710.6	760.8	724.1	729.1	797.8	835	859	871	878	875
Spain	366.5	357.6	380.8	370.1	354.7	341	310	353	355	361	353
Sweden	78.9	82.2	82.9	83.7	77.1	81.5	100	97	96	99	97
Switzerland	75.3	76	79.2	72.6	80.9	73.4	73	71	72	67	60
Turkey	36.3	30.4	37.5	54.1	60	41.7	45	62	61	58	60
United Kingdom	240.8	252.5	287.9	275.4	275.9	294.4	300	297	290	299	295
Yugoslavia	220.1	258.2	267.5	271.1	273.2	281.1	315	337	349	346	349
Total	3 563	3 611	3 807	3 653	3 734	3 777	3 857	3 977	3 975	3 877	3 834

Sources: James F. King (consultants), *World Capacity and Market Report* (August 1991); Shearson Lehman Hutton, *Annual Review of the World Aluminium Industry* (1989).

a/ As of 3 October 1989, Germany.

Aluminium-Werke smelter at Luenen by the early 1990s further reductions in Germany primary production are in prospect, and for 1992 a decrease of more than 8 per cent on its current output is expected.

4. *Greece*

Pechiney has a majority (68%) stake in Greece's only smelter, the 148,000 tonnes per year plant of Aluminium de Grèce at Distoman. Power costs are high at the plant. Until the improvement in market conditions in 1988, the plant operated at well below capacity. In 1990, production was 155,000 tonnes, compared to 126,100 tonnes in 1987.

5. *Iceland*

Iceland has just one smelter, Isal's 88,000 tonnes per year facility at Straumsvik, which is wholly owned by Alusuisse. Expansion has been under consideration for some time. In 1988 the threat of industrial action caused a loss of output of around 5,000 tonnes, restricting production to approximately 80,000 tonnes. In 1991, there was a return to 88,000 tonnes, which will probably be maintained in the early 1990s.

6. *Italy*

The Italian primary aluminium industry is in the process of contracting. The State-owned Aluminia Italia, the largest producer, is closing down its ageing Bolzano smelter, leaving it withthe Porto Vesme and Fusina plants, which have a combined capacity of 166,000 tonnes. Aluminia Italia has a 50 per cent stake in Italy's other producer, Sava; the other half is owned by Alusuisse. Output in Italy has fallen in recent years, from 243,000 tonnes in 1986 to 222,000 tonnes in 1990.

7. *Netherlands*

There are two producers in the Netherlands. Alumina Beheer is wholly owned by Hoogovens; its smelter at Delfzijl has two pot-lines with a total capacity of 96,000 tonnes. Pechiney is the sole owner of the other facility, a 170,000 tonnes per year smelter at Vlissingen-Oost. Both plants are operating at capacity and had a total output of 268,000 tonnes in 1991.

8. *Norway*

European aluminium smelting outside the European Community is dominated by Norway. Indeed, Norwegian output overtook that of Germany in 1987, making the country Europe's largest producer. It is a position that will be consolidated in the future, as further expansions are planned. Capacity at the end of 1991 stood at 878,000 tonnes; by the end of the 1990s, it should be close to 900,000 tonnes.

9. *Spain*

A rationalization of Spanish production facilities has left Inespal, the State concern, in control of the country's three smelters. Until recently, Alcan had a 23.9 per cent stake in the company. It disposed of the holding at the end of 1991. Inespal has a total nameplate capacity of 346,000 tonnes. The largest smelter, at San Ciprián, has a capacity of 188,000 tonnes. Output in 1988 was curtailed when a wildcat strike damaged pot-lines; the loss of output was estimated at 30,000 tonnes. Since June 1988, the smelter has again been operating. Indeed, the three plants have operated above their nameplate capacity since 1988. Problems with costs and profits have obligated Inespal to reduce the production of primary aluminium at its plants in Avilés and La Coruña; this would serve to decrease total output by over 73,000 tonnes per year [9].

10. Sweden

A modernization programme wants to lift capacity at Sweden's only aluminium smelter, the Grange plant at Sundsvall, to 100,000 tonnes per year by the end of the 1990s.

11. Switzerland

Despite the position of Alusuisse as a major force in the industry, Swiss production is very limited, with an annual output of 99,000 tonnes in 1991, which is expected to decrease by the end of the 1990s.

12. Turkey

Turkish production lies in the hands of the State through Etibank, which operates a 60,000 tonnes per year smelter at Seydişehir. An expansion programme that has been temporarily shelved may eventually take capacity to 90,000 tonnes. The plant has generally operated below capacity, producing 41,000 tonnes in 1987 and 45,000 tonnes in 1988; in 1989, however, it increased its production to 62,000 tonnes, which was nearly maintained to 1991.

13. United Kingdom

The country's primary aluminium production is dominated by British Alcan, which is wholly owned by Alcan. It operates three smelters with a combined capacity of 174,000 tonnes. The remaining facility is Angelsey Aluminium's 120,000 tonnes per year smelter at Holyhead, a joint venture between RTZ (51%) and Kaiser (49%). Output at both companies last year was at capacity, and at the end of 1991 the capacity was over 299,000 tonnes.

14. Yugoslavia

Although information on the Yugoslav industry is difficult to come by, it appears that the country has plans for expansion. A plan to bring on a third pot-line at Šibenik with a capacity of 110,000 tonnes per year is under consideration; existing capacity is 85,000 tonnes. Less clear is the expansion planned at Kidricevo. The two other existing producers are Energoinvest, at Mostar, and Kat, at Titograd, each with the capacity to produce about 100,000 tonnes per year.

The country's primary aluminium production increased every year in the 1980s, rising from 161,400 tonnes in 1980 to just over 349,000 tonnes in 1990. Given the expansion programme that is under way, further increases are expected in coming years.

IV. The bauxite industry

A. World production and capacity

Table 11 gives the world production of bauxite from 1980 to 1990. Recession at the start of the decade cut deeply into demand throughout the aluminium industry, and the output of bauxite fell sharply in 1981-1982. The situation stabilized in 1983, but in the following year NCW production soared to a record of 97 million tonnes in spite of the fact that the market remained weak. Output grew in most of the major producing countries (including in Jamaica), but the performance of Australia was exceptional. There, a return to normal production at the traditional mines coincided with the opening of two new ones, at Willowdale and Mount Saddleback. Then, in 1985, stagnation was seen in many regions, notably in Latin America, where the problems of Jamaica in particular worsened, leaving regional output at a low of 7.3 million tonnes.

A further turn-round occurred in 1986 as record production levels were registered in Australia, Guinea, Brazil and India and substantial recovery took place in Jamaica. The NCW as a whole was held back only by a continuation of the long-term decline of the European and United States industries, and growth was still 3.8 per cent. The two largest producers, Australia and Guinea, achieved all-time record production as capacity levels were approached. Continued growth was registered in Brazil, India, Guyana and Sierra Leone, and the Jamaican industry furthered its recovery. Of the major producers, only Suriname suffered, but it suffered severely because the largest mine in the country was closed for most of the year by a strike. One other feature of note: 1987 saw the first contribution from the potentially huge Los Pijiguaos mine in Venezuela, and during the 1980s Venezuelan production of bauxite increased steadily, reaching over 2 million tonnes in 1991 (in 1996 it is expected to be over 6 million tonnes) [10].

Bauxite production in the Western countries in 1990 was at all-time record of almost 106 million tonnes, the fifth successive year of record production. Total bauxite mining capacity at the end of 1990 was over 125 million tonnes per year in the Western countries, of which some 6.7 million tonnes was for non-metallurgical applications such as refractories and abrasives (table 12).

In recent years several million tonnes of capacity were added as a result of developments in Brazil, Venezuela and Australia. The bauxite industry in 1990 was therefore operating overall at about 85 per cent of capacity. Despite this apparently moderate level of capacity utilization, certain grades of bauxite, particularly material from Guinea and all exportable trihydrate bauxites, were in short supply between 1988 and 1990. Tighter market conditions and higher prices for the metal and alumina caused bauxite prices to rise in 1988 and 1989. An increased supply in 1990 seems to have eased the bauxite market to some degree, despite very high demand. In the face of record alumina production, the bauxite market seems likely to ease in the second half of 1991 and into 1992. Figure III shows world bauxite production.

Table 11. Total world bauxite production by country and region
(Thousands of tonnes)

Country or region	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*
Africa											
Ghana	197	181	64	70	49	170	204	196	785	348	381
Guinea	13 911	12 822	11 827	12 986	14 738	13 950	14 835	16 282	16 800	17 500	17 524
Mozambique	0	0	0	0	0	0	5	5	7	6	7
Sierra Leone	766	616	630	783	1 041	1 185	1 242	1 391	1 403	1 548	1 445
Zimbabwe	4	5	8	23	23	29	24	0	0	0	0
Asia											
India	1 785	1 955	1 854	1 976	2 078	2 341	2 322	2 816	4 013	4 345	4 340
Indonesia	1 249	1 203	700	778	1 003	831	650	635	513	862	1 206
Iran (Islamic Republic of)	0	0	0	0	0	0	0	0	93	100	100
Malaysia	920	701	589	502	680	492	566	482	361	355	398
Pakistan	0	0	3	2	3	2	3	3	3	2	2
Europe											
France	1 892	1 828	1 737	1 595	1 530	1 330	1 379	1 388	978	720	548
Greece	3 012	3 216	2 846	2 455	2 296	2 435	2 231	2 467	2 533	2 576	2 504
Italy	23	19	24	13	0	0	0	17	17	12	0
Spain	5	9	7	5	7	2	3	3	3	0	0
Turkey	547	590	508	306	132	214	280	258	269	562	498
Yugoslavia	3 138	3 249	3 668	3 500	3 347	3 538	3 459	3 394	3 034	3 252	1 952
Latin America											
Brazil	4 152	4 463	4 187	5 239	6 433	5 846	6 446	6 567	7 728	7 894	9 876
Dominican Republic	601	482	179	0	0	0	0	248	197	194	100
Guyana	3 179	2 496	1 857	2 327	2 589	2 298	2 708	2 901	1 848	1 396	1 483
Haiti	542	634	440	0	0	0	0	0	0	0	0
Jamaica	14 092	13 654	9 805	9 039	10 276	7 340	8 193	9 012	8 716	11 053	12 867
Suriname	4 903	4 125	3 060	2 793	3 375	3 738	3 731	2 581	3 434	3 530	3 267
Venezuela	0	0	0	0	0	0	0	217	550	702	771

continued

Table 11 (*continued*)

