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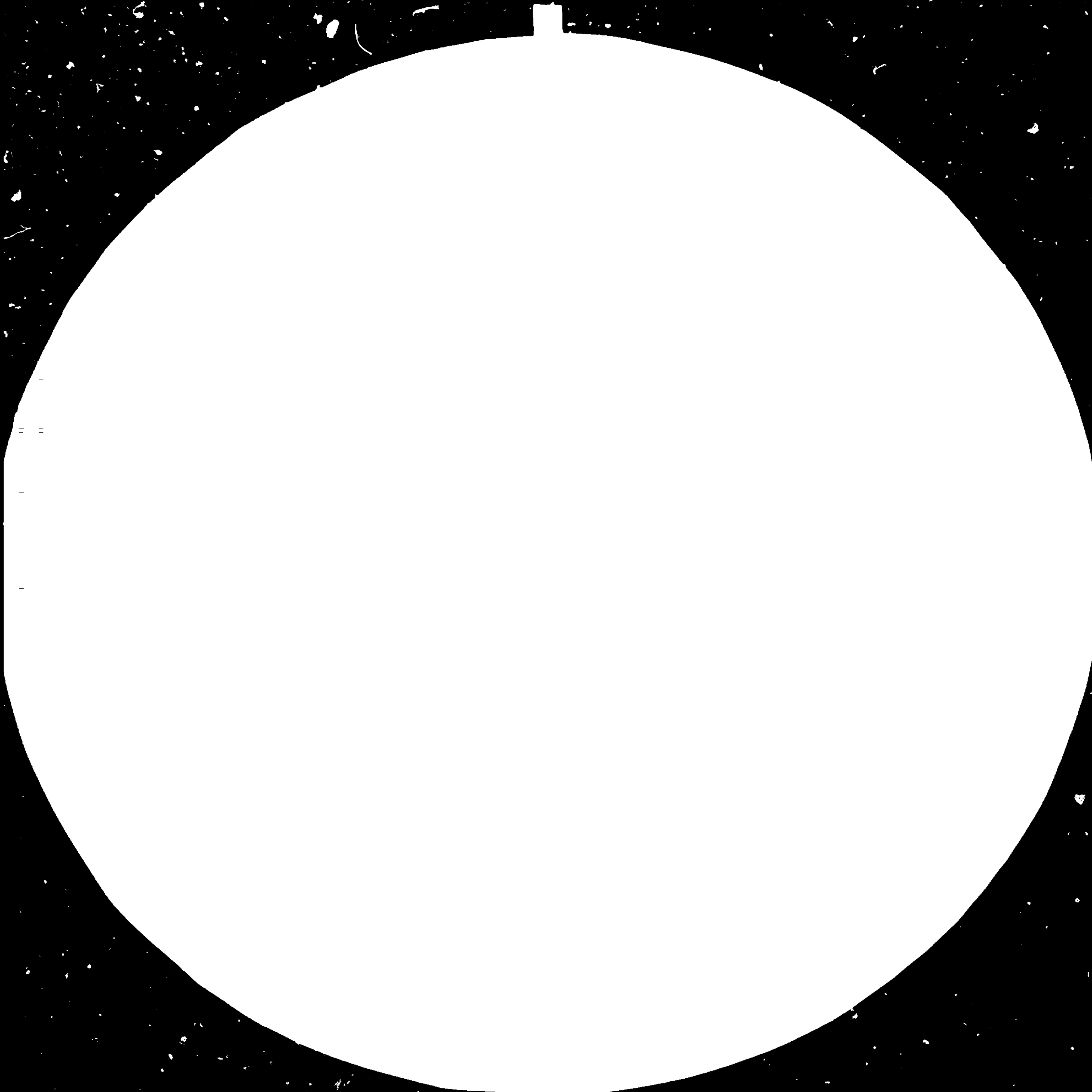

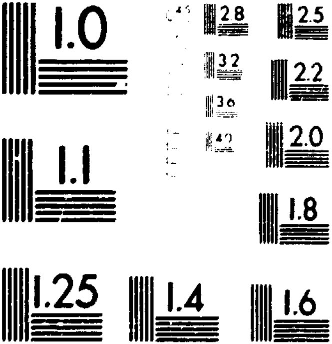

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MINING AND MINERAL PROCESSING IN DEVELOPING COUNTRIES*

by

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INTRODUCTION

This report is prepared pursuant to Agreement No. CLT-84-147 between the consultant and the United Nations Industrial Development Organization. The terms of reference for this study are as follows:

> The study is to cover the industries of aluminium, copper, nickel, tin, lead and zinc.
>
> The main aspects to be covered by the study are the following:
>
> 1. Projection of the demand for the 1980s of the different processed metals in the developed and developing countries.
>
> 2. Definition of the capacity of industrial production in the 1980s in the developed and developing countries.
>
> 3. Define the main balances between supply and demand in the developed and developing countries.
>
> 4. Prospects for further local processing by developing countries. In the context of the actual crisis and the division of labour that is taking place, define the possibilities and degree of industrial processing that can take place in the developing countries.
>
>   In the development of this point special attention has to be given to the analysis of the possibilities to establish a more integrated development between the non-ferrous industry and the capital goods and steel industries in the developing countries.
>
> 5. Main barriers and benefits to be gained from local processing. In the analysis of the barriers special atten- has to be paid to the following aspects:
>
>   (a) economic factors
>   (i) tariffs and other trade limitations
>   (ii) marketing problems
>   (iii) technological changes
>   (iv) energy costs
>   (v) high intensity of capital in the non-ferrous industries

(b) Non-economic factors
(i) main strategies of transnational corporations

6. Government strategies of the developing countries that are main producers.

In this aspect it is important to consider:

(a) the impact of the crisis on the policies of the developing countries related to the non-ferrous industry.

(b) the role of the state and state-owned enterprises and implications for developing countries' investment capabilities.

7. Possibilities of co-operation between the developing countries for further local processing.

The structure of this report follows the outline of topics as set out in these terms of reference. Moreover, the report has been prepared in the light of previous UNIDO work in this area, including the study prepared by the present author and Marian Radetzki on "Mineral Processing in Developing Countries" (1980) and the material on the non-ferrous metals sector prepared by Mr. Christian Gillen of UNIDO (1984).

The basic conclusions of the report can be summed up briefly:

1. Demand for most of the metals studied can be expected to increase more slowly in the remainder of the 1980s than in the 1970s; the lower growth rate is a function both of the expected slower growth of the world economy and of the lower intensity of use of most metals, which is itself a product of higher energy prices in the 1970s, leading to increased materials conservation and

the use of non-metal substitutes, and of the mid-1970s concern with the possibilities of resource exhaustion.

2. Capacity closures can be expected in North America and in Western Europe and Japan, especially in the energy-intensive processing facilities. These closures will provide some opportunity for a re-structuring of world metal production, by opening the way for new facilities in the developing countries, but these opportunities will be limited by difficulties in securing adequate financing and by competition among countries, resulting in the distinct possibility of over-capacity in many metals.

3. For most metals, supply can be expected to continue to outstrip demand for the remainder of the 1980s; in particular, developing-country suppliers in the copper, bauxite and nickel industries can be expected to become the marginal or "swing" production, as the industrial countries come under increased pressure to adopt protective measures to safeguard their remaining existing mining and processing industries.

4. If financing problems can be resolved, the establishment of mineral-processing facilities in the larger developing countries can be justified, and may contribute to the retention of a larger share of the value of mineral production in the producing countries. For many smaller

countries, however, the economics of mineral processing and semi-fabrication are, at best, questionable, and many of these countries will face a choice between remaining exporters of unprocessed raw materials or participating in regional processing initiatives, if these exist.

5. While tariffs and other barriers to developing countries' processed minerals and metals imposed by the industrialized countries have diminished in importance in the past decades, these barriers still exert a certain bias against the Third World's products. In addition, the recent strategy of transnational corporations in the minerals industries, to diversify their sources of raw materials supply and to concentrate their processing and fabricating operations in what they consider to be politically "safe" countries has had the effect of depriving developing countries of an important potential source of capital for processing operations. On the other hand, the developing countries often possess locational advantages, especially in the form of low-cost energy; these advantages account, for example, for the building of aluminium smelters in Bahrain, Algeria and Egypt.

6. Appropriate government strategies depend on the situation of the particular country in question; it does

not usually make sense for all countries to proceed to mineral processing merely because their mine production capacity exceeds some theoretical minimum efficient level. As such recent projects as the Pasar copper smelter in the Philippines have shown, the start-up of a processing project may actually reduce the profitability of domestic minerals enterprises. (This reduction in profitability may, of course, be justified on the basis of other national benefits, such as increased integration of the national economy, employment, etc.) The most important general aspect of developing countries' strategy in this area is that the strategy must suit a country's level of economic development.

7. Opportunities for co-operation among developing countries are particularly promising in the minerals processing field. Many regions encompass some countries with low-cost mineral resources, others with low-cost energy, and still others with well-developed industrial bases and sizeable markets; in such situations, the prospects for co-operative processing projects are good. Difficulties have repeatedly arisen, however, in bringing such co-operative projects to fruition. The repeated failures of the Caribbean and Central American countries, for example, to agree on a bauxite-alumina-aluminium complex are typical examples. Promotion of such regional co-operation is an area in

which United Nations agencies with appropriate expertise, including UNIDO and the Minerals Branch of the Department of Technical Co-operation for Development, might play a particularly important catalytic role.

All in all, the conclusions of this report are less optimistic, as regards prospects for mineral processing in developing countries, than some other recent studies, including the author's earlier Mineral Processing in Developing Countries (1980) and the publication of the same name produced by UN/DTCD in 1984.1/ The decline in many minerals markets, which many developing-country observers have wanted to see as a short-term or cyclical phenomenon, is more and more appearing to be a long-term secular trend. The age of metals as the basis of the world economy may well be drawing to a close, and with it the opportunities for developing countries to rely on their mineral endowments as the sole basis for economic development.

1/ United Nations (Department of Technical Co-operation for Development), Mineral Processing in Developing Countries, London, Gr-ham & Trotman (special issue of Natural Resources Forum) 1984.

I. DEMAND PROJECTIONS FOR NON-FERROUS METALS

Two basic factors contribute to the demand for non-ferrous metals: the level of economic activity, especially in the industrialized countries, and the intensity of use of metals in industrial activity. Any projection of demand growth must be based on certain assumptions regarding each of these variables.

The overall level of economic activity, especially in the industrialized countries of the OECD, has been erratic and low over the past decade. In some years, economic activity actually declined, and in all years since the mid-1970s, the growth rate for the OECD as a whole, whether measured in terms of real GDP or industrial production, has been lower than during the preceding two decades. According to UNCTAD estimates, OECD economic growth from 1980 through 1984 will average only 1.5% per year. Along with these generally low levels of economic growth have gone particularly low levels of capital formation, especially in 1982, when private fixed investment actually declined in the United States, Japan and the European Community.

These low growth rates in the industrialized countries have also, as has been widely noted, had a strong impact in restricting the growth of developing countries, by reducing demand for these nations' exports and by contributing to the now-chronic over-supply situation for most non-ferrous metals, a situation that has resulted in metal prices which are currently at or near the lowest point, in real terms, that has been reached in the past 40 to 50 years.