Country or region	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*
North America											
United States	1 732	1 678	813	754	951	749	567	653	653	744	551
Oceania											
Australia	29 542	27 653	25 679	29 492	34 279	34 608	35 200	37 067	39 533	41 938	44 990
Total West	86 193	81 579	70 486	71 642	84 830	81 303	84 048	88 570	92 970	99 639	105 811
Albania	0	0	0	0	0	20	20	20	20	20	20
China	1 700	1 800	2 050	2 300	2 500	2 800	2 900	3 200	3 500	3 650	3 800
Hungary	2 950	2 914	2 627	2 917	2 994	2 815	3 022	3 101	2 906	2 532	2 559
Romania	450	400	380	420	460	460	500	480	435	345	350
USSR	6 400	6 400	6 400	6 300	6 200	6 400	6 275	5 700	5 900	5 750	5 750
Total East	11 500	11 514	11 457	11 937	12 154	12 475	12 697	12 481	12 741	12 097	12 459
Total World	97 693	95 093	81 943	83 579	96 984	93 778	96 745	101 051	105 712	111 735	118 270
Africa	14 878	13 624	12 529	13 864	15 851	15 342	16 310	17 874	18 495	19 402	19 358
Asia	3 954	3 859	3 146	3 259	3 765	3 665	3 541	3 936	4 983	5 664	6 046
Europe	8 617	8 911	8 790	7 874	7 312	7 718	7 352	7 527	6 834	7 122	6 503
Latin America	27 469	25 854	19 528	19 398	22 673	19 222	21 078	21 526	22 473	24 769	28 364
North America	1 732	1 678	813	754	951	749	567	640	653	744	551
Oceania	29 542	27 653	25 679	26 492	34 279	34 608	35 200	37 067	39 533	41 938	44 990
Total East	11 500	11 514	11 457	11 937	12 154	12 475	12 697	12 481	12 741	12 097	12 459
Total World	97 693	95 093	81 943	83 579	96 984	93 778	96 745	101 051	105 712	111 736	118 270

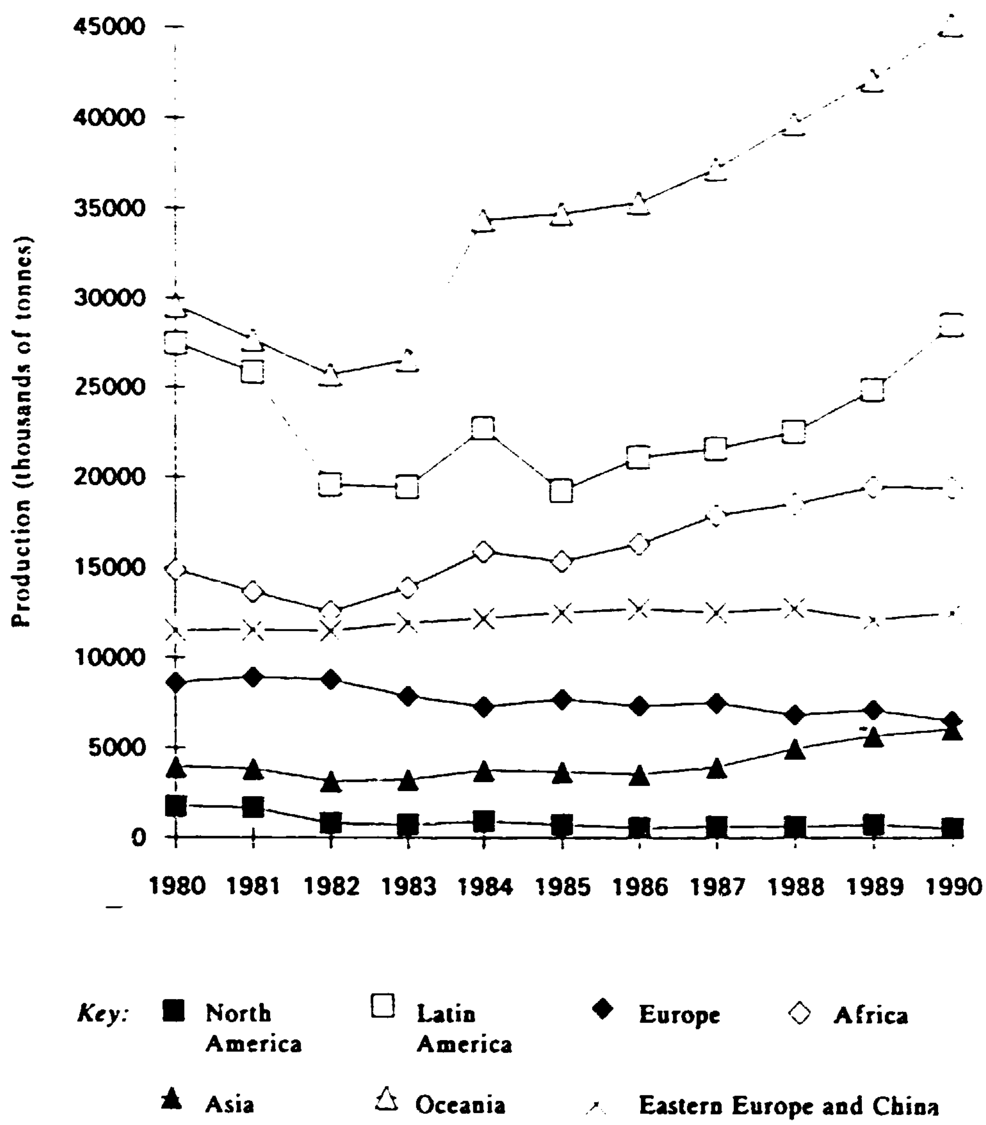
Source: CRU Consultants Inc., *Quarterly Market Service: Aluminium* (October 1991).

Table 12. Bauxite production capacity, metallurgical/non-metallurgical, end 1990
(Thousands of tonnes per year)

Country or region	*Non-metallurgical*	*Metallurgical*	*Total*
Africa	19 450	150	19 600
Ghana	400	0	400
Guinea	17 500	150	17 650
Sierra Leone	1 550	0	1 550
Asia	6 805	800	7 605
India	4 705	500	5 205
Indonesia	1 300	0	1 300
Iran (Islamic Republic of)	0	100	100
Malaysia	800	200	1 000
Europe	7 750	1 750	9 500
France	690	450	1 140
Greece	2 200	1 150	3 350
Italy	0	0	0
Turkey	460	150	610
Yugoslavia	4 400	0	4 400
Latin America	37 100	2 020	39 120
Brazil	10 400	720	11 120
Dominican Republic	250	0	250
Guyana	3 100	1 300	4 400
Haiti	0	0	0
Jamaica	16 250	0	16 250
Suriname	5 100	0	5 100
Venezuela	2 000	0	2 000
North America	0	1 2600	1 260
United States	0	1 260	1 260
Oceania	46 950	700	47 650
Australia	46 950	700	47 650
Total West	118 055	6 680	124 735
Albania	0	20	20
China	3 000	750	3 750
Hungary	3 260	200	2 460
Romania	750	0	750
USSR	11 500	300	11 800
Total East	18 510	1 270	19 780
Total World	136 565	7 950	144 515

Source: CRU Consultants Inc., *Quarterly Market Service: Aluminium* (October 1991).

Figure III. World bauxite production



B. Developments in bauxite production in Latin America

1. Brazil

In Brazil, output at the Trombetas mine reached 1 million tonnes in 1990 and is expected to remain around that level in 1991. Some 62 per cent of the output in 1990 was shipped within the region, equally divided between the Alumar refinery in Brazil and the Interalumina refinery in Venezuela.

2. Guyana

In Guyana, shipments of bauxite from the Aroaima mine started early in 1991, a month or two later than originally planned, owing to heavy rainfall. The mine is expected to produce 1.5 million tonnes of very good quality trihydrate bauxite in 1991.

3. Suriname

In Suriname, the Moengo mines are expected to be depleted by the end of July 1991. The new Coermotibo mine will become operational around that time and start supplying bauxite to the alumina refinery at Paranam. The deposits in the Coermotibo area are large enough to last 10-12 years before they too are depleted. Meanwhile, work is in progress to open the new Accaribo mine, which is expected to become operational in 1992.

4. Venezuela

Production at the Los Pijiguaos mine in Venezuela amounted to over 1 million tonnes in 1990. Output should reach at least 1.5 million tonnes in 1992, as the infrastructural facilities are nearing completion. If the target level of production is reached, some small amounts of Trombetas bauxite could be replaced by Los Pijiguaos bauxite at the Interalumina refinery. This process will continue in the next few years until Venezuela becomes entirely self-sufficient in bauxite [11].

The market for traded bauxite is currently in better shape than that for alumina. However, additional output from Brazil, Venezuela and Guyana could cause the market for bauxite to become softer by the end of 1991 and part of 1992. Substantial improvements are expected for 1993 [11].

V. The alumina industry

The production of alumina has gone through the same business cycle as bauxite since it is also heavily dependent on the aluminium industry. Recent trends indicate that this could change dramatically depending on the restructuring that is going on in the alumina industry. Recent trends in alumina production are shown in table 13. After the recession-induced fall in demand for the material, output began to recover in 1983 and 1984. This was mainly the result of new capacity in Australia, Venezuela, Brazil and Ireland rather than a response to rising demand from aluminium producers. The result was a surplus of alumina, and spot-market prices fell well below US$ 150 per tonne.

In 1985 the situation deteriorated much further as primary aluminium production fell nearly 4 per cent. (It is estimated that aluminium accounts for around 91 per cent of total alumina usage [12].) Unfortunately, much of the alumina industry is rife with factors that make supply somewhat inflexible. Australian refineries are low-cost and would therefore be reluctant to cut back first. At the same time several developing countries have political and economic reasons for keeping plants functioning. More generally, the nature of the operations - they are usually run by - consortia - makes for an inflexibility of supply just as it does for bauxite; proposed cutbacks must have the agreement of all participants or penalty clauses may come into force. Finally, it is believed that refineries do not function efficiently if they operate at less than 70 per cent of capacity. Not surprisingly, then, the only cutbacks in 1985 came in the major industrialized economies and in Jamaica. Although output fell by over 5 per cent to 27 million tonnes, that drop was not sufficient to prevent another large surplus of alumina. At the same time, refinery capacity utilization was only 75-80 per cent. Spot prices therefore continued to fall, to below US$ 100 per tonne for the first time in the 1980s.

In 1986, refinery capacity utilization improved slightly, to around 80 per cent. Although a further decline in alumina output was seen in the United States, Japan and Germany, expansion occurred elsewhere in Europe, in all of Latin America, except Jamaica, and, above all, in the huge Australian industry. Production in the West rose by a modest 1.8 per cent in 1986, to 27.5 million tonnes, which was enough to keep the alumina market in surplus. The year's average spot price was nearly US$ 115 per tonne.

In 1987, primary aluminium production rose 6 per cent. The response of alumina producers was large and prompt, and operating rates rose substantially in Australia, the United States, Brazil, Jamaica and some of the smaller European countries. In addition, a new plant was opened in India. The only factors holding output back were the decline in production in Germany and Japan and the extreme difficulties suffered by the refinery in Suriname. Demand for alumina in the Eastern bloc declined, so that the market remained oversupplied. At least as important is that the capacity utilization rose again sharply to average around 85 per cent, the highest since 1981. The year's average spot price was nearly US$ 135 per tonne.

In 1988, the upward trend in aluminium production continued. Some plants in Europe and the United States remained closed, but the decrease in production in those countries was absorbed by the increase in Latin America and Australia, where plants exceeded their design capacities even further, and also in India, where Nalco's Damanjoli plant began to produce large quantities. The average capacity utilization for 1988 exceeded 87 per cent. It was a year of expansion programmes for the Interalumina plant in Venezuela and the Alcoa plant in Australia. All these programmes were based on the deficit in supply during 1988.

From 1989 to 1990 the coming on stream of new alumina production caused an oversupply. In 1991, alumina production remained substantially greater than consumption, the market was becoming increasingly oversupplied and spot prices drifted lower. A balancing of the market would require some curtailment of alumina production in the immediate future. Primary

Table 13. Alumina production, 1981-1992
(Thousands of tonnes)

Country or region	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
Africa	679	578	564	535	565	572	542	600	627	642	641	650
Guinea	679	578	564	535	565	572	542	600	627	642	641	650
Asia	2 246	1 781	1 915	2 132	2 020	1 714	1 450	2 050	2 282	2 211	2 329	2 305
India	489	485	480	569	571	586	650	1 070	1 419	1 235	1 391	1 385
Japan	1 619	1 212	1 378	1 488	1 336	986	711	830	863	976	938	920
Europe	5 997	5 531	5 405	6 471	6 025	6 180	6 196	6 120	6 450	6 537	6 593	6 601
France	1 236	1 087	1 009	1 031	877	884	866	810	624	640	701	690
Germany, Federal Republic of a/	1 651	1 509	1 580	1 701	1 657	1 560	1 291	1 120	1 174	1 176	1 136	1 150
Greece	502	404	413	482	402	458	529	580	533	576	592	590
Ireland			105	650	557	685	[illegible]	840	891	904	948	940
Italy	786	698	465	625	555	618	700	715	722	750	760	760
Spain	695	673	729	742	729	748	801	810	949	1 002	1 016	1 016
Turkey	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	201	190	190	190
United Kingdom	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	116	118	104	105
Yugoslavia	1 037	1 072	1 010	1 135	1 138	1 117	1 112	1 140	1 240	1 180	1 146	1 160
Latin America	4 488	3 435	4 250	4 971	5 095	5 523	5 876	5 880	6 686	7 405	7 838	8 135
Brazil	520	552	629	882	1 096	1 197	1 532	1 490	1 624	1 700	1 658	1 740
Jamaica	2 550	1 758	1 907	1 713	1 622	1 586	1 634	1 660	2 205	2 900	3 083	3 145
Suriname	1 248	1 052	1 154	1 237	1 242	1 471	1 363	1 440	1 567	1 505	1 684	1 650
Venezuela	N.A.	N.A.	560	1 139	1 135	1 269	1 347	1 290	1 290	1 300	1 413	1 600
North America	7 168	5 257	5 116	5 671	4 484	4 120	5 003	4 980	5 908	6 332	6 546	6 695
Canada	1 208	1 127	1 116	1 126	1 019	1 015	997	1 000	1 048	1 018	1 005	1 005
United States	5 960	4 130	4 000	4 545	3 465	3 105	4 006	3 980	4 860	5 313	5 541	5 690
Oceania	7 079	6 631	7 305	8 800	8 804	9 368	10 098	10 480	10 823	11 197	11 542	11 780
Australia	7 079	6 631	7 305	8 800	8 804	9 368	10 098	10 480	10 823	11 197	11 542	11 780
Total West	27 657	23 213	24 555	28 580	26 993	27 477	29 165	30 110	32776	34 324	35 489	36 166

continued

Table 13 (*continued*)

Country or region	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
China									1 650	1 596	1 743	1 825
Czechoslovakia									228	200	200	200
German Democratic Republic a/									63	49	50	50
Hungary		No figures available for individual Eastern countries or for the							891	855	851	850
Romania		East as a whole or for the world as a whole until 1989.							611	540	411	360
USSR									4 550	4 625	4 403	4 200
Total East									7 993	7 865	7 657	7 485
Total World									40 769	42 189	43 146	43 651

Sources: Anthony Bird Associates, *Aluminium Analysis*, No. 51 (October 1991); Shearson Lehman Hutton, *Annual Review of the World Aluminium Industry 1989* (February 1989).

Note: N.A.: not available.

a/ As of 3 October 1989, Germany

aluminium smelters continued operations at very close to full capacity. The worldwide production of alumina in 1991 was about 43.1 million tonnes, and for 1992 a further increase of around 500,000 tonnes is expected, a substantial proportion of which may be added to stocks. In any case, alumina production is directly related to aluminium production, which makes possible the development of an interdependent market. For this reason one of the most important economic goals is to increase the production of those products with the highest value-added, which can be done by making special aluminas using the conventional Bayer process [2].

It is clear that given the current market situation, European alumina refineries cannot be competitive with the Brazilian, Australian or Venezuelan giant refineries in the long term, especially by processing costly imported bauxite. The only favourable condition in Europe is the existing demand of smelters in the region for metallurgical-grade alumina, which will allow some refineries to keep operating, at least in the near or medium term. The main task is to increase efficiency by means of technological development and to produce more and more valuable special products [13]. Table 14 shows how the production of non-metallurgical-grade alumina has increased in European plants.

Table 14. Alumina production, metallurgical/non-metallurgical, 1989-1992 a/

	1989		*1990*		*1991*		*1992*	
Country or region	*M*	*NM*	*M*	*NM*	*M*	*NM*	*M*	*NM*
Africa	627	0	642	0	641	0	650	0
Guinea	627	0	642	0	641	0	650	0
Asia	1 412	870	1 319	892	1 456	873	14 250	880
India	1 344	75	1 177	58	1 336	55	1 325	60
Japan	68	795	142	834	121	817	100	820
Europe	5 367	1 083	5 390	1 147	9 509	1 084	5 500	1 101
France	274	350	308	332	395	306	380	310
Germany b/	728	446	698	478	699	437	700	450
Greece	513	20	556	20	572	20	570	210
Iceland	876	15	884	20	928	20	920	20
Italy	692	30	720	30	730	30	730	30
Spain	933	16	986	16	1 000	16	1 000	16
Turkey	181	20	160	30	149	40	150	40
United Kingdom	0	116	0	118	0	104	0	105
Yugoslavia	1 170	70	1 077	103	1 036	110	1 050	110
Latin America	6 369	317	7 178	227	7 575	263	7 885	250
Brazil	1 394	230	1 538	162	1 483	175	1 660	180
Guyana	0	0	0	0	0	0	0	0
Jamaica	2 190	15	2 885	15	3 063	20	3 125	20
Suriname	1 495	72	1 455	50	16 165	68	1 600	50
Venezuela	1 290	0	1 300	0	1 413	0	1 600	0
North America	5 095	813	5 548	784	5 723	823	5 835	860
Canada	929	119	893	125	376	119	880	125
United States	4 166	694	4 654	659	4 847	694	4 955	735
Oceania	10 668	155	11 001	196	11 270	273	11 505	275
Australia	10 668	155	11 001	196	11 270	273	11 505	275
Total West	29 538	3 238	31 078	3 246	32 174	3 315	32 800	3 366