With the exception of aluminium and, to a lesser extent, nickel, the outlook for demand for the major non-ferrous metals is also dampened by the substantial decline in intensity of use which has occurred since the oil price increases of 1973-74, and especially since the second major round of oil price increases in 1979-80. In the case of copper, for example, the use of optical fibers has substantially eroded the potential for growth in copper consumption in communications, one of the metal's major traditional markets. At the same time, copper use in the automotive industry has been substantially cut back, by the use of plastics and other substitutes and by the development of metals-saving technologies, as, for example, in light-weight automobile radiators. Similarly, the use of zinc in automobiles has declined substantially, as weight-saving technologies are adopted in order to provide better fuel economy. And the traditional market for tinplate in beverage cans has been virtually eliminated by the substitution of aluminium, plastic and glass containers.

Table 1 shows worldwide consumption of the six non-ferrous metals included in this study. Even for aluminium, the most buoyant of the metals, the 1970-83 consumption growth rate is only 3% per annum, while copper, nickel and zinc show growth rates between 1% and 2%, and tin actually has a negative consumption growth rate of 0.6%. No compelling reasons have been advanced that would, in the author's view, support predictions of greater growth in the coming decade.

TABLE 1. WORLDWIDE CONSUMPTION OF NON-FERROUS METALS

(thousand tonnes)

	1970	1975	1980	1983 1/	1970-83 Growth Rate (%)
Aluminium	9996	11350	15312	14666	3.0%
Copper	7271	7458	9385	9050	1.7%
Tin	227	219	223	210	-0.6%
Nickel	577	576	717	672	1.1%
Zinc	5056	5066	6131	6308	1.7%
Lead	3871	4526	5348	5263	2.4%

1/ Estimated.

Sources: World Metal Statistics; Mining Annual Review 1984.

Aluminium

Despite substantial recovery in demand in 1983 (an increase of consumption over 1982 of 16% in the United States and 9% in the rest of the market-economy countries), most observers agree that the longer-term outlook for aluminium demand is for increases that more or less approximate world economic growth rates. Substantial areas of strong demand include food processing and beverage canning, and the continuing substitution of aluminium in vehicles, replacing other metals, so as to decrease weight and increase fuel efficiency. Growth of demand in such more traditional applications as aircraft and industrial machinery, however, is generally expected to lag behind overall economic growth in the major industrial countries. On balance, assuming continuation of recent OECD growth rates, an aluminium consumption growth of 3-4% per annum appears to be a reasonable estimate.

Copper

The rapid growth in worldwide copper consumption in the 1960s (annual growth rates approaching 6%) was largely the result of the economic reconstruction of Japan and Western Europe. Now that a basic economic infrastructure exists in these areas, and the financial situation of such potential industrializing countries as Brazil, India and China makes it unlikely that they will take the place of Japan and Western Europe as copper consumers, at least in the 1980s, the outlook for copper demand is universally agreed to be pessimistic. The 1970-83 growth rate of 1.7% is a rough approximation of the forecasts for consumption growth over the next decade that are currently being made (once again, assuming a continuation of recent OECD growth rates). To put this rate in perspective, it implies an increase of a little more than 100,000 tonnes per year, or less than one major new mine annually. With some 25-30 already-evaluated mining projects awaiting development around the world, this is not a promising outlook. Moreover, the increasing use of scrap as a source of copper (a growth rate in scrap consumption of 6.5% annually in recent years) further depresses the prospects for new mine development. Demand for copper has also been restricted in communications, as a result of the increasing use of optic fibers, in transportation, where it has been replaced by weight-saving materials, and in electrical transmission, where the continuing scaling-down of electricity demand forecasts has led to a sharp reduction in the need for transmission cables.

Nickel

Nickel demand is largely derived from demand for steel, and has been sharply affected by the depression in this industry, especially since 1980. Nickel consumption in 1983, while still well below the peak level of 1979, was somewhat higher than in 1982, reflecting a modest upturn in steel demand. For the longer term, however, few predictions of nickel demand foresee growth rates much in excess of the 1% per annum level that has been achieved since 1970.

Lead

Although worldwide demand for lead was somewhat stronger than that for copper or nickel in the 1970-83 period, the longer-term outlook appears to be more pessimistic. Recent improvements in electric storage-battery technology require less lead per unit. Similarly, plastic has been substituted for lead in a number of plumbing applications, and a generalized concern with lead's toxic qualities will undoubtedly restrict its use in the future. On the other hand, there has been some increase in lead demand for use in automobiles, especially in corrosion applications. One long-term possibility for substantial use of lead is in the storage and disposal of radioactive material; this is a market that will develop more rapidly as existing nuclear power stayions reach the end of their useful lives and as agreement is reached on appropriate permanent disposal methods for nuclear waste. The size of this market for lead is, however, virtually unpredictable. In any event, a growth rate somewhat less than the overall OECD economic growth rate seems a reasonable forecast for lead demand for the coming decade.

Zinc

The most important determinant of zinc demand is the overall state of the economy in the industrialized countries, since the bulk of zinc use is in applications with relatively little elasticity -- automobiles and construction. Recent technological developments, including the use of zinc alloy coatings, have contradictory effects; on the one hand, they reduce the amount of zinc used in some of the traditional applications, while, on the other hand, they may open up new markets, as, for example, in situations where newly-developed zinc casting alloys can more effectively compete with other materials and processes. A further possible area of increased demand is in the use of zinc for low-value coinage; the United States shifted from copper to zinc as the basis for its lowest-value coin in 1982, and other countries are likely to follow suit.

While few industry analysts foresee demand for zinc rising faster than overall OECD economic growth, some improvement from the growth rates of the 1970-83 period does appear to be a distinct possibility.

Tin

Demand for tin has now been declining for many years; it appears that tin is a fully "mature" metal, and that the development of substantial new areas of use is extremely unlikely. The use of tin in tinplate (which accounts for a third of total tin consumption) has declined by more than 35% in the past decade, reflecting the substitution of aluminium and plastics in beverage containers. In the U.S., for example, 98% of beer cans and 88% of soft drink cans are now made of aluminium, and similar shifts are underway in Europe and Japan. Moreover, even where tinplate is still used, technological advances have substantially reduced the amount of tin metal used in the tinplate.

Tin's other major market, solder for electrical uses, is also threatened by technological change, as electronic equipment is increasingly based on the use of printed circuits and miniaturized components. Thus, tin use per unit of production in the electronics industry has substantially declined, although overall tin use in this sector has not fallen to as large an extent, because of the rapid growth in overall electronic equipment demand.

Summary

While making precise predictions as to future rates of demand growth for the non-ferrous metals would be a somewhat pointless exercise, as these growth rates are so dependent on overall levels of economic activity, one can with reaspnable confidence say that demand growth is unlikely, for the remainder of this century, to reach the high levels that obtained in the 1960s.At best, consumption of metals appears likely to grow no faster than the OECD economies as a whole, and, for most of the metals surveyed, a more defensible prediction would be that consumption growth will lag substantially behind overall economic growth, reflecting the declining intensity of metal use in the maturing industrial economies.

II. MINING AND PROCESSING CAPACITY

As is well known, the basic pattern in the location of mining and processing facilities around the world is that mining operations are considerably more heavily concentrated in the developing countries than are processing installations. Within this general pattern, however, there are significant differences; the bulk of tin refining, for example, is carried out in the developing countries, to take one extreme, while a very large proportion of aluminium smelting capacity is located in the industrial countries and relies on raw materials supplies from developing nations. The specific distribution of production in each of the major non-ferrous metals is described in more detail below.

Aluminium

Table 2 shows world bauxite and aluminium production in 1983. As the table indicates, roughly half of market-economy bauxite production is from developing countries (the principal industrial-country supplier, Australia, alone accounts for 40% of total production), while less than 20% of metal production comes from developing countries. It should be noted, moreover, that the production figures mask an even greater disparity in capacity, as smelters in the industrialized countries were operating at relatively low rates of capacity in 1983 (the capacity utilization rate in Japan, for example, was only 36%.)

Table 2. Bauxite and Aluminium Production, 1983

(thousand tonnes)

	Bauxite	Aluminium
United Kingdom	...	253
France	1,800	367
Fed. Rep. Germany	...	743
Greece	2,400	136
Italy	...	196
Netherlands	...	234
Norway	...	716
Spain	...	357
Yugoslavia	3,500	248
Other Europe	...	323
Total Europe	7,700	3,573
Cameroon	...	80
Egypt	...	150
Ghana	700	38
Guinea	11,600	...
South Africa	...	162
Total Africa	12,300	430
United States	700	3,353
Canada	...	1,095
Total North America	700	4,448
Brazil	4,200	402
Guyana	1,000	...
Jamaica	7,300	...
Suriname	2,000	35
Venezuela	...	343
Other Latin America		162
Total Latin America/Caribbean	15,200	942
Bahrain	...	160
Dubai	...	151
India	2,000	210
Japan	...	256
Other Asia	2,000	209
Total Asia/Middle East	4,000	986

Table 2 (continued)

	Bauxite	Aluminium
Australia	26,000	475
New Zealand	...	225
Total Australasia	26,000	700
World Total (excluding centrally planned economies)	65,200	11,085

Source: Mining Annual Review 1984.

Among the more important recent developments affecting the location of capacity are: (a) the permanent closure of additional smelters in Japan, reducing that nation's former leading role in the industry; (b) the continuing expansion of all phases of the industry in Australia, including development of at least four new smelters; (c) continuing expansion in Brazil, again at all stages of the industry; (d) the opening of alumina and aluminium plants in Indonesia; and (e) the apparent role of the Caribbean countries -- Jamaica, Guyana and Suriname -- as, increasingly, suppliers of last resort, meeting marginal demand for bauxite. Smelter location appears to be strongly influenced both by the availability of low-cost energy (new facilities are almost universally based on hydro-power, as in Canada and Brazil, or on cheap coal, as in Australia) and by the concern of the major transnational firms in the aluminium industry to diversify away from dependence on one or a few developing countries, in the wake of the imposition of a bauxite levy by Jamaica and other Caribbean producers in the mid-1970s.

A number of recent efforts by developing countries to establish processing facilities have failed. For example, Ghana still lacks an integrated aluminium industry, even though it has both bauxite deposits and hydro-power which supplies an aluminium smelter. More than a decade of effort has not yet resolved the anomaly whereby Ghana's bauxite is exported in raw form, and imported alumina is used in the smelter. Similarly, various efforts by the Jamaican government in the late 1970s and early 1980s to establish an integrated aluminium industry in the Caribbean, in cooperation with Mexico and Trinidad and Tobago, foundered on the inability of the various countries to agree on mutually acceptable terms.

In the light of the very slow development of additional smelting capacity in most developing countries, prospects for the future appear less than bright, particularly in those developing countries that lack a large internal market for aluminium metal. As aluminium is the major non-ferrous metal most strongly controlled by multinational corporations (the traditional Big Six companies still, as of 1981, accounted for 52% of world alumina production capacity and 43% of aluminium metal capacity, these companies' traditional view that developing-country investment is high-risk, and will only be undertaken if prospective profits are higher than those required in the industrialized countries, acts as a substantial barrier to the flow of investment capital into new developing-country processing facilities. This is especially true when, as in the mid-1980s, many developing countries, because of their external debt burden, are effectively cut off from access to commercial bank funds for their own investment projects.

Copper

In contrast to the situation in aluminium, the developing countries have, especially in the past 15 years, made significant gains in establishing national ownership and control over their copper industries. As a result of these efforts, the major developing-country state enterprises, such as Codelco-Chile, Mineroperu and Centromin of Peru, Gecamines of Zaire and the state mining companies of Zambia, have displaced transnational corporations as the leading force in world copper production. Most of the traditional transnational companies, in fact, have either disappeared completely (as, for example, in the case of Anaconda), or have been absorbed into larger firms, where copper mining is only a minor activity (examples include Kennecott's acquisition by Sohio/British Petroleum, and St. Joe Minerals' absorbtion into Fluor Corp.).