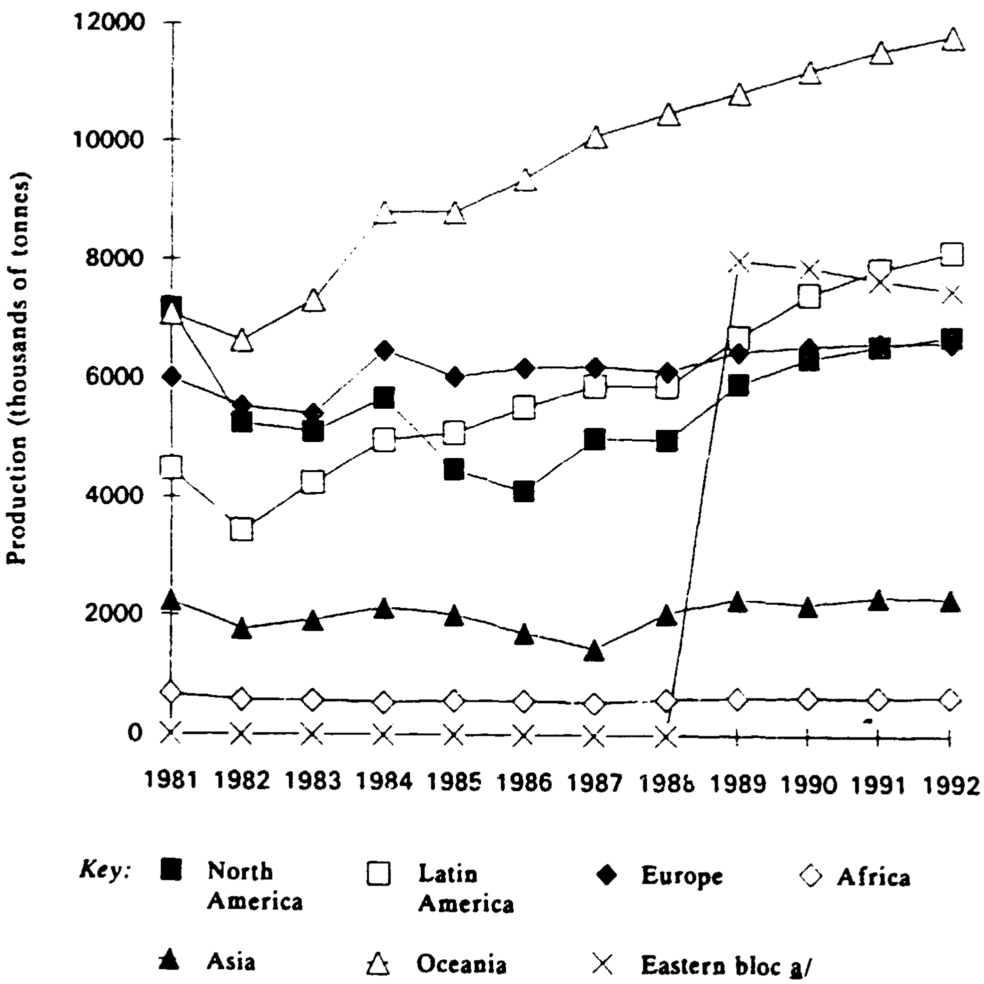
Source: Anthony Bird Associates, *Aluminium Analysis*, No. 51 (October 1991).

a/ M = metallurgical grade; NM = non-metallurgical grade.
b/ Until 3 October 1989, Federal Republic of Germany.

Another factor that affects alumina production is the increasing amount of secondary, recycled aluminium, which decreases the demand for the primary metal and metallurgical-grade alumina. In the light of this trend, the less economic alumina refineries should gradually be closed, especially in Europe, in connection with the geographical restructuring of the world alumina/aluminium industry. Figure IV shows world alumina production.

According to some industry analysts, the longer term market outlook for metallurgical-grade alumina remains somewhat bearish, mainly because of fears that net exports to the Eastern bloc may decline owing to those countries' inability to pay for the alumina. However, this sentiment is not shared by most executives of alumina-producing and -selling companies in the West, who feel that there is substantial scope for increased future supplies of this material to those countries [11].

Figure IV. World alumina production



a/ China, Czechoslovakia, former German Democratic Republic, Hungary, Romania and (former) Soviet Union; no data are available for these countries from 1981 to 1988.

VI. Caustic soda in the aluminium industry

The fortunes of the caustic soda (NaOH) industry depend on its end-uses. Caustic soda (NaOH) can in theory compete with soda ash or even sodium sulphate for a variety of purposes. Caustic soda provides a source of sodium and alkalinity. In the downstream chemicals market, it is more or less interchangeable with soda ash. Chemical use for caustic soda is split between the inorganic and organic functions. In inorganic chemicals such as phosphates, soda ash and caustic soda are equally functional, and a large-scale switch to caustic could occur in these applications. Some inorganic chemical end-uses demand caustic soda, however. The dominant Bayer process for making alumina is one process where caustic soda is essential.

Of the total world production of caustic soda of nearly 40 million tonnes, the aluminium industry consumes almost 3 million tonnes. Table 15 shows the capacity, production and consumption of caustic soda in 1988 and the forecast for 1992. Table 16 shows the estimated consumption of caustic soda by aluminium smelters from 1989 to 1992.

Table 15. Caustic soda market, 1988 and 1992
(Thousands of tonnes)

	1988			*1992*		
Country or region	*Capacity*	*Production*	*Consumption*	*Capacity*	*Production*	*Consumption*
Africa and the Middle East	1 403	1 158	917	1 901	1 512	1 150
Australia and South Asia	1 753	1 225	2 265	2 468	1 801	2 760
East Asia	2 589	3 269	3 541	3 707	3 670	3 866
Eastern Europe	7 425	6 028	6 184	7 885	6 691	6 787
Japan	4 321	3 508	3 232	4 321	3 600	3 353
United States	11 480	10 544	9 816	12 599	11 600	10 726
Western Europe	12 015	10 354	9 635	12 079	10 590	10 092
Western hemisphere	4 074	3 500	4 104	4 662	3 760	4 472
Total	45 061	39 586	39 694	49 622	43 224	43 206

Source: TECNON, *Caustic Soda into the 1990s: A World Survey of Supply, Demand and Trade* (June 1989).

Table 16. Estimated consumption of caustic soda by aluminium smelters, 1989-1992
(Thousands of tonnes)

Country or region	*1989*	*1990*	*1991*	*1992*
Africa	63	64	64	65
Guinea	62	64	64	65
Asia	183	177	184	181
India	104	87	97	97
Japan	79	90	86	85
Europe	449	446	449	450
France	46	40	43	43
Germany, Federal Republic of a/	81	81	78	79

continued

Table 16 (*continued*)

Country or region	*1989*	*1990*	*1991*	*1992*
Greece	39	42	43	43
Iceland	32	32	34	33
Italy	51	53	54	54
Spain	34	36	36	36
Turkey	25	24	24	24
United Kirgdom	5	5	5	5
Yugoslavia	137	134	132	134
Latin America	520	548	580	604
Brazil	128	134	136	136
Guyana	0	0	0	0
Jamaica	129	169	180	183
Suriname	157	131	146	144
Venezuela	106	114	124	141
North America	418	417	41	422
Canada	34	91	89	89
United States	344	326	323	333
Oceania	933	957	991	1 014
Australia	933	957	991	1 014
Total West	2 566	2 610	2 680	2 737

Source: TECNON, *Caustic Soda into the 1990s: A World Survey of Supply, Demand and Trade* (June 1989).

a/ As of 3 October 1989, Germany.

VII. Overview of market conditions for the aluminium downstream industry

Aluminium is used in a multitude of applications in all sectors of the economy. Thus, in contrast to the situation for most other metals, demand for aluminium does not depend on events within one or two narrow end-uses, and it is in any case protected from substitution because its technical advantages are so large that relative prices play a subordinate role.

Major aluminium producers have traditionally emphasized research and development, in particular the development of new products, to stimulate aluminium demand. The research and development activities of these companies have increasingly focused on the development of new alloys and production processes for specific end-uses and on broader materials research. This is partly a consequence of user specifications having become more stringent, necessitating the tailoring of materials to specific end-uses. This tendency carries certain risks for developing country producers since they often lack the close contacts with final consumers as well as the technological know-how to be competitive in these highly specialized markets. In the following paragraphs, developments in the main end-uses are briefly reviewed, with particular emphasis on two sectors where technological development has proceeded rapidly, namely, transport equipment and packaging.

The production of semi-finished products, including plates, sheets, strips, foils, bars, rods, sections, tubes, wires and forgings, is concentrated in three regions: North America, Europe and Japan. Owing to a lack of data for centrally planned European countries and most developing countries, the amount of world production cannot be stated. During the 1980s the output of most countries and areas increased, with the exception of Spain, Taiwan Province and Yugoslavia. The biggest expansions occurred in Denmark (117%), the Netherlands (54%), Japan (49%), Austria (41%) and Switzerland (36%). The other countries showed moderate growth, ranging between 4 per cent for Sweden and 20 per cent for Norway. In all countries for which data were available, except Denmark, 1987 output was below the 1986 level.

In the United States, which is by far the world's largest producer of aluminium semi-finished products, output decreased by nearly 7 per cent between 1986 and 1987. Japan, ranking second and with less than half the output of the United States, reported a level of production that was nearly 10 per cent lower than in 1986. Germany was listed in third position ahead of France, Italy and the United Kingdom. The only major producer among developing countries was Brazil, where in 1986 output reached 362,000 tonnes, 27.7 per cent above the 1980 level.

Table 17 shows the capacity for semi-finished products at the end of 1990, and Figure V shows the production, by region, of such products in that year. The developed countries have much more capacity and production than the rest of the world.

Table 17. Capacity for semi-finished aluminium products, end 1990
(Thousands of tonnes per year)

Country/region	*Rolled products*	*Billets*	*Alloys*	*Other hots*
Africa	265	205	20	85
Cameroon	50	0	0	0
Egypt	75	125	20	52
Ghana	80	40	0	0
South Africa	60	40	0	33

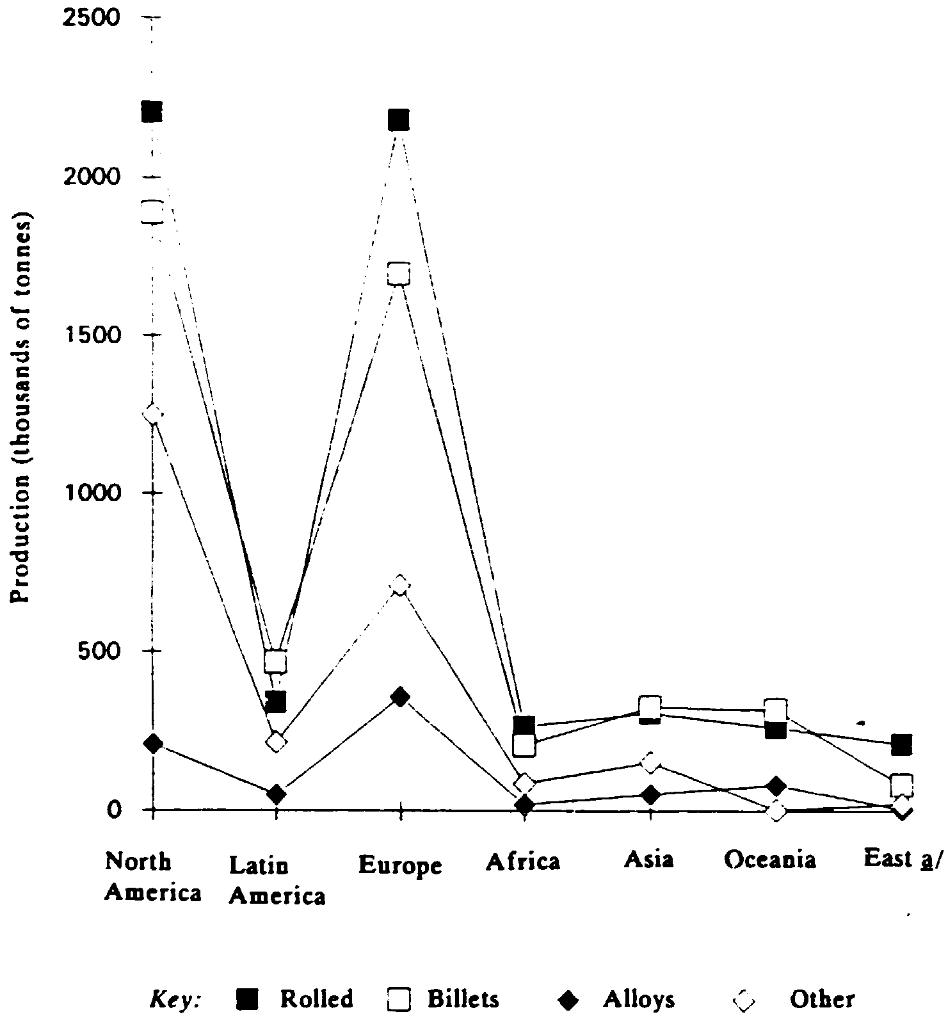
continued

Table 17 (*continued*)

Country/region	*Rolled products*	*Billets*	*Alloys*	*Other hots*
Asia	307	325	52	153
Bahrain	40	65	0	36
India	167	75	2	117
Indonesia	0	0	0	0
Iran (Islamic Republic of)	30	30	0	0
Japan	70	30	10	0
Korea	0	0	0	0
United Arab Emirates	0	125	40	0
Europe	2 178	1 690	358	709
Austria	130	57	35	26
France	210	80	40	112
Germany	344	205	133	263
Greece	60	60	0	0
Iceland	60	30	0	0
Italy	150	155	45	56
Netherlands	240	140	0	5
Norway	310	495	37	109
Spain	210	110	40	32
Sweden	30	70	0	0
Switzerland	119	28	10	0
Turkey	0	20	0	0
United Kingdom	215	160	10	0
Yugoslavia	100	80	8	106
Latin America	340	465	50	215
Argentina	50	50	0	26
Brazil	140	165	20	75
Mexico	60	30	0	12
Suriname	0	0	0	0
Venezuela	90	220	30	102
North America	2 204	1 888	209	1 246
Canada	840	698	20	371
United States	1 364	1 190	189	875
Oceania	260	315	80	3
Australia	240	295	80	3
New Zealand	20	20	0	0
Total West	5 554	4 888	769	2 411
Czechoslovakia	30	0	0	0
Hungary	120	60	0	21
Poland	60	20	4	0
Total East	210	80	4	21
Total World	5 764	4 968	773	2 432

Source: CRU Consultants Inc., *Quarterly Market Service: Aluminium* (October 1991).

Figure V. Production of semi-finished aluminium products in 1990



a/ Czechoslovakia, Hungary and Poland.

A. The transport sector

The transport sector is the single largest market for aluminium semi-finished products. In 1987 it accounted for 25.7 per cent of all shipments of such product in the six large economies for which statistics are available.

Table 18 shows the consumption of semi-finished aluminium products in the transport sector of six major economies from 1979 to 1988. Consumption grew strongly during 1987, rising by 5 per cent over the level in 1986. Further strong growth was registered during 1988, when it is estimated that consumption rose by 4.4 per cent, to 3,290,000 tonnes in the six countries.

It should be noted that there are considerable differences between countries: the share of the transport sector in aluminium consumption declined from 1978 to 1988 in the United Kingdom and the United States, while it increased in Germany, France and Japan, reflecting differences in the performance of the automobile industries in those countries.

Table 18. Consumption of semi-finished aluminium products in the transport sectors of six large economies, 1979-1988
(Thousands of tonnes)

Year	*France*	*Germany, Federal Republic of*	*Italy*	*Japan*	*United Kingdom*	*United States*	*Total*
1979	187.5	284.4	196.7	503	103.9	1 426.6	2 702.1
1980	180.3	282.3	207.4	582	72.5	1 041.5	2 366
1981	161.4	278.5	187	615	62.5	1 005.2	2 309.6
1982	185.8	273.3	181.2	596.1	56.9	832.8	2 126.1
1983	178.8	281.4	187.9	635.4	55.6	1 100.9	2 440
1984	164.4	299.4	211.2	688.9	51.1	1 374.8	2 789.8
1985	164.1	342.1	208.3	762.8	52.4	1 363.5	2 893.2
1986	181.6	387.9	218.4	785.2	52.7	1 372	2 997.8
1987	197.9	402.4	246	834.5	55.7	1 410	3 146.5
1988	205	425	255	890	60	1 450	3 285
Average annual growth 1979-1988 (%)	1.00	4.60	2.90	6.50	-5.90	-0.10	2.2

Source: Shearson Lehman Hutton, *Annual Review of the World Aluminium Industry* (1989).

The consumption of aluminium in the transport sector is dominated by the passenger car industry. In the United States, its consumption in cars accounts for over 60 per cent of total transport consumption. In the early 1980s, about 4 per cent by weight of the material used in automobile manufacturing was aluminium; the proportion is now approaching 10 per cent in many countries. To a large extent, aluminium has been able to increase its share because of its favourable strength:weight ratio. Thus, efforts to reduce the weight of cars in order to reduce petrol consumption have favoured aluminium consumption. Other important uses include commercial vehicles, boats, railway rolling stock and aerospace. In the boat-building industry, aluminium is mostly used in sheet form for hulls, but some cast metal is used for propellers. In the aerospace industry, aluminium alloys have gained wide acceptance in commercial airframes and structural components.

However, despite growth in these areas, there is no doubt that aluminium consumption in the transport sector as a whole is very much dependent on developments in the motor vehicle industry, which dwarfs the others in terms of metal consumption. The volume of aluminium used in the automobile industry depends on the number of vehicles built and the intensity of the metals used within those vehicles.

There are several ongoing development projects that aim to increase dramatically the amount of aluminium used in cars, in particular by building the frame of the car in aluminium instead of steel. While aluminium is more expensive than steel, savings could be made in the production process, either by using extruded aluminium rather than stamped sheet for the space frame, or by using adhesive bonding techniques, thus reducing the number of welding spots. Additional advantages would accrue from savings on corrosion protection.

In Western European countries with significant automobile industries, including France, Germany, Italy and Spain, this industry ranks first in the consumption of aluminium. In Germany and France, automobile use accounts for more than a third of the total. In Italy and Spain, the industry accounts for 29 and 27.3 per cent, respectively.

B. The construction sector

The use of aluminium in building and construction varies greatly from country to country, according to local traditions and tastes. This sector ranks as the second largest user of aluminium. Construction comprises a wide range of activities, including the building of roads, railway track, bridges, factories, office buildings, public buildings and private residences. It is difficult to discern a clear trend in consumption. Although the definition of the sector varies from one country to another, it is certainly the most diverse sector in which aluminium is consumed and probably the one in which it faces the most severe competition from a wide range of alternative metals and materials. In some of its construction applications it competes with timber, plastics and coated steels; in others, lead, cast iron and concrete are all potential substitutes. The large variations in aluminium use in this sector from country to country could be indicative of a significant potential for consumption increases in many countries.

C. The packaging sector

The packaging sector is of paramount importance for the aluminium market. The consumption of aluminium in packaging has generally grown at least as fast as aluminium consumption in general. Although on a worldwide basis it still ranks as only the third largest market, behind transport and construction, the strong growth in this sector was largely responsible for the increase in aluminium demand during the course of the 1980s. Between 1979 and 1988, aluminium consumption in the packaging sector grew at an annual average rate of 3.6 per cent; this compares favourably with annual growth rates of 1.7 per cent and 0.8 per cent in the transport and construction industries. In industrialized countries, aluminium use in this sector in 1987 varied from 0.83 kg per capita in France to 8.42 kg per capita in the United States [14].

Another feature that makes this sector stand out is the massive dominance of the United States. In 1987 in the United States, aluminium cans accounted for over 80 per cent of the total consumption by the packaging sector. In Western Europe, they accounted for about 50 per cent and in Japan, for about 20 per cent, owing to strong competition from glass, plastic and tinplate.

The greatest problem facing aluminium in Europe is that the metal can is by no means the favourite means of packaging beverages in most of the major markets. Overall, beverage consumption and packaging is increasing in Europe. In most countries, the trend is away from non-packaged (i.e. bulk) consumption towards packaged drinks. A recent study by EAA suggested that while the European drinks market as a whole was growing at a modest 1.1 per cent per year, the demand for packaging was growing at over 2.5 per cent because of the growing preference for packaged drinks.