In terms of production, developing countries account for more than half of world copper reserves, and for approximately 45% of world mine production of copper contained in ores and concentrates. Table 3 shows world mining and refinery production (excluding the centrally planned economies) in 1983.

Substantial gains have been made in establishing processing

Table 3. World Copper Mine and Refinery Production 1981-1983

(thousand tonnes)

Mine Production	1981	1982	1983
Yugoslavia	111	119	110
Other Europe	184	186	197
South Africa	211	207	211
Zaire	505	503	503
Zambia	587	581	570
Other Africa	95	113	116
Philippines	302	292	275
Other Asia	210	262	294
Canada	691	612	615
United States	1,538	1,140	1,046
Chile	1,081	1,240	1,257
Mexico	230	239	193
Peru	328	356	317
Other America	18	27	42
Australia	231	245	265
Papua New Guinea	165	170	183
World (excl. CPEs)	6,487	6,292	6,194

Refinery Production	1981	1982	1983
Belgium	428	458	394
Fed. Rep. Germany	387	394	421
Spain	152	176	159
United Kingdom	136	134	144
Yugoslavia	133	127	124
Other Europe	236	240	252
South Africa	145	143	152
Zaire	151	175	227
Zambia	564	587	575
Other Africa	19	28	26
Japan	1,050	1,075	1,092
South Korea	113	116	126
Other Asia	100	107	148
Canada	477	312	464
United States	1,996	1,683	1,581

Table 3 (continued)

Refinery Production	1981	1982	1983
Chile	776	852	833
Mexico	68	74	76
Peru	209	225	191
Other America	27	45	92
Australia	191	178	202
World (excl. CPEs)	7,358	7,129	7,279

Source: Mining Annual Review 1984, p. 29.

facilities in the more important developing country producers. Zambia, for example, refines virtually all the copper ore it produces, while Chile, Peru and Zaire smelt and refine the large majority of their production. On the other hand, such major ore-producing countries as Papua New Guinea, the Philippines and Indonesia do little or no processing (with the exception of one new smelter in the Philippines); almost all these countries' copper is exported for procesing in Japan and Europe.

A further factor that deserves mention is the location of semi--fabricating facilities. In the past decade, a substantial technological change has occurred, with the development of continuous-casting techniques and increasing utilization of high-grade cathode as the major fabricating feedstock. Because of the difficulty in shipping continuous-cast rod to far-off consumers, most new rod facilities (92%) are located in the industrialized countries. Where developing-country copper producers have moved into this new semi-fabrication technology, they have done so in joint ventures with transnational corporations, located near the major markets. Examples of this approach include Zambia's joint venture with Thomson-Brandt of France, and Codelco's with Duisberger Kupferhutte of the Federal Republic of Germany.

In the light of the near-stagnation of the world copper market (as evidenced by the production statistics in Table 3 above), the outlook for the establishment of new mines or processing facilities in developing countries can only be described as guarded at bes . There are at least 30 already-identified and evaluated copper prospects around the world awaiting development; at present consumption growth rates, only one of these new projects would be needed each year to meet increasing demand and replace depleting mines. Thus, the outlook is for a very long wait for some of these prospects -- if, indeed, they are ever to be brought into production at all. At present, the only major copper development under active construction is the Ok Tedi mine in Papua New Guinea, and even this project, which is made economically attractive by its high-grade gold ore overburden, has been postponed and may (at least as far as its copper production is concerned) be cancelled altogether.

Nickel

The world nickel industry has historically been highly concentrated, both geographically (in Canada, New Caledonia and Soviet Union) and in terms of corporate control (with Inco of Canada the dominant force). Several recent events, however, have changed this pattern. First, the severe downturn in the world steel industry has drastically affected nickel demand and prices, as the major use of nickel is in steel alloys. Second, the development of techniques for treating laterite (oxide) ores has re-directed production toward developing countries, as most laterite deposits are found in equatorial regions. Table 4 compares mine and metal production in 1971 and 1981 (little change has been evident in 1982 and 1983).

As in the case of copper, few new nickel facilities are under development in market-economy countries. And many of the past decade's projects have either been closed (for example, Falconbridge Dominicana and Inco's Exmibal project in Guatemala) or are continuing to operate only at a huge loss (as in Selebi-Pikwe in Botswana, Marinduque in the Philippines or Greenvale in Australia). The only firm plans for development listed in the 1984 Engineering & Mining Journal survey of new mines and plants, for example, are two replacement mines to maintain production levels in Canada's Sudbury mining district, and the Punta Gorda project being built with the assistance of the Soviet Union in Cuba. The outlook for such identified but still undeveloped prospects as Ramu River in Papua New Guinea or Wadi Qatan in Saudi Arabia is distinctly pessimistic. Moreover, the continuing possibility that deep-ocean nodule mining will contribute an appreciable part of the world's future nickel needs operates as an ongoing barrier to investment in land-based nickel projects. For the foreseeable future, then, the distribution of nickel mining and processing capacity is unlikely to undergo major change.

Table 4. World Nickel Production 1971-81

(per cent)

	Mine Prod. 1971	Mine Prod. 1981	Metal Prod. 1971	Metal Prod. 1981
South Africa	1.8	3.6	1.8	2.4
Japan	...	...	16.6	13.7
Finland	0.5	1.0	0.6	1.9
France	...	...	1.6	1.4
Greece	1.5	1.7	1.7	1.6
Norway	0.1	0.1	6.7	5.3
United Kingdom	...	...	6.2	3.6
Canada	39.2	22.0	28.5	15.4
United States	2.1	1.6	2.3	6.2
Australia	5.2	10.6	2.4	6.0
Total DMEs	50.4	40.8	68.4	57.5
Botswana	...	2.6	...	...
Zimbabwe	1.7	2.2	1.3	1.8
Indonesia	2.2	6.4	...	0.7
Philippines	0.1	4.2	...	2.7
Brazil	0.5	0.4	0.4	0.3
Dominican Rep.	0.1	2.6	...	2.7
New Caledonia	22.2	11.1	5.2	4.0
Total LDCs	26.7	29.5	6.9	12.2
China	...	1.6	...	1.7
Cuba	5.4	5.7	2.9	3.0
Soviet Union	16.1	20.6	20.3	24.1
Other CPEs	1.4	3.4	1.5	3.2
Total CPEs	22.9	29.7	24.7	30.3
World Total (kt metal content)	681	703	620	704

Source: Annuaire Statistique Minemet 1982.

Lead

In contrast to bauxite, copper or nickel, the production of lead is very largely determined by demand for the other metals -- principally zinc and silver -- with which lead is typically associated in commercial deposits. Even though lead use in such traditional applications as storage batteries is decreasing, the strong demand for zinc in recent years has kept lead production at relatively higher levels than could be expected based on an analysis of supply and demand for lead itself.

The major producers of lead are the United States, Australia and Canada. Among developing countries, Mexico, Peru and Morocco are the most important suppliers, and all these countries have plans for expansion of both their mining and processing industries. Table 5 shows world mine and metal production of lead in 1981-83.

In contrast to the situation in nickel, a substantial number of lead/zinc/silver projects are either under construction or well advanced in the planning stages. The 1984 Engineering & Mining Journal investment survey, for example, list some 15 lead prospects under active development, including projects in Peru, Morocco, Tunisia, India and Thailand, as well as in Canada, Yugoslavia and Australia. In virtually all cases, these new developments will produce zinc and silver as well as lead.

Table 5. World Lead Mine and Metal Production 1981-83

(thousand tonnes)

	Mine Prod. 1981	Mine Prod. 1983	Metal Prod. 1981	Metal Prod. 1983
Austria	4	4	16	17
Belgium	...	...	102	125
Denmark	27[1]	20[1]	27	10
France	19	2	228	198
Fed. Rep. Germany	29	30	348	352
Greece	23	21	21	...
Ireland	29	34	10	8
Italy	21	24	133	131
Netherlands	...	...	20	38
Spain	84	84	120	135
Sweden	85	79	29	53
United Kingdom	7	2	333	314
Yugoslavia	119	118	126	123
Total Europe	452	424	1,532	1,522
Morocco	118	111	52	58
South Africa	147	128	67	65
Total Africa	298	268	154	157
Brazil	22	31	66	49
Canada	332	252	238	242
Mexico	150	172	166	179
Peru	187	207	85	66
United States	455	456	1,067	1,006
Total America	1,208	1,176	1,676	1,598
Japan	47	47	317	322
Total Asia	125	143	420	437
Australia	380	450	252	229
World (excl. CPEs)	2,463	2,461	4,034	3,943

Source: International Lead/Zinc Study Group.

A notable feature of the lead processing industry, in contrast to copper, aluminium or nickel, is the very high proportion of metal supply which is produced from scrap. Nearly 40% of the world's lead consumption is secondary (scrap) production, reflecting the metal's maturity and the large stock available for recycling. As the more energy-efficient recycling techniques continue to extend their cost advantages over energy-intensive primary smelting, the share of mine ore in final lead metal supply can be expected to continue to decline, further limiting opportunities for the addition of processing capacity in the developing countries.

Zinc

As noted above, zinc production is closely linked with that of lead. The most significant producing countries are Canada, Peru and Australia, although production is fairly widely distributed. Table 6 show world zinc mine and metal production for 1981-83.

Unlike the market for lead, that for zinc has been moderately strong in recent years, as new galvanizing applications have been developed, replacing the declining markets for traditional zinc die castings. A potentially significant development is the introduction of zinc for coinage in the United States, replacing copper. An important regional market is the use of zinc in construction in France.

Table 6. World Zinc Mine and Metal Production 1981-83

(thousand tonnes)

	Mine Prod.		Metal Prod.	
	1981	1983	1981	1983
Austria	18	19	23	23
Belgium	...	...	235	263
Denmark	79[1]	73[1]	...	...
Finland	54	56	140	155
France	37	31	257	249
Fed. Rep. Germany	111	113	366	357
Greece	27	22	...	...
Ireland	117	186	...	...
Italy	42	44	181	154
Netherlands	...	...	177	187
Norway	28	32	80	90
Portugal	...	...	5	4
Spain	182	171	189	195
Sweden	181	203	...	...
United Kingdom	11	9	82	88
Yugoslavia	89	90	96	88
Total Europe	976	1,049	1,831	1,853
South Africa	123	137	81	82
Zaire	76	81	58	62
Zambia	40	42	33	38
Total Africa	275	296	203	212
Brazil	71	73	92	100
Canada	1,096	1,069	619	617
Mexico	216	241	127	179
Peru	497	560	126	154
United States	343	302	393	294
Total America	2,330	2,369	1,384	1,376
Japan	242	256	670	701
Total Asia	403	418	827	873
Australia	485	647	301	301
World (excl. CPEs)	4,469	4,779	4,546	4,615

Source: International Lead/Zinc Study Group

Tin

Although mine production of tin reached its lowest level in 17 years in 1983, there remained a substantial surplus on the market, inhibiting plans for future mine and plant development. Tin is a fully mature metal, with little or no growth in demand likely for the foreseeable future, and so existing patterns of production are likely to change little, if at all.

In contrast to most of the other non-ferrous metals, production of tin, both at the mine and smelter stages, is heavily concentrated in the developing countries. Among the industrialized countries, only the United Kingdom and Australia each account for as much as 2% of world mine production, while Malaysia supplies 30% of world supplies and Bolivia, Indonesia and Thailand each account for more than 15% of production. Table 7 shows world mine production of tin in 1972-82.