It is believed that this sector will continue to boost aluminium consumption: although the rate of growth is likely to slow in the United States, there are ample growth opportunities in other Western markets, particularly given the promotional activities of bodies such as the EAA and individual companies.

D. The electrical sector

This end-use encompasses a myriad of applications for aluminium, including conductors, overhead-underground lines and cables, transformers and capacitors. Growth in the use of aluminium in this sector was sluggish in the 1980s; indeed, the figures that are available show that between 1979 and 1987 the off-take by the sector actually fell. During the eight-year period, consumption fell by an average of 0.46 per cent per year. Despite the generally buoyant conditions that were experienced in 1988, consumption in the six major economies was still below that in 1979.

Two trends appear to account for most of the slow-down in the rate of growth: substitution and downsizing in the electronics industry and reduced investment in electricity transmission networks, resulting from slower growth in demand for electricity and the lack of investment funds, particularly in developing countries. The first trend is unlikely to be reversed. Investment in electricity transmission, which can be seen as a relatively safe market for aluminium, will depend on the availability of funds for infrastructural investment. The process of modernization in eastern Europe is of potential importance in this respect. In summary, consumption in this sector may make some positive contribution to demand growth over the next few years.

The sector did, however, enjoy a period of growth during the 1960s and 1970s, when there was a switch away from copper to aluminium for overhead transmission networks in most industrialized countries. While part of the switch reflected the extended period of price stability enjoyed by aluminium in that period, it is also true that aluminium has some technical advantages over copper. Although copper is a better conductor on a diameter-of-wire basis, aluminium has the advantage on a per-pound basis and is thus the more economical. It is only in underground installations, where limited ducting space makes cable diameter a major consideration, that copper has the advantage.

In all the major developed economies, overhead high- and medium-voltage distribution cable is almost exclusively aluminium. Aluminium is also favoured for medium-voltage underground cable in much of the United States and some European countries. However, in Japan and many developing countries copper is preferred in this application.

The substitution process is largely complete, and aluminium consumption now largely reflects the level of activity in the sector. Thus, no great improvement in demand can be expected from this end-use in coming years.

E. The mechanical sector

Mechanical engineering accounts for a relatively small share of aluminium consumption, less than 10 per cent in most countries. However, in spite of being a relatively small market for aluminium, it covers a myriad of end-uses, finding its way into applications such as industrial machinery and agricultural equipment. Off-take by this sector has improved in recent years in line with the recovery in industrial activity.

The growth exhibited in this sector since the previous cyclical peak in aluminium has only been surpassed by the rapidly expanding packaging sector. Between 1979 and 1988, off-take within the six major economies grew at an average annual rate of 1.72 per cent, from 645,000 tonnes to an estimated 805,000 tonnes in 1988. The United States dominates consumption in this category, accounting for over 50 per cent of off-take. Growth in the United States has been fairly sluggish. Despite strong performance in 1988, the average annual growth since 1979 has been just 1.2 per cent. Perhaps not surprisingly, Japan is the second largest market; here, growth has been more impressive, expanding at an average annual rate of 2.4 per cent. The prognosis seems to be for modest but constant growth.

VIII. Environmental aspects of the aluminium industry

A. An overview of world environmental trends

In the minds of many people the words "industry" and "environment" immediately spell conflict. They see industrial prosperity and environmental protection as mutually exclusive, since the requirements of industry for raw materials and outlets for waste are incompatible with the demands of the environment. There is ample evidence from the past and the present in support of this conflict model, but it is not as generally valid as is often claimed.

The exploitation and management of natural resources is an entirely legitimate activity providing that due regard is given to the conservation of the environment and its vital natural systems. All organisms exploit their environment in order to live, and human beings are no exception. Where human activities differ from those of other organisms, however, is in their potential for causing serious, irreversible and widespread damage to other species and systems.

Two aspects of the human impact - the withdrawal of resources and the input of wastes to the environment - can generate pollution, alter the critical parameters of global cycles and destroy habitats at rates and on a scale generally unmatched by other organisms. It must not be forgotten that humanity is dependent on natural systems, for despite its technological sophistication, food is still ultimately derived from photosynthesis, many valuable pharmaceuticals and raw materials are obtained from natural sources and the composition of the air that people breathe is still largely determined by natural processes [15].

Of course, the term "due regard for the environment" is interpreted differently, depending very much on one's perspective. There are still those in industry who believe that the planting of a few pollution-resistant trees around a factory producing unacceptable emissions constitutes due regard. Public relations ploys can, fortunately, usually be readily recognized as such and then disregarded. Just as easily dismissable are those who equate due regard for the environment with the complete preservation of the status quo, irrespective of the circumstances. Conservation does not mean putting the entire planet in a museum, where no changes are permitted. Instead, it means the rational and sustainable management of the resources with which the earth is endowed. In some cases this may mean the protection of specific areas from development or pollution, while in others it may mean comparatively minor changes in the rate or pattern of exploitation.

The extreme views cited above are less commonly encountered these days than a couple of decades ago, although the media are quick to seize on conflicts and to polarize the different points of view. The environmental movement, as it may loosely be termed, has matured with experience and growing knowledge, although it may still sometimes find it necessary to be strident or flamboyant.

Industry, too, has refined its perspective, frequently recognizing the need to take environmental implications into account at an early stage of a project's development. The reasons for doing so may vary, from altruism to fear of adverse publicity, but irrespective of the motivation it is a welcome improvement. Some companies have found that pollution prevention pays in simple economic terms. Unfortunately the practice is not yet universal, and there are still some operators who would attempt to make quick profits at the expense of the environment. This alone is sufficient justification for the existence of environmental pressure groups such as Friends of the Earth and Greenpeace.

In political circles, environmental issues are also considered, but it is tempting to suggest that they are only taken seriously when they become embarrassing. This view may be cynical, yet the complacency shown by successive Governments over such issues as lead and petrol, the hazards of asbestos and the destruction of wildlife habitats more than justifies the cynicism. However, it is true to say that government perspectives on environmental matters are sounder now than they were 20 years ago, and as perspectives on all sides mature, progress can yet be made.

B. Industry response to the environmental challenge of aluminium

An overwhelming majority of the leadership in the aluminium sector agrees with Sony president Akio Morita's assertion that the environmental challenge will be one of the central issues of the twenty-first century [16]. Organizations with a poor environmental record will probably find it more and more difficult to recruit and retain high calibre staff. Many senior managers also foresee increasing pressure from consumers, who will ask "How green is your company?" before buying a product.

In almost all industrialized countries, government environmental policy was at first motivated by a concern about public health. Only in the early 1970s, when the inadequacy of existing approaches became obvious, was environmental policy split off from national departments of health, becoming a separate area of government attention.

Senior aluminium industry managers seriously doubt that environment-related costs can be recouped through higher prices. They also feel strongly that the mounting costs of environmental measures will hurt competitiveness. According to the Sony president, "At present, the aluminium sector does not enjoy excessively good relationships with the main players in the environmental policy arena, although it compares with other industries in this regard." [16]

In dealing with the environmental challenge, the aluminium sector must expect to be confronted with real issues. There are a number of indications that the corporate response to this challenge is currently inadequate. Only 33 per cent of aluminium companies worldwide said they had assigned responsibility for environmental matters to a member of their company's board of directors. A limited number of companies have installed an advisory board or a group of external experts to assist management with its environmental policy-making.

C. The environmental effects of the aluminium industry

Aluminium is a peculiar metal because its production is extremely energy-intensive and environment-polluting, whereas its use is energy-saving. Since it is likely that consumption will increase, it is important to deal with the detrimental effects of aluminium and its raw materials on the environment and humanity.

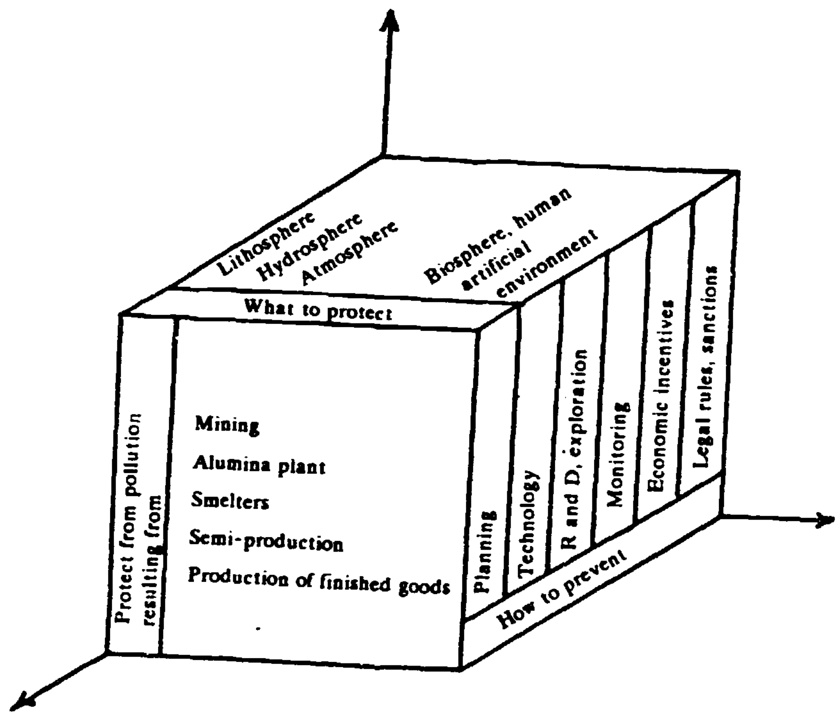
Figure VI, adapted from Varga [17], shows the affected elements of the environment, the processes that are causing the pollution and ways in which the environment can be protected.

Each element of the environment suffers a different impairment by each process. Bauxite mining injures mainly the lithosphere (the rock bed), the pedosphere (the soil layer) and the hydrosphere (the undersurface and surface waters) and, to a lesser extent, the biosphere (the fauna, the flora and the microorganisms). At the same time, the heavy phyical work being done underground means above-average stress on the human being.