The relatively small expansion plans in the world tin industry (only three projects are listed by Engineering & Mining Journal) are concentrated in already-producing countries, although it appears that what little investment interest exists favors the United Kingdom and Australia over developing-country producers. At the processing stage, it should be noted that the vast majority of developing countries' tin production is already smelted locally; the recent completion of smelter facilities by Bolivia removes the last case in which a major tin producer depended on smelting facilities in the industrialized countries.

Table 7. World Tin Mine Production 1972-83

(thousand tonnes)

	1972	1983
Int'l Tin Council Members		
Australia	12.0	9.6
Indonesia	21.8	26.6
Malaysia	76.8	41.4
Nigeria	6.7	1.4
Thailand	22.0	20.0
Zaire	6.0	2.0
Total ITC Members	145.4	101.0
Non-Member Producers		
Bolivia	32.4	25.0
Brazil	2.8	13.1
United Kingdom	3.3	4.1
Total Non-Members	50.9	71.4
World Total (excl. CPEs)	196.3	172.4

Source: Mining Annual Review 1984, p. 42.

Note: Discrepancies in the totals in the above table reflect illegal tin trade, primarily in Southeast Asia.

III. SUPPLY AND DEMAND BALANCES

Although the general market situation for the major non-ferrous metals has already been alluded to, this section of the report brings together views obtained from industry analysts regarding the near- and medium-term outlook for supply and demand balances.

Aluminium

Compared to the very low operating rates recorded in the last several years, most existing aluminium producers expect to be operating at higher levels of capacity in 1984-85. Growth projections for aluminium demand both in the U.S. and in the European and Japanese markets were for increases on the order of 9% in 1984, over 1983 levels; if this increase is realized, the high level of producers' inventories should decline somewhat. Even so, the 83% of capacity that major industry analysts see as a likely operating level for 1983 still leaves substantial slack and will deter immediate investment in new facilities. The postponement or cancellation of several planned smelters in Australia is a concrete indication of the continuing slackness in the world aluminium market.

Copper

Copper stocks, particularly those held on the metal exchanges, have declined in 1984, but prices remain at very low levels in real terms (the lowest, adjusted for inflation, since the Depression of the 1930s). Moreover, very large amounts of capacity have been closed, either temporarily or permanently. As of mid-1984, Mining Annual Review reported the following tonnages of shut-in capacity:

Australia	18,000 tonnes
Canada	248,000 tonnes
Philippines	110,000 tonnes
South Africa	2,000 tonnes
United States	762,000 tonnes
Zimbabwe	5,000 tonnes
Total	1,145,000 tonnes

This shut-in capacity amounts to more than 15% of total world mine production. In addition, many other mines are operating at well under full capacity. Thus, even with the drawdown of short-term stocks, the copper market still faces substantial over-supply, and most analysts expect this situation to continue into the late 1980s. The result of continuing technological change -- the substitution of satellite, microwave and fiber-optics communications facilities for traditional copper wire, for example -- makes it unlikely that demand will grow at more than 1-2% per year, compared to the 3-4% rates achieved in the 1960s and early 1970s.

Nickel

While nickel consumption growth rates of more than 4% per annum were predicted a few years ago, most current forecasts see demand increasing at 2-2.5% per year through the 1980s. The expected recovery in 1984 brought capacity utilization in the industry up to about 80%, but this figure reflects the permanent closure of some nickel mines that could not operate profitably at prices of $3.00 per pound or less.

In the near term, over-capacity will continue to be a feature of the world nickel market, and there appears to be little room for development of new projects. A number of existing producers, in fact, continue to operate either because they receive government subsidies (e.g., Selebi-Pikwe) or because they have preferential trade arrangements for their production (e.g., the Cuban state enterprises). On a purely commercial basis, it would be difficult to justify investment in a new nickel venture.

Lead

Most lead consumption forecasts see demand increasing at 2-2.5% per year through the remainder of the 1980s. As the supply of lead is not wholly responsive to market forces (because lead is produced in conjunction with zinc and silver), it is difficult to predict whether the world lead market will be in balance. For the past several years, there has been a small but persistent over-supply situation, but stocks began to decline somewhat in 1984. The medium-term outlook is uncertain.

Zinc

Prices and market balance in zinc were maintain in past years through the concerted action of the major producers, acting as a cartel in the European market; this arrangement apparently persisted from 1964 through 1979 and involved price fixing, market-sharing arrangements, restrictions on resale by consumers, refusal to sell to dealers and direct intervention on the London market. Since the discovery of the cartel, concerted action has obviously not been a viable alternative, and there has been considerable disarray in the zinc markets. A recent increase in demand, reflecting new uses for galvanizing processes, may, however, prove strong enough to support a relatively stable market over the next several years.

Tin

As noted above, tin is a fully mature metal, and demand is unlikely to increase by more than 1% per year. The existing producers have, through the mechanism of the International Tin

Agreements, long attempted to support the market through a combination of production and export restrictions, on the one hand, and direct market intervention, using a buffer stock mechanism, on the other hand. In the long term, these machanisms only provide a device for cushioning the impact of market forces; there is general agreement that prices will remain at relatively low real levels for the near term.

IV. PROSPECTS FOR FURTHER PROCESSING

Increased processing of minerals has become a key element in developing countries' proposals for a New International Economic Order. The primary reasons that developing-country governments have advocated increased local mineral processing include: industrialization strategies based on the use of local raw materials; reduction of dependence on the industrialized countries; creation of opportunities for the training of nationals and the development of skills which can be used in other sectors of the economy; limitation of transnational corporations' ability to engage in transfer pricing; capture of a greater share of the economic rent from mineral production; and the hope of obtaining access to capital which might not otherwise be available.

In view of the limited success of import-substitution strategies for industrialization and the limited number of countries which have been able successfully to pursue an export-oriented strategy based on manufacturing or assembly operations, strategies of resource-based industrialization have been claiming increasing attention from developing-country planners. Two variations of such strategies have been tried. One, which could be called "primary export processing," is based on the assumption that more processing of, and, hence, more value-added from, primary product exports will speed the overall development of an economy. Success in pursuing such a strategy depends on the ability of the processed materials to compete in world markets, although it may be possible for a producer-country government to subsidize processing by making inputs, such as energy or infrastructure, available at less than market price.

The second strategy, which can be called "basic goods production," concentrates on the use of agricultural and natural-resource products not primarily for export, but rather for domestic consumption. This approach is in direct contrast to the typical post-colonial trade pattern in much of the Third World, where primary-product exports are used as a means of generating foreign exchange to pay for the import of intermediate and capital goods for import-substitution industries. In its most complete form, this basic goods strategy has been attempted for considerable periods by China and North Korea. In non-socialist countries, a comparable approach has sometimes been advocated, but never wholly put into practice.

Many resource-rich developing countries have pursued a combination of the two strategies. Chile and Venezuela, for example, have sought increased domestic processing of copper and iron ore, respectively, both for export and for use in domestic industries. Countries with a smaller domestic industrial base, such as Jamaica in the case of bauxite, have vigorously pursued further processing as a means of adding value to exports, while countries with greater domestic opportunities, such as Mexico, have emphasized the basic goods production aspect of mineral processing. Many of the petroleum-producing countries have adopted ambitious industrialization plans based on export-oriented refining and the use of natural gas as a feedstock for petrochemical production.

One of the major arguments for increased domestic processing of natural resources, even where a basic goods production strategy is not immediately feasible, concerns the supposed linkage, or "ripple" effects of such processing. These effects are often said to be of two kinds:

(a) linked downstream processing of the same product, for domestic and regional use as well as for export, and linked upstream activities, where local processing makes possible the primary production of another product (for example, where establishment of processing facilities for phosphate rock generates a demand for sulphuric acid which could be produced from local gypsum); and

(b) indirect effects outside the primary-product sector itself, in the use of infrastructure, supply of equipment, construction, fiscal impacts, etc.

Whether any particular mineral processing project actually produces the desired effect is a factual question; one needs to be especially careful in considering the possibility of establishing large-scale processing facilities in small Third World countries not to overestimate linkage effects. It is unlikely, for example, that a very small economy would ever support a well-rounded capital-goods industry, simply because the domestic market involved is too small. Thus, care should be taken in assessing the feasibility of mineral processing projects to limit any quantification of expected benefits to those linkages which can be demonstrated as sure to occur, rather than including all those linkages which are merely thought to be possible or desirable.

B. Reducing Dependence

Further processing of natural resources is often seen as a means of reducing a developing country's dependence, either on the outside world in general or on particular countries or transnational corporations. In broad terms, five different types of dependence can be identified: (a) trade dependence, in which a developing country's ability to import desired consumer and capital goods is a function of that country's exports of primary products; (b) financial dependence, in which the exploitation of raw materials for export and the construction of the infrastructure associated with that exploitation are financed by large flows of capital from the industrialized countries; (c) technological dependence, in which capital goods embodying foreign technologies are imported for purposes of natural resource exploitation; (d) managerial dependence, resulting both from the lack, in the developing country, of adequate education for and experience with industrialization and from the need to import foreign technologies with which local managers and technicians are not familiar; and (e) market dependence, in which control is exercised over a country's export markets or import sources by a few integrated transnational corporations, and in which export sales and/or import purchases are concentrated in a few foreign countries.

The impact on these various forms of dependence of a strategy that emphasizes the further processing of natural resources is not clear-cut. For example, additional processing may well improve a country's balance of payments, by adding value to exports, but at the same time will tend to intensify the lopsided structure of the economy by increasing dependence on export earnings to finance the capital goods and materials needed for the processing industry. This kind of dependence will be reduced, in all but the largest developing countries, only if processing can be done in small units, using relatively accessible technologies, so that a steady demand can be generated over a long period of time for processing inputs which can be supplied domestically. Such a pattern is possible for sawmilling and vegetable oil processing, for example, but may not be achievable in the cases of minerals, pulp and paper, rubber, or many other natural resources.

Similarly, because most resource-processing activities are large-scale and capital-intensive, their immediate impact in many developing countries may be to deepen financial dependence. In addition, technological and managerial dependence are likely to be increased where a country must import processing techniques, equipment and management from transnational corporations, as is generally the case in mineral processing. Forward linkages (i.e., into semi-fabricated products) may also increase a country's risk of technological obsolescence; once a country is committed to processing a commodity into a specific product, using a particular technology, it exposes itself to the risk that competing producers will develop more efficient technologies, leaving the exporting country with an unprofitable investment. The relatively recent development of continuous casting in the metals industries is a good example of this type of risk. The same kind of technological risk exists, of course, in the extraction of raw materials, but may be less severe, because extraction techniques are somewhat more stable than processing techniques.

The impact of further processing on market dependence varies according to the commodity involved and the extent of processing. In some cases (e.g., production of refined copper or aluminum ingot), processing will widen the market options of producer countries, since there are many more metal fabricating enterprises than there are smelters and refiners. Integration into forward processing may also, in the case of some metals, be useful in creating brand loyalty among consumers.

C. Development of National Capacity

Although mining and mineral processing produce relatively little direct employment, because of their high capital intensity, these industries may provide valuable training and development of skills which are related to, but nonetheless distinct from, those directly required in the mineral industries. Thus, the construction of large-scale mineral processing facilities can stimulate the training of nationals in construction industry skills and can generate demand for transport and business services and hence contribute to the development of skills needed in those sectors.