The production of alumina pollutes, first of all, the atmosphere (dust, flue gases, alkaline aerosols); however, the soil is also seriously polluted (red mud ponds, seepage of caustic solutions and spillage of waste). The injurious effects of alumina plants may also be perceptible in the artificial environment, namely, in houses. To lessen pollution, the recultivation and utilization of red mud ponds will be an important task for the future.

Aluminium smelting pollutes the air. The main pollutants are fluorides, either gaseous or solid. In addition, there are carbon monoxide, carbon dioxide and sulphur dioxide gases and tar fumes, which contain polycyclic aromatic hydrocarbons (PAHs). The World Health Organization (WHO) has classified PAHs as carcinogenic chemicals. The health of workers in the smelters must therefore be continuously controlled. Coal slag from electrolytic cells and slag from cathode decomposition also have a considerable polluting effect. The air pollution from aluminium smelting not only affects the metal workers at their workplace and in their nearby homes but it also affects the surrounding open spaces. Indirectly, the water and the soil in and near the plant become polluted. Indeed, of all industrial plants that pollute the environment, the aluminium smelter is one of the most dangerous.

Figure VI. Environmental impacts of the aluminium industry and mechanisms for mitigating the damage



Within the aluminium industry, the semi-production plants cause the least environmental pollution. The components of this pollution are the gases, oil and solvent fumes, and dust that pollute the air; the oil, emulsions, oil-sludge and alkaline pickling solutions that pollute the soil and water; and the storage of the scrap. Plants that make finished products in the machine industry have a similar profile: they too are not as polluting as other sectors of the aluminium industry.

The direct effects of aluminium on the human organism, the detrimental mechanism involved and the indirect effects when "infected" plants and animals are consumed by humans must be subjected to further research. In the light of the results of this research, a defensive action can be elaborated and further investigations can be planned.

1. Environmental considerations in the exploitation of bauxite mines

The main deposits of bauxite are in regions of the world where natural conditions are very susceptible to the action of the industrial processes involved. The deposits are often in or near important natural features, such as the Amazon basin. Such is the case with Venezuela and Brazil, which are the most important producers of bauxite in South America. Because they are also home to the world's largest tropical forest, which plays a vital role in regulating the earth's climate, these countries are a focus for the eyes of the world. In all their development projects they must take into account the environmental aspects.

The experience of Brazil with the Lower Trombeta bauxite deposits in the heart of the Brazilian Amazon basin has been very important in the development of environmental policies, which involve the relationship between human beings, the industry and the environment. The same is true in Venezuela with respect to the Los Pijiguaos bauxite mine [18].

The main environmental damage attributable to the establishment and operation of bauxite mines may be listed as follows:

Loss of the vegetation coverage
Loss of topsoil
Inversion of the soil layers
Soil compaction
Soil impermeabilization
Landscape modifications
Erosion
Landslides
Watercourse damming
Watercourse silting
Dust
Smoke and fly ash
Detonations and other noises
Liquid residues
Solid residues
Tailings
Oil in the soil and water
Liquid ballast from ore carriers
Industrial toxic wastes
Pesticides
Garbage in the soil and water
Sewage
Loss of fauna habitat
Hunting
Permanent intensive fishing
Grass and bush fires
Deforestation

In addition, there have been parallel activities by others who are not involved in the mines *per se* but who take advantage of the improved access to set up agricultural communities based on slash-and-burn farming or illicit lumbering.

Brazilian federal and state environmental legislation is well conceived and establishes an adequate national control structure. The 97 laws and standards (in addition to 27 references in the new constitution of 1988) are based in many ways on laws and standards extant in the more developed countries. However, there are differences of interpretation and application, due principally to the lack of administrative organization and professional expertise at the state and municipal levels that have been entrusted with surveillance and decision-making powers.

To fully comply with the law, a mining company should complete six procedures with the state environmental authority before starting up mining and beneficiation or before substantially modifying the existing layout:

(a) Submit an environmental impact study for the proposed activity;

(b) Receive a licence to plan the project;

(c) Submit the project plan, incorporating environmental considerations;

(d) Receive a licence to install the project;

(e) Request an official inspection of the installation and the pollution control equipment;

(f) Receive the operating licence.

However, companies that started up before the 1983 law was promulgated are still unclear as to what they should do to bring their activities in line with the law. Can licensing be retroactive? Also, there is no way to enforce this law among the many independent, unregistered alluvial panners scattered throughout the country who are responsible for a considerable amount of environmental damage, especially to rivers and streams.

Another impediment is the lack of standard technical guidelines for field activities that are potentially damaging to the environment. Consequently, the authorities often act without coordination, are confused and undecided on how to interpret the regulations, and tend to hand down hasty decisions, especially on problems that have been sensationally reported in the press.

So for the moment it is very much a matter of industry policing itself, with results depending on an individual company's ethics. It is precisely in this respect that authorities in the Ministry of Natural Resources feel challenged, especially considering that the companies in this sector have international participation and that their mining activities take place within a region recently declared to be part of the national heritage. It is necessary to have flexible corporate policies that allow modifications to the functional structure and the manipulation of material, financial and human resources to maintain a high degree of environmental protection. There has been considerable investment in technical innovations and ecological studies that will reduce and eventually eliminate pollution and environmental degradation in and around the sites of industrial mining operations.

2. *Environmental considerations in alumina production*

In alumina production one of the most critical issues from the environmental point of view is the red mud, whose main constituents are non-toxic oxides and silicates (Fe_2O_3, Al_2O_3, SiO_2, TiO_2, Na_2O and CaO). The problems are caused by the large volume of the mud, by the alkali content of the liquid phase of the mud slurry and by the fact that the NaOH content is bound in the solid phase in the form of sodium aluminium hydrosilicates, which tend to dissolve slowly and partially in a process of hydrolysis. The environmental effects can be summarized as follows:

(a) The impoundment areas reduce the land available for agriculture;

(b) The alkaline solution seeping out of them may lead to a chemical imbalance in the soil around them and contaminate the groundwater;

(c) The dusting of dried-out mud lakes can be felt over wide areas.

The huge amount of digestion residues produced every year and the many years over which the Bayer process has been operated mean that about 1 billion (dry) tonnes of this material has been impounded so far. This figure increases by 3-4 per cent every year. Efforts to reduce the negative environmental effects of the red mud have taken the following directions:

(a) The development of new storage methods and the revegetation of abandoned impoundment areas;

(b) The modification of the alumina manufacturing process to discharge a residue less harmful to the environment;

(c) The utilization of red mud in agriculture to improve soil;

(d) Processing the red mud by complex, waste-free processes [19].

In 1980, UNIDO, in close cooperation with the United Nations Environment Programme (UNEP) [20], presented a paper on the disposal and utilization of bauxite residues (red mud) for the UNEP/UNIDO Workshop on the Environmental Aspects of Alumina Production, held at Paris in January 1981. That paper was based on information from some large alumina-producing companies, institutions and Governments, on the technical literature and on the results of field missions carried out by a team from ALUTERV-FKI, the Research and Engineering Centre of the Hungarian Aluminium Corporation, which has more than half a century of experience in the disposal and use of red mud.

Developments in the handling and disposal of red mud were rapid during the 10 years between 1980 and 1990. Processes mentioned by Sigmond and others [20] as distant possibilities have now been realized in the majority of plants, and environmentally sustainable technologies are now in place [21]. The engineering designs of all new alumina plants pay special attention to this issue.

Finally, the negative environmental impact of the alumina industry can be mitigated by a number of measures:

(a) Reduction in the amount of natural resources (primarily energy) consumed per unit of alumina produced;

(b) Reduction in the amount of residual discharges (effluents, dust, stack gases) per unit of alumina produced;

(c) Environmentally sustainable discharge and storage of digestion residue (dry stacking of red mud) and recultivation of the filled-up storage areas

To achieve these reductions, it will be necessary to improve operational and maintenance practices. Economically reasonable measures for the efficient utilization of resources, pollution control and waste disposal will also need to be introduced. All these measures must conform with the requirements of economically sustainable economic development.

3. Environmental considerations in aluminium smelting

The principal areas of concern in the smelting of aluminium are emissions to the atmosphere, as well as liquid and solid wastes.

(a) Emissions into the atmosphere

Long before the protection of the environment became a concern, the aluminium industry was developing and applying emission controls. Most of the early efforts were directed towards controlling fluoride emissions because of their potential to harm vegetation, cattle and the atmosphere. The technology to control fluoride emissions is now well established, and attention is being shifted to other emissions [22].

The gases and particulate matter given off by a (chemical) process are known as the evolution from that process, and those gases and particulates that escape collection and treatment are known as emissions. Atmospheric evolution from an aluminium cell consists of particulate fluorides, gaseous fluorides, aluminium dust, carbon dust, sulphur dioxide, carbon dioxide and carbon monoxide. Cells typically evolve 20-30 kg of fluoride per tonne of aluminium produced and approximately the same amount of alumina and carbon dust. Sulphur dioxide evolution varies according to the sulphur content of the coke used in the anodes. Most of the carbon monoxide burns as it leaves the cell.

There are two methods approved by the United States Environmental Protection Agency (USEPA) for measuring fluoride emissions: the EPA method [23] and the Alcoa method 4075A [24]. Both sampling methods involve isokinetic sampling, the collection of particulate on a filter and scrubbing of the gas stream. The analytical methods involve the distillation of the fluorides and their determination by ultraviolet spectrophotometry or by a specific ion electrode. While both methods accurately measure total particulate, Alcoa method 4075A has the advantage of determining total particulate while determining the form of the fluoride emission, gaseous or particulate. These data allow more effective control of the smelter emissions through process modifications or installation of the proper control equipment.