It should be kept in mind, however, that the employment effects of mineral processing industries are not always positive. Direct employment in the mineral processing industries themselves is quite limited. The UNIDO study cited earlier estimated, for example, that the amounts of capital investment shown in Table 8 were required to create each job in mineral processing.

Even if a Third World government wished to increase employment in mineral-processing industries, there is little scope for substituting labor for capital. Most technological change in processing has been aimed at increasing the efficiency of raw material use. Given the high share represented by raw material costs, and the relatively low share of labor costs, in the value of finished metal products, Table

Employment in Mineral Processing

Process	Output per Man-year (tonnes)	Capital Cost per Job (1980 dollars)[a]
Alumina refining	800	667,000
Aluminium smelting	90	312,000
Copper smelting/refining	140	450,000
Steelmaking	200	210,000
Lead smelting/refining	225	202,000
Nickel processing (sulphides)	150	1,540,000
Tin smelting	20	205,000
Zinc smelting	200	410,000

Source: UNIDO, Mineral Processing In Developing Countries, P.76.

Note: (a) Costs adjusted to 1980 basis by using Marshall and Swift index of mining and milling costs, as published in Chemical Engineering.

especially in developing countries where wage rates are low, there is little incentive for corporate managers to focus on labor-capital substitution. The available evidence suggests that, since most innovations in copper and aluminum processing, at least, have significantly increased resource recovery rates as well as increasing the capital-labor ratio, there is probably little scope for a plant to operate using older technology in order to generate greater employment per unit of output. This conclusion is reinforced by the past decade's increases in energy costs, since the older processing technologies are considerably more energy-intensive than new processes.

Moreover, employment in mineral processing, as well as in mining, may reinforce tendencies in small economies that favor creation of a small, highly paid elite segment of the working class. The relatively high productivity of labor in these industries, combined with the low share of wages in total product costs, have often made mining and mineral processing enterprises willing to concede to workers' pressure for high hourly wages. The creation of such high-wage enclaves in a small developing economy has been shown to lead to continuing unemployment and undesirable rural-urban migration, as workers leave their traditional agricultural jobs to seek work in the high-wage mining sector, even if in so doing they run the risk of a considerable period of unemployment.

D. Curbing of Transfer-Pricing Abuses

Where both mining and mineral-processing operations are under the same corporate ownership, the establishment of processing facilities in the country where the raw materials are produced can benefit the host government by reducing the company's opportunity to manipulate profits and tax liabilities through transfer pricing. In the bauxite-aluminum industry, for example, the six largest transnational corporations account for 65 per cent of worldwide alumina refining capacity and 55 per cent of smelting capacity. In this situation, the price paid to bauxite mines by refineries is often a purely notional one, established by the corporations in order to minimize their worldwide tax liability (i.e., to adjust prices so that profits are concentrated in low-tax jurisdictions). No "free market" can be said to exist, on a worldwide basis, for bauxite or alumina, even though there are a few arm's length sales. Similarly, in the cases of copper and iron ore, a significant amount of trade in unprocessed and partially processed material has traditionally been conducted between units of large transnational corporations, although the degree of concentration in these industries has decreased in the past two decades and is significantly less than in bauxite-aluminum.

E. Capture of Economic Rents

A producer of refined metal has, typically, a wider range of potential customers than does a producer of unprocessed or semi-processed material. Most markets where unprocessed minerals are bought are highly concentrated. Non-ferrous metal smelters and steelworks, as indicated below, have important economy-of-scale factors. Often their large size dictates the purchase of supplies from several different mines. The limited number of such processing facilities, dealing with a large number of raw-material sellers, might reasonably be expected to create possibilities for monopsony gains by the processors. In contrast, refined metals are typically bought by a large number of customers, and the concentration among buyers of, say, copper cathode or aluminum ingot is much less than among buyers of copper concentrate, bauxite or alumina.

For example, in the case of copper, there are fewer than two dozen independent copper smelters in the world which are prepared to buy significant tonnages of concentrate from independent mines. Concentrate sales contracts with these smelters are usually based on the London Metal Exchange price for refined copper, but actual payments are arrived at only after subtraction of complicated and often ambiguously defined deductions for smelting and refining charges, impurities, etc. The smelters' powerful market position often gives them the opportunity to shift contract terms in their favor. In contrast, the producers of refined copper in international trade have a great number of potential customers to choose from. Trade in refined copper is normally on the basis of a relatively straightforward contract, which specifies quantities, chemical specifications, and delivery and payment terms, usually on the basis of London or New York metal exchange prices. If a supplier of refined copper is unable to find a customer, it can usually dispose of the product directly on these exchanges, an option not available to producers of concentrate.

The above argument does not imply that refined metal prices would be likely to increase if additional processing facilities were located in developing countries, but only that such facilities could help Third World countries to capture some of the monopsony gains which may currently be accruing to processors. It should, however, be kept in mind that the available literature does not suggest that such gains are very large. In addition, there is little substance to the argument which is sometimes made that processing through to refined metal will help to stabilize the export earnings of developing countries. It is well documented that the major cause of price instability in mineral markets is variation in demand, induced by business-cycle fluctuations. This variation in demand, in turn, results from changes in the demand for mineral-containing finished consumer goods and capital equipment. Producers, whether of raw materials, refined metal or finished goods, can react to these changes in demand either by continuing to produce at full capacity and accepting the likely decline in prices, or by cutting back production and attempting to maintain price levels, or through a strategy containing elements of both actions. There is little evidence, however, to show that these business-cycle-induced fluctuations are less severe in the case of refined metal than in the case of ores and concentrates.

F. Access to Capital

A final reason for a developing country to pursue downstream processing of mineral may be that foreign capital for such a project is easier to obtain than other kinds of funds. Certain industrialized nations which are heavily dependent on mineral imports are prepared, for example, to provide government funds for projects which help to assure their long-term materials-supply needs. The governments of Japan, West Germany and France, among others, have subsidized mining and mineral-processing investment in Third World countries, provided that such projects included a long-term sales contract or other mechanism for assuring a mineral supply to the capital-exporting country. Foreign investors in such ventures may be willing, as a condition of obtaining access to a developing country's raw materials, to accept the host government's demands for establishment of local processing facilities, especially where the companies benefit from their home governments' offers of tax concessions and subsidies. In contrast, a developing country is unlikely to have similar leverage when trying to obtain foreign capital for other sectors of the economy. It should be kept in mind, however, that the bargaining advantage which Third World nations have because of industrial countries' desire to assure mineral supplies may be considerably less in the 1980s than it was in the mid-1970s, at the height of international concern over raw materials shortages.

V. BARRIERS TO LOCAL MINERAL PROCESSING

A good deal of the discussion of mineral processing in developing countries has focussed on "barriers" or obstacles to the development of processing facilities. These barriers are seen to be policy distortions or market imperfections which have resulted in a lesser amount of processing in Third World countries than would have resulted from the unimpeded operation of competitive market forces. In the literature on this issue, barriers to processing are often classified as either "artificial" or "natural." The artificial barriers are said to include trade-distorting policies introduced by the industrialized countries, restrictive business practices of transnational corporations, and production-distorting policies of the developing countries themselves. The natural barriers, on the other hand, are said to be the underlying economic characteristics of particular Third World countries. These latter factors are more properly considered in the context of an overall economic analysis of processing projects, in the following section of this article. This section discusses some of the more commonly cited "artificial" barriers to processing.

A. Tariffs and Other Trade Limitations

The tariff structures of the industrialized countries frequently impose higher rates of duty on the import of processed materials than on unprocessed ores. This situation can, in theory, result in a very high rate of effective protection for processing operations, with the result that further processing in developing countries is discouraged. In practice, however, it is not clear that many developing countries are significantly affected by this tariff escalation, at least in respect of smelting and refining operations. The combined effect of the tariff-reducing negotiations of the General Agreement on Tariffs and Trade (GATT), the Generalized System of Preferences which is applied by most Western countries to Third World exports, and the preferential-access provisions of the Lome Convention in respect of exports to the European Economic Community have, taken together, reduced tariff barriers on imports of refined metal from developing countries to insignificant levels. One recent study of the impact of tariffs on mineral processing concludes that "the reduction or removal of developed countries' tariffs on processed raw materials originating in developing countries may not, by itself, do much for the level of processing activity in the Third World." It remains to be seen whether the current worldwide recession, which has produced serious overcapacity in many industrialized nations' mineral--processing industries, will lead to a re-introduction of tariff obstacles to Third World metal sales.

Similarly, while non-tariff barriers to trade, such as the quantitative import restrictions imposed by certain industrialized countries, can, in theory, have a deterrent effect on developing--country processing, there is little concrete evidence to show that such non-tariff barriers do in fact have such an effect in the specific case of non-fuel minerals.

B. Market Distortion by Transnational Corporations

For a number of reasons, transnational corporations in the minerals sector tend to avoid locating processing facilities in developing countries, even if all purely economic factors appear, at first analysis, to support such a location. A TNC will normally attempt to reduce risk by diversifying its investments, and in particular will attempt to avoid a concentration of investment in countries thought to be prone to nationalization. TNCs may also be subject to pressure from their home governments, whose defense and strategic interests or whose concern with maintaining domestic employment levels may favor expansion, or at least maintenance, of their home processing capacities. These non-economic reasons are in addition to such purely economic considerations as the fact that a TNC may have different factor costs than a developing country, because the corporation has easier access to world capital and raw materials markets, or that the TNC may face, within its own vertically integrated operations, a set of marginal costs that differ from the world prices or the costs faced by the producing country.

The extent to which these factors limit a mineral-producing country's ability to establish processing facilities depends greatly on the extent of corporate concentration in the particular mineral industry. For example, company concentration ratios are very high in aluminum, while the copper and iron-and-steel industries are considerably less concentrated. All other things being equal, a developing country would probably have a better chance of negotiating the establishment of domestic processing arrangements in copper than in aluminum.

TNCs can restrict developing countries' processing potential through the use of export-restraining business practices. Such practices include restrictions on exports from developing-country plants or even complete refusal by the TNC to permit such exports. In the case of most minerals, however, there is little clear evidence that TNCs have used such monopoly power to restrict developing-country exports, at least in the past decade, although worldwide apportionment of markets for metals has been a feature of past cartel arrangements, such as the short-lived copper cartels of the late 1880s, 1899-1901 and 1936-39.

A more specific use of monopoly power which is sometimes cited as a barrier to Third World processing is the tendency of shipping conferences to increase freight rates for processed products solely because of the shipowners' superior bargaining power vis-a-vis the exporting countries, and without any justification based on the increased cost of handling processed material. While unit freight rates are normally higher for materials such as copper cathodes, aluminum ingots or steel shapes than for bulk cargoes like copper concentrate, bauxite, alumina or iron ore, these differences may merely reflect specific conditions in the world markets for ships of different types (e.g., for the past few years there has been a persistent over-supply of large bulk carriers, as compared to a more balanced supply-demand situation for smaller cargo liners). There is little significant evidence to show that differences in ocean freight rates for different degrees of processing can be attributed to shipowners' monopoly power.

A final aspect of monopoly power sometimes cited as a barrier to developing-country processing is the use of massive advertising by TNCs to create brand-name loyalty that is not necessarily justified on the basis of product quality differences. In the case of minerals, however, advertising is of relatively little importance, since quality standards for refined metals are normally set by the various materials testing organizations or by the metal exchanges themselves. Once a producer has its brand certified as good for delivery on the relevant metal exchange, little further assurance of basic quality is required. Some customers may prefer deliveries from industrial-country suppliers, either because transportation and delivery are thought to be more reliable or because the buyer prefers a specific brand for particular end-uses (e.g., the use of high-silver fire-refined copper in certain electrical applications), but it appears unlikely that mere advertising significantly affects mineral buyers' preferences.

C. Marketing Problems

While the use of advertising by TNCs may not, in itself, constitute a major barrier to further processing in developing countries, there are some objective difficulties for Third World producers in the marketing of refined and semi-fabricated mineral products. The actual selling of mineral products requires a reasonably extensive marketing organization; this can be supplied, at a price, by a state enterprise in the mineral-producing country, perhaps using foreign firms as agents in specific geographical markets -- the strategy followed, for example, by the state copper company, Codelco-Chile -- or by a foreign investor. In any event, marketing will involve certain costs, such as travel to establish and maintain sales and distribution outlets, the negotiation of shipping, insurance and documentation, and after-sales service to customers. The level of such costs can be such that, even though a developing country might have a competitive cost advantage in the actual production of minerals, it may not be able to achieve market entry in some or all of its potential markets because of marketing costs. The marketing problem is likely to be more severe in the case of metals like aluminum, where markets are highly concentrated and the market of last resort - the metal exchange - is not a significant factor. But all producers of refined metals usually see a need for some marketing effort.

D. the Effect of Technology

The lack of availability of industrial technology is often seen as a barrier to further industrialization in developing countries; hence, the concern of Third World nations with efforts to secure effective transfer of technology. In the case of mineral smelting and refining, however, the fundamental technology is widely available from a variety of sources, and almost no cases are known in which a developing country was unable to purchase the required technology, provided the country had adequate financing.

The knowledge required for efficient mineral processing, however, is not only a matter of obtaining the equipment needed to carry out particular operations. Such equipment, and instructions for its use, can be obtained, but many developing countries lack the "know--how" which comes from actual experience. This know-how is often internalized within TNCs, and hence is difficult to obtain unless a TNC is a partner in the processing venture. Lack of management experience, lack of knowledge of industrial operations, and lack of group know-how built up over time in an ongoing organization are likely to be more of a constraint on the ability of developing countries to process their raw materials than is the lack of merely theoretical knowledge.

The rapid technological change occurring in some mineral processing industries also has implications for developing countries' ability to establish processing facilities. On the one hand, certain developments, such as the use of direct-reduction/electric arc furnace technology for steelmaking, permit the construction of plants on a much smaller scale than was previously thought economical, opening the way for processing for the domestic market in many countries.

On the other hand, new developments such as continuous casting in copper have the effect of making it more difficult for producers located at considerable distances from major markets to compete effectively.

E. Economies of Scale

A final issue often cited as a barrier to increased processing activity in developing countries concerns economies of scale and minimum efficient plant sizes. To a large extent, this issue is simply one of basic economic analysis: can a plant of a given size in a particular location produce at a cost which is competitive? It does appear, however, that there are certain basic efficiencies in the standard mineral processing technologies, and that the choice of a plant size below these minima will likely lead to higher unit costs. In the case of many Third World countries, this factor is reinforced by requirements for large amounts of infrastructure development to support any processing industry at all, and by the real economies of scale in certain infrastructure facilities (e.g., hydroelectric power plants).

The apparent advantages in constructing an optimum-size plant are often, however, not realized in developing countries. Among the specific difficulties which often arise in such projects are the following:

(a) large plants often experience longer construction times, higher costs and greater difficulties in arranging utilities, ancillary facilities and infrastructure than small plants;

(b) large plants tend to experience more technical operating problems than small plants, maintenance may be more problematic, and technological rigidities are more likely to occur; and

(c) operating rates tend to be lower in large plants than in smaller units, thus increasing average fixed costs.

As a general rule, it would probably not be too far off to estimate that unit costs associated with large mineral processing plants in developing countries could be as much as 40 per cent higher than the equivalent cost if the same plant, with the same factor availability (i.e., energy, complementary inputs, labor, etc.) were located in an already industrialized country.

The "barriers" to further processing of minerals in developing countries cited in the preceding section are not so much impenetrable roadblocks as they are factors which tend to have a stronger impact on developing-country projects than on those in industrialized countries. Rather, however, than say that such barriers are either so important that one cannot think at all about further processing in Third World countries, or, on the other hand, that the barriers are of little or no importance, a more fruitful approach may be to consider in detail the economics of specific processing facilities. The following paragraphs discuss in general terms the major headings under which economic analysis of mineral processing projects can proceed.

A. Capital Costs

Capital costs are typically a high proportion of total costs in mineral processing (with the partial exception of aluminum smelting, where energy and labor costs dominate). For most processing industries, capital costs account for 40 per cent or more of total processing costs and dominate the non-raw-materials share of the cost structure. It is not entirely clear whether the dominance of capital costs in processing favors or hampers developing countries. On the one hand, capital goods will tend to be cheaper in industrialized countries, and the poor conditions under which many Third World plants are built tends to inflate capital charges for those locations. On the other hand, the initial cost of buying and preparing sites for new plants is rising more rapidly in most industrialized countries than in the Third World, and developing countries may also have access to relatively low-cost sources of finance, through the World Bank or other public international agencies or through bilateral assistance arrangements, that have the effect of reducing the impact on a project of high initial capital costs. It is clear, however, that capital costs are likely to be the most significant single element affecting the feasibility of a proposed processing venture, and that, therefore, every effort must be made to obtain estimates of those costs that are as accurate and realistic as possible and to assemble a package of financing that minimizes the annual capital charge to the project.

B. Transport Costs

A reduction in transport costs appears to be an obvious reason for locating processing facilities in the country or region where the mineral is extracted. Frequently, minerals are consumed in countries at great distances from the mine, and transport costs of shipping unprocessed ore, with a metal content of only a few per cent, would be prohibitive. Thus, the transport savings from undertaking at least initial concentration of low-metal-content ores near the mine are essential, and such concentration is virtually always carried out in the mineral-producing country in the case of copper, nickel and similar ores.

On the other hand, long-distance transport is quite common for materials with slightly higher metal content, such as bauxite (15-25 per cent aluminum content), copper concentrates (25-30 per cent), or iron ore (35-65 per cent). The advent of large-tonnage bulk shipping has made transport of these commodities relatively cheap and hence has discouraged further processing in the countries where the material is mined.

Nonetheless, there is often some possibility of achieving further transport savings through additional processing. For example, in the case of bauxite, if shipping costs are $12 per ton and processing costs to convert five tons of bauxite to two tons of alumina are $100, then the transport savings from conversion will equal roughly one-third of the total processing costs, a very considerable savings. In the case of copper, if conversion of four tons of concentrate to one ton of blister copper through smelting costs $440 (i.e., 20 cents per pound) and shipping costs are the same $12 per ton, then the transport saving through smelting prior to shipping would theoretically be $36, or 8.2 per cent of the processing cost. One should note, however, that this latter savings may not be realized in practice, because of a differential in freight rates which sets lower charges for bulk materials like bauxite, alumina and copper concentrate, as compared to metal shapes. There may also be a possibility that shipping services will be available only from a limited number of suppliers, especially in the case of cargo liner services for handling smelted or refined metal, and that shippers may use their monopoly or oligopoly position to capture some of the transport savings achieved through processing.

Even if transport cost savings through processing are small in absolute terms, they may still provide some competitive advantage in specific markets. For example, in supplying Japanese markets, the Pacific Island countries could combine processing with shorter transport routes to gain some advantage over, say, African copper suppliers. African suppliers, in turn, might have a similar advantage in shipping to European markets. This locational advantage would exist even though the overall ratio of transport costs to total production and processing costs is relatively low.

C. Environmental Costs

A factor of fairly recent origin which may favor the establishment of processing facilities in developing countries is the question of environmental protection and pollution control. Many mineral-processing activities, such as alumina refining or copper smelting, are potentially highly polluting. In most developed countries, where sensitivity to environmental issues has increased significantly in the past two decades, complex and costly regulations have been imposed on these processing operations. In the US, for example, it has been estimated that pollution control costs in copper smelting may have increased total costs by from 30 to 50 per cent.

The situation is potentially different in many developing countries, Only a few Third World countries have elaborate environmental legislation. In addition, because developing countries, by definition, do not have as much industry as the developed countries, the former may have less existing pollution-causing activity to which the effects of mineral processing would be added, and thus a greater pollution-absorbing capacity, especially if processing facilities can be located in relatively unpopulated areas.

Even assuming, however, that some developing countries may wish to utilize this cost advantage, there are certain potential obstacles. First, the industrialized countries, responding to pressure from domestic industries, may impose environmental tariffs on goods from countries where environmental restrictions are not so severe. Such a policy would be consistent with the fairly common "sweated labor" tariffs that are imposed by industrial countries on goods from low-wage countries. US copper producers, for example, have been advocating such a tariff for some time.

Second, many international financial institutions are themselves insisting on the application of strict environmental controls. The World Bank and the regional development banks, for example, have issued a joint statement requiring environmental considerations to be taken into account in any project in which they are involved as lenders. Such a policy may have the effect of forcing Third World countries to adopt environmental standards based on those of the industrialized countries, and so remove the possibility of the former countries' gaining a competitive advantage in this respect.

D. Energy Costs

Where a developing country has access to relatively low-cost sources of energy, that country may have a significant competitive advantage in certain energy-intensive mineral processing activities. More than half of aluminum smelting costs, and perhaps one-quarter of copper smelting and refining costs, consist of energy.

Thus, the availability of fixed sources of low-cost energy (hydro-electric potential, small natural gas fields, or even geothermal energy) can make metal processing competitive where energy is important in the total cost structure. Table 9 , for example, shows the effect of changes in energy prices on the cost of aluminum ingot.

It can be seen from Table 9 that the availability of low-cost power represents a very significant cost advantage and, moreover, that the absence of a source of low-cost energy, when combined with the other cost disadvantages typically faced by developing countries, may well make it impossible to establish a competitive pro-

Table 9

Energy Costs in Aluminium Smelting

Power Source	Cost per kwh (U.S. cents)	Cost per pound Al (U.S. cents)[a]
1. Hydroelectric (established - Iceland, Ghana)	.6 - 1.4	3.8 - 8.9
2. Hydroelectric (new)[b]	.75 - 3.0	4.8 - 19.0
3. Coal (Australia)	2.1	13.3
4. Oil[c] (Japan)	4.5	28.6
5. Oil[c] (New)	6.0 - 8.0	38.1 - 50.8

Source: Trade journal reports.

Notes:

(a) based on 14,000 kwh per metric tonne Al.

(b) based on capital cost of US$500-2000 per kilowatt, 12.5 percent annual capital charge, 75 percent availability.

(c) based on fuel oil @ US$35/bbl.

cessing plant.

There is a substantial variation in capital costs for power plants, particularly in developing countries. Typical ranges of costs per installed kilowatt of electric-power capacity might be (in 1981 dollars) as follows:

Type of Plant	Cost per KW (US$)
hydro	500 - 2000
geothermal	600 - 1500
oil/diesel	500 - 1200
natural gas	800 - 1500
coal	1000 - 1500
nuclear	1500 - 2500 (65)

These costs could be increased by up to 40 per cent for plants in particularly unfavorable locations, including many developing--country sites, and by up to $500/KW for coal-fired plants if all available pollution-control equipment is installed.

The effect of power plant capital costs on the ultimate cost of power to mineral-processing plants is shown in Figure 1. As the figure indicates, at a moderate level of profitability, corresponding to the 12 per cent capital charge in the figure, it would be necessary for a hydroelectric plant to be built at a cost of well under $2000 per installed kilowatt if the power is to be available at a competitive cost.