Emissions in the pot-room can be measured by USEPA method 14 [25] or by the treated pad method proposed by Alcan [26]. Method 14 describes how to obtain an isokinetic sample from the pot-room monitor. The fluoride content of the sample is then determined using method 13 or method 4075A. The Alcan method obtains a particulate and gaseous fluoride sample on a series of pads. These pads are then analysed by the technique described in method 14 or method 4075A. USEPA method 14 is difficult and expensive to retrofit to existing pot-lines. The Alcan approach offers significant advantages for sampling existing smelters. Court and Ferrari [27] discuss the two methods.

(b) The control of cell emissions

Today's cells are equipped with closely fitted hoods to collect the evolved gases. The hoods are kept at a negative pressure and draw in approximately a hundred times as much air as cell gas. This assures high collection efficiency and lowers the gas temperature from 1230 ± 20° K, as it comes from the cell, to 380 ± 20° K in the ducts carrying the gas to the pollution control equipment. Such high dilution is energy-inefficient, and techniques are being studied to draw in less air and still maintain high collection efficiency. Both wet and dry scrubbing systems are used to treat the cell gases, but dry scrubbers are considered state-of-the-art. Some older smelting facilities use a combination of electrostatic precipitators to remove solids, followed by spray towers to remove hydrofluoric acid and some of the sulphur dioxide; other installations use wet electrostatic precipitators, which effectively collect both gaseous and particulate fluorides and some sulphur dioxide. All these gaseous emissions have become relevant in recent times because of their effect on the atmosphere and, principally, the ozone.

(c) Waste water treatment

Waste water effluent is not usually a major problem except in plants where wet scrubbers are still used to control emissions to the atmosphere. Dry scrubber systems have greatly reduced the generation of waste water. Some of the older facilities, however, still use wet collection devices that generate waste water contaminated with acid fluoride and organics. The conventional treatment is to add lime to neutralize the acids, to precipitate the fluoride as calcium fluoride and to precipitate a significant proportion of the dissolved organics. Subsequent biological treatment with either aerobic or anaerobic bacteria removes at least 98 per cent of the organics. Skimming, absorption and sedimentation are also used. Some plants recover the fluoride value of the sludge.

The removal of spent cell lining after cathode failure presents a special waste-water-treatment problem. Water is applied to thermally shock and fracture the deposit of aluminium. Excess water is collected in a designated sump and used as make-up for the next cell. Under no circumstances may this water be discharged, for it may contain 10-200 mg/l of complex, free cyanides and 100-600 mg/l of fluoride. Complex cyanide compounds are very difficult to treat, so reuse of the water for pot cooling is the best alternative.

A major source of waste-water at a smelting plant is storm runoff. Although intermittent, the contamination loading can be significant unless efforts are made to protect pot-lines from the rain. Many smelting plants direct their storm sewer through an equalization holding basin before discharge to minimize the environmental impact of storm water. The basin is designed for the removal of floating oils, the settling of particulate and the adjustment of pH.

(d) Occupational health

The environmental contaminants cited above do not cause diseases that can be considered characteristic of the aluminium industry. Dusts of bauxite, alumina and aluminium are generally regarded as non-fibrogenic. Although there are some reports to the contrary, they are not corroborated by the bulk of the literature. Most toxicological and epidemiological studies indicate that exposures to aluminium and its compounds are relatively innocuous [28]-[31]. Many of the government agencies that regulate occupational health consider dusts of aluminium and alumina to be biologically inert (nuisance) particulates [32].

Workers involved in the production of the electrodes used in the electrolytic reduction process are exposed to petroleum coke dust and coal tar pitch volatiles that originate from the raw material. Although the coke is a nuisance material, the coal tar pitch is not. Employee exposures to coal tar pitch volatiles in both the electrode plants and the Soderberg pot-rooms, where electrodes are baked in place, have occupational health experts worried about the possibility of an increased incidence of lung cancer. Their concern is due largely to the finding of an increased (up to 10 times) risk in coke-oven workers who are exposed to similar coal tar products, but with some significant qualitative and quantitative differences. Epidemiological studies of the aluminium industry have not conclusively demonstrated an increased risk of cancer.

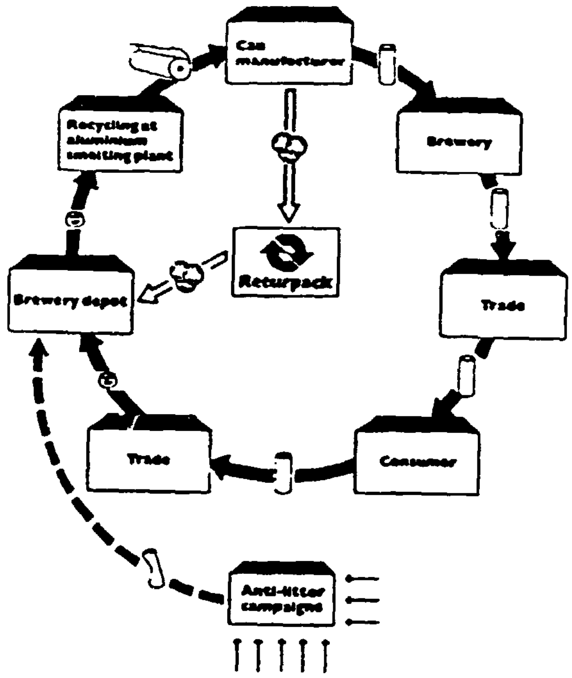
The other common contaminant to which workers in aluminium smelters are exposed is fluoride. Exposures to gaseous and particulate fluoride occur mainly in the pot-rooms. There is nothing to indicate that fluoride exposures represent a major threat to health. Pot-rooms are usually well-ventilated, and when the pots are hooded and exhausted, as most are today, there is little likelihood of occupational fluorosis occurring in the pot-room population. The good ventilation in the pot-rooms also makes it highly unlikely that carbon monoxide or sulphur dioxide will become troublesome contaminants.

4. The recycling of aluminium products

Recycling is a process that has a great impact on the environment. In the case of aluminium, it takes on great importance. Eight years ago, a recycling system for aluminium cans was introduced in Sweden, and the recycling rate has been raised over the last six years from 60 per cent to 83 per cent. The recycling system for aluminium cans is shown schematically in figure VII. All the cans collected are used for the manufacture of new aluminium cans [33].

The high rate of recycling cans is very significant: the smelting of one tonne of recycled aluminium requires only 5 per cent of the energy needed for smelting one tonne of primary aluminium [34]. This gives some idea of the overriding importance of energy in the aluminium production process.

Figure VII. Scheme for recycling aluminium cans



D. Economy and environment

Sound environmental management has become a part of economic development. It must be promoted by propagating modern, environment-friendly industrial technologies, by training expert staff and continuing their education, and by organizing international professional conferences [17].

The connected problems of ecology and the economy can be solved through international cooperation. It will be easier to identify and achieve the common interest if everyone can be convinced of the economic benefit. However, because the effects of the environmental damage are usually delayed, such direct benefits may be hard to demonstrate.

Air and water, the basic elements for human life, had always been regarded as free goods. However, it is now realized that there are costs of protecting them. The question is not whether these costs are justified, but who should bear them. It is important that regulations or levels of pollutant emissions should be established for the whole world (they could, however, vary by region). They should be applied strictly when new establishments are constructed and should be aimed for in retrofitting [35]. In general, modifications to existing old plants are relatively costly(they may reach 30-50% of the original investments costs); environmental safeguards incorporated into the design of a new plant, or the significant expansion of an existing one, do not increase the capital costs by more than 5-10 per cent. New plants usually have a competitive edge because they make use of environmentally sustainable solutions [19].

The costs of preventing or repairing environmental damage may be borne by individual countries, as communal costs, or by the companies that cause the damage. The mining laws of the countries of the world generally put the burden of compensation for damage on the companies exercising mining rights. The presumption is that since the aluminium industry is a worldwide industry it will be able to manipulate prices so as to recoup environmental costs from the end-users. The "polluter pays" principle has to be enforced generally.

It would be possible to organize complex data collection on the effects of the specific environmental damage effects of the aluminium industry, on the standards causing said damage, and on the measures for the prevention of the damage. This could be followed by the transfer of knowledge (training, continuing education) and the control of the standards [36].

Research into environmental effects and, as part of this, the raising of people's awareness of the issue would be facilitated if international funding could be arranged. Such funding would be justified by the fact that environmental damage affects the whole of humanity [17].

IX. Conclusions

The aluminium trade exhibits cyclical behaviour, with the last cycle having occurred between 1988 (peak) and 1991 (valley). In 1991, the production costs of most of the primary aluminium smelters were higher than market prices for the product; however, some of the smelters were obtaining marginal profits. This situation has led many unprofitable smelters to shut down. In the last quarter of 1991, the total cut in output was nearly 800,000 tonnes; despite this, prices were dropping. From December 1991 to January 1992, prices reached US$ 1,253 per tonne. In 1992, the price is expected to be approximately US$ 1,000 per tonne because of oversupply, excess inventories and the poor economic situation in developed countries.

Keen competition in the aluminium trade worldwide has made it necessary to review the patterns of aluminium production and to rationalize and integrate its various phases. Plants in Europe and Japan and some in the United States are not as competitive as plants in Latin America, the Middle East and Oceania. This explains why growth in the latter regions has been consistent. On the other hand, production at European plants is steadily shrinking, with some plants closing, and at North American plants is stabilizing.

The bauxite and alumina industries exhibit similar behaviour. The European bauxite mines are exhausted, and in North America the exploitation of the mines is decreasing. Mines in Oceania, Latin America and Asia have increased their output significantly.

The situation in the alumina industry is the same. The European producing countries, however, instead of maintaining the same production level of metallurgical-grade alumina are producing more non-metallurgical-grade alumina, which gives better profits owing to its high value-added.

The production of semi-finished and finished aluminium products has been concentrated in the developed countries, and there are no political, technological or economical conditions that would cause this situation to change.

Because the production of aluminium is a very energy-intensive process, the effects of the industry on the environment are of great concern. Research should be intensified, to gain a better understanding of the contamination processes and to ensure a green aluminium industry.

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