E. Complementary Inputs

In addition to energy, a variety of other complementary inputs are usually required in mineral processing. Alumina refining, for example, requires caustic soda and lime, while aluminum smelting requires cryolite, aluminum fluoride and calcium fluoride. Copper smelting requires silica, while refining requires sulphuric acid, itself a byproduct of smelting. Depending on the particular process being used, a specific form of energy (e.g., natural gas) may be desirable. In some cases, the location of complementary inputs is the deciding factor in locating processing facilities; in traditional steel-making, for example, coking coal availability has often been more important than iron ore or energy costs in determining where steelworks were located.

Most developing countries do not have the various complementary inputs for mineral processing readily available. This means that they will need to import the required materials, and presumably will have to pay a higher price for such imports than the price which facilities in already industrialized countries will have to pay for locally produced materials.

F. Labor Costs

In view of the relatively low share of labor costs in the to-

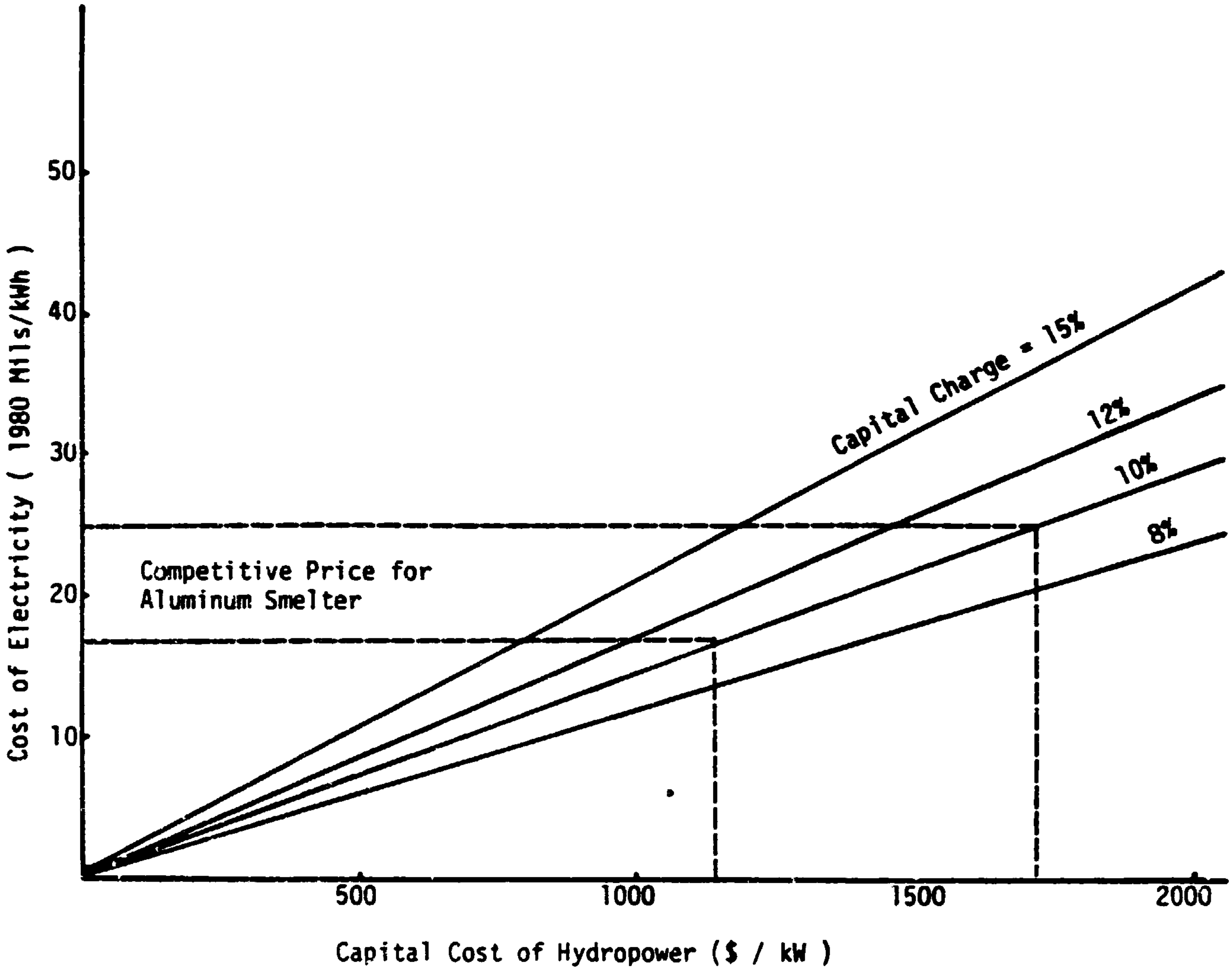


Figure 1. Cost of Electricity from Hydropower ($ / kWh)

Assumptions: Capital charge calculated on basis of 30-year investment recovery

Annual plant utilization factor-- 90%

Taxes not included

Operating and maintenance = 2% of capital cost / year tal cost structure of mineral processing (see Table 10) it is unlikely that developing countries in general possess a major competitive advantage as a result of low labor costs. This is particularly true where domestic wage rates, while lower than those in the industrialized countries, are still higher than in such developing-country manufacturing centers as South Korea, Taiwan or Singapore, or where a significant number of skilled, managerial and technical employees would need to be brought in from other countries because the requisite skills are not available domestically. In addition, processing facilities in developing countries tend to have higher levels of staffing per ton of capacity than similar facilities in the industrialized countries. This fsctor alone cancels out much of the potential advantage that would result from low labor costs.

G. Infrastructure

It is becoming increasingly common for develoing countries to insist that the cost of infrastructure required by mining projects to be paid for directly by the mining enterprise. This can be accomplished either by having the mining company directly supply the capital for infrastructure development or by the state's constructing the infrastructure facilities subject to a prior agreement of the mining company under which the latter undertakes to make annual payments sufficient to meet operating costs and to pay off the ca-

Table 10

Labor Share in Processing Costs

	Approximate Share (%) of Total Cost Due to:			
		Value Added		
	Raw Material	Labor	Other[a]	Capital[b]
Aluminium (input)				
Alumina (bauxite)	30	10	12	48
Aluminium ingot				
(alumina)	31	16	21	32
(bauxite)[c]	9	19	25	47
Copper (input)				
Blister (concentrate)	68	6	7	19
Refined				
(blister)	89	3	4	4
(concentrate)[c]	60	8	10	21
Nickel				
Laterite	65	2	12	21
Sulphide	60	4	12	24

Source: calculated from UNIDO, Mineral Processing in Developing Countries, pp. 124-39.

Notes: (a) includes complementary inputs and energy.

(b) 12.5 percent annual capital change (equal to 10.9 percent real rate of return over 20 years).

(c) capital, labor, and other cost shares at previous stage (alumina and blister copper) are included under those headings rather than as part of raw material cost at metal ingot stage.

pital cost, including interest, over an agreed period of time. Naturally, from the point of view of the mining company, such expenses are a deterrent to investment. In the case of mineral processing projects, as opposed to mining, a company will likely prefer to establish processing facilities where major items of infrastructure, such as transportation systems, ports and power supply, are already in place, or can be made suitable for the project at minimal cost, as opposed to supplying a full range of infrastructure at a "greenfields" site.

To the extent that developing-country governments have access to low-cost sources of finance through aid arrangements or international-agency loans, these countries may be in a position to provide certain items of infrastructure, while at the same time obtaining facilities which can be used for purposes other than those of the mining and mineral-processing project. In general, however, the relative lack of infrastructure in such countries can be expected to act as a disincentive to investment in processing in Third World countries.

H. Externalities

A variety of economic side effects or externalities are important in the analysis of processing projects. For example, one reason why a copper smelter for some developing-country mines may be considered uneconomic is the lack of a local market for by-product sulfuric acid. Similarly, a number of US alumina refineries were built in Louisiana because of the existence of chemical industries which could supply necessary inputs and could purchase by-products of the refining process, even though other factors, such as shipping costs, favored locating the refineries near the source of bauxite in Jamaica.

In a country with a variety of natural resources and a relatively large domestic market, it may be possible to think of establishing "territorial production complexes" in which a number of facilities are located close together so they can supply each other with necessary inputs. It is not clear, however, whether such massive industrial developments could be justified, even on the basis of supplying regional markets, for very small developing countries.

The argument concerning externalities and economic linkages can, however, be turned around and used to justify establishment of processing facilities in mineral-exporting countries to stimulate the growth of related industries. The linkage from mining of ore through smelting and refining to fabrication of metal products and finally to capital-goods production is one of the basic patterns of successful industrialization. A recent study shows that the basic metals are among the highest-ranking industrial sectors in terms of ability to generate economic linkages and promote growth. Once again, however, the linkage argument has somewhat less force in very small economies, where development of a well-rounded industrial economy may in any event be impossible.

I. New vs. Expansion Projects

A further factor in favor of locating additional mineral processing in the industrialized countries, as opposed to developing mineral-producing countries, is that in the former, significant additional capacity can often be added through expansion of existing plants, rather than construction of entirely new facilities. In virtually all cases, expansion capacity can be supplied at a lower capital cost than the same amount of new "greenfields" capacity. Table 11 shows capital costs per annual ton of capacity for alumina refineries and aluminum smelters currently under construction or in the planning stsges. As the table shows, expansion capacity in alumina can be brought onstream at about 20 per cent less than the cost of new capacity, while for smelters, expansion projects have a 35 per cent cost advantage over new facilities.

Exceptions to the general cost trends shown in Table 11 will generally result only when pollution-control requirements in the industrialized countries are so stringent that they increase expansion costs by significant levels.

J. Summary of Economic Factors

The various economic factors discussed in the preceding paragraphs do not always interact so as to produce an entirely predic-

Table 11

Capital Cost of New Alumina Refineries and Aluminium Smelters

	Refineries		Smelters	
	number	capital cost ($ per ton)	number	capital cost ($ per ton)
All projects	11	647	28	4547
New plants	6	676	16	4892
Expansions	5	541	12	3152
Developing Country - new projects	4	580	9	6873
Developing Country - expansions	2	540	2	2150
Industrial Country - new projects	2	959	7	3068
Industrial Country - expansions	3	543	10	3220

Source: "Mining Investment 1981," Engineering and Mining Journal, January 1981, pp. 59-81.

table result. Some developing-country mineral processing projects will show a high rate of return or will have a significant competitive advantage in a particular product market, while other proposed projects will clearly be uneconomical and will result in high-cost production and a possible loss of the economic rents earned at the mining stage. The history of a number of ill-fated processing ventures in developing countries suggests that it is essential for any Third World government contemplating a procesing project to carry out a realistic and comprehensive feasibility study which quantifies the various factors discussed above, considers realistic technological options, and which is carried out with a clear understanding of the market situation for the specific commodity involved.

VI. GOVERNMENT STRATEGIES FOR PROCESSING

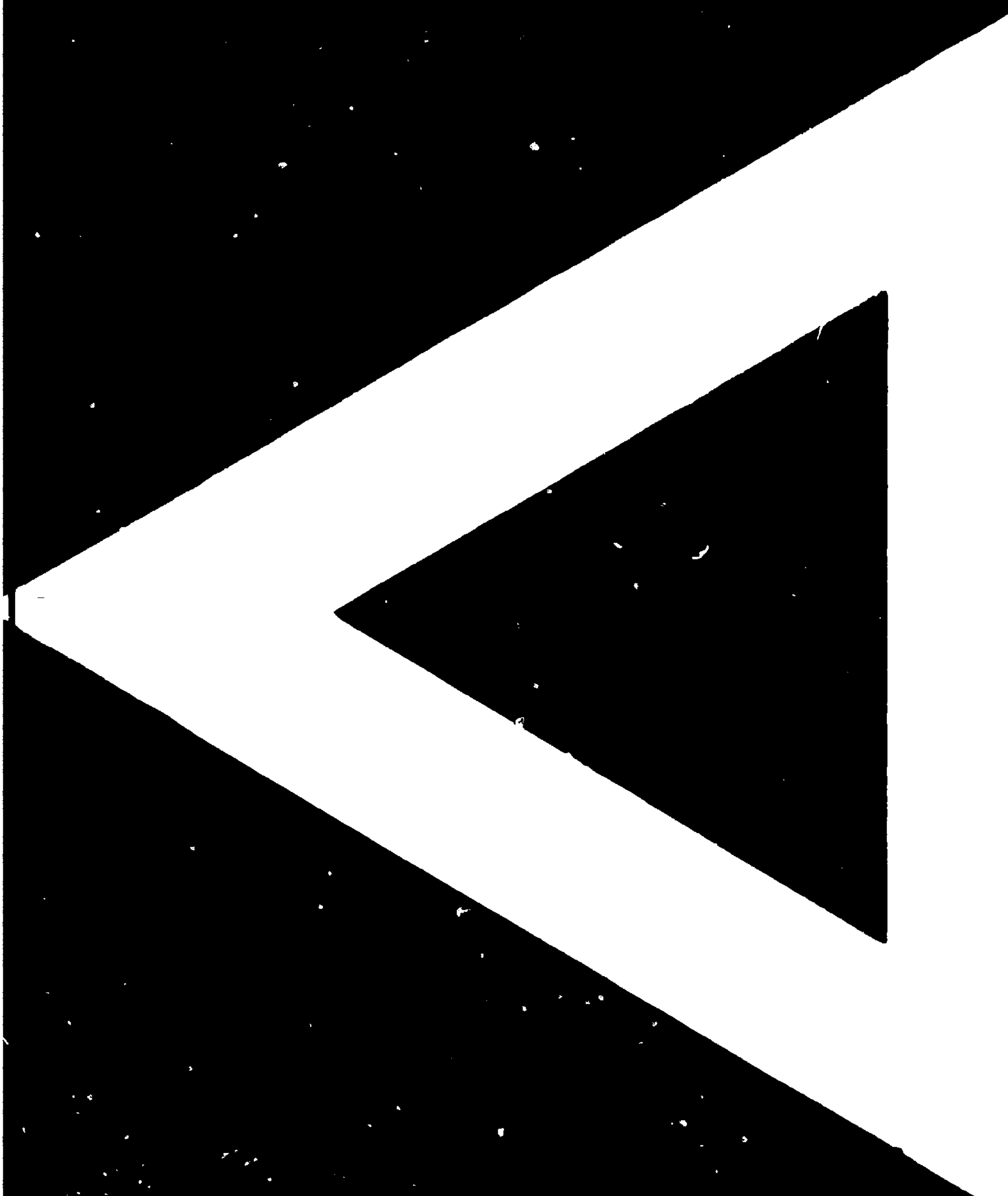
In what has become the conventional wisdom of the New International Economic Order, the further processing of natural resources in producing countries is an essential element in national development strategies. Much of this conventional wisdom, however, appears to be based on the idea that developing countries can simply assume a place within the existing world market economy. Instead of being suppliers of crude materials, they will become suppliers of semi-processed goods, with consequent improvements, it is argued, in their trade balances and industrial capabilities.

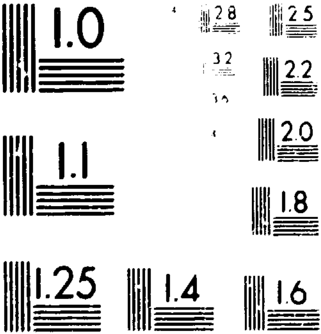
But, nonetheless, they will still be integrated into a worldwide economic system which has not been notable in the past for its enrichment of the periphery.

This paper has presented evidence that, in many cases, it will be difficult to justify the establishment of mineral-processing facilities in the developing countries on the basis of conventional economic analysis. In these terms, developing countries may often be better off, at least in the short term, by continuing to function purely as raw materials suppliers, and extracting, to the best of their ability, a major share of the economic rent associated with mining.

It should be clear, however, that such an approach cannot, in the longer term, provide a basis for autonomous industrialization and development. Therefore, it would appear logical for those developing countries which wish to pursue workable national development strategies to examine alternative approaches to the mineral processing issue. Such approaches could involve, for example, cooperative efforts among developing countries, using raw materials from one, energy from another, and capital from a third to produce products required in all three countries. Or they could involve regional planning efforts, so as to permit comstruction of economical-scale processing plants to serve regional markets where national markets are not large enough. Or they could involve strategies of reducing mineral production and waiting for further development which would permit the establishment of processing facilities on a national basis.

None of these strategies are easy. The pressures for rapid mineral production to generate revenue are severe in many countries, and the difficulties in making cooperative or regional arrangements have already been well demonstrated in practice, in the Andean Pact, the association of Southeast Asian Nations (ASEAN), and elsewhere. But such new approaches do deserve further analysis, as they offer what may be the only means by which many developing countries may effectively build on their mineral resources and avoid the fate of being forever nothing more than crude materials suppliers, dependent on the decisions made in Western markets and boardrooms.





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MINING AND MINERAL PROCESSING IN DEVELOPING COUNTRIES *

Prepared by

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UNIDO consultant

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CONTENTS

INTRODUCTION

This report is prepared pursuant to Agreement No. CLT-84-147 between the consultant and the United Nations Industrial Development Organization. The terms of reference for this study are as follows:

The study is to cover the industries of aluminium, copper, nickel, tin, lead and zinc.

The main aspects to be covered by the study are the following:

1. Projection of the demand for the 1980s of the different processed metals in the developed and developing countries.

2. Definition of the capacity of industrial production in the 1980s in the developed and developing countries.

3. Define the main balances between supply and demand in the developed and developing countries.

4. Prospects for further local processing by developing countries. In the context of the actual crisis and the division of labour that is taking place, define the possibilities and degree of industrial processing that can take place in the developing countries.

   In the development of this point special attention has to be given to the analysis of the possibilities to establish a more integrated development between the non-ferrous industry and the capital goods and steel industries in the developing countries.

5. Main barriers and benefits to be gained from local processing. In the analysis of the barriers special atten- has to be paid to the following aspects:

   (a) economic factors
      (i) tariffs and other trade limitations
      (ii) marketing problems
      (iii) technological changes
      (iv) energy costs
      (v) high intensity of capital in the non-ferrous industries

(b) Non-economic factors
  (i) main strategies of transnational corporations

6. Government strategies of the developing countries that are main producers.

   In this aspect it is important to consider:

   (a) the impact of the crisis on the policies of the developing countries related to the non-ferrous industry.

   (b) the role of the state and state-owned enterprises and implications for developing countries' investment capabilities.

7. Possibilities of co-operation between the developing countries for further local processing.

The structure of this report follows the outline of topics as set out in these terms of reference. Moreover, the report has been prepared in the light of previous UNIDO work in this area, including the study prepared by the present author and Marian Radetzki on "Mineral Processing in Developing Countries" (1980) and the material on the non-ferrous metals sector prepared by Mr. Christian Gillen of UNIDO (1984).

The basic conclusions of the report can be summed up briefly:

1. Demand for most of the metals studied can be expected to increase more slowly in the remainder of the 1980s than in the 1970s; the lower growth rate is a function both of the expected slower growth of the world economy and of the lower intensity of use of most metals, which is itself a product of higher energy prices in the 1970s, leading to increased materials conservation and

the use of non-metal substitutes, and of the mid-1970s concern with the possibilities of resource exhaustion.

2. Capacity closures can be expected in North America and in Western Europe and Japan, especially in the energy-intensive processing facilities. These closures will provide some opportunity for a re-structuring of world metal production, by opening the way for new facilities in the developing countries, but these opportunities will be limited by difficulties in securing adequate financing and by competition among countries, resulting in the distinct possibility of over-capacity in many metals.

3. For most metals, supply can be expected to continue to outstrip demand for the remainder of the 1980s; in particular, developing-country suppliers in the copper, bauxite and nickel industries can be expected to become the marginal or "swing" production, as the industrial countries come under increased pressure to adopt protective measures to safeguard their remaining existing mining and processing industries.

4. If financing problems can be resolved, the establishment of mineral-processing facilities in the larger developing countries can be justified, and may contribute to the retention of a larger share of the value of mineral production in the producing countries. For many smaller

countries, however, the economics of mineral processing and semi-fabrication are, at best, questionable, and many of these countries will face a choice between remaining exporters of unprocessed raw materials or participating in regional processing initiatives, if these exist.

5. While tariffs and other barriers to developing countries' processed minerals and metals imposed by the industrialized countries have diminished in importance in the past decades, these barriers still exert a certain bias against the Third World's products. In addition, the recent strategy of transnational corporations in the minerals industries, to diversify their sources of raw materials supply and to concentrate their processing and fabricating operations in what they consider to be politically "safe" countries has had the effect of depriving developing countries of an important potential source of capital for processing operations. On the other hand, the developing countries often possess locational advantages, especially in the form of low-cost energy; these advantages account, for example, for the building of aluminium smelters in Bahrain, Algeria and Egypt.

6. Appropriate government strategies depend on the situation of the particular country in question; it does

not usually make sense for all countries to proceed to mineral processing merely because their mine production capacity exceeds some theoretical minimum efficient level. As such recent projects as the Pasar copper smelter in the Philippines have shown, the start-up of a processing project may actually reduce the profitability of domestic minerals enterprises. (This reduction in profitability may, of course, be justified on the basis of other national benefits, such as increased integration of the national economy, employment, etc.) The most important general aspect of developing countries' strategy in this area is that the strategy must suit a country's level of economic development.

7. Opportunities for co-operation among developing countries are particularly promising in the minerals processing field. Many regions encompass some countries with low-cost mineral resources, others with low-cost energy, and still others with well-developed industrial bases and sizeable markets; in such situations, the prospects for co-operative processing projects are good. Difficulties have repeatedly arisen, however, in bringing such co-operative projects to fruition. The repeated failures of the Caribbean and Central American countries, for example, to agree on a bauxite-alumina-aluminium complex are typical examples. Promotion of such regional co-operation is an area in

which United Nations agencies with appropriate expertise, including UNIDO and the Minerals Branch of the Department of Technical Co-operation for Development, might play a particularly important catalytic role.

All in all, the conclusions of this report are less optimistic, as regards prospects for mineral processing in developing countries, than some other recent studies, including the author's earlier Mineral Processing in Developing Countries (1980) and the publication of the same name produced by UN/DTCD in 1984.[1/] The decline in many minerals markets, which many developing-country observers have wanted to see as a short-term or cyclical phenomenon, is more and more appearing to be a long-term secular trend. The age of metals as the basis of the world economy may well be drawing to a close, and with it the opportunities for developing countries to rely on their mineral endowments as the sole basis for economic development.

1/ United Nations (Department of Technical Co-operation for Development), Mineral Processing in Developing Countries, London, Gr-ham & Trotman (special issue of Natural Resources Forum) 1984.

I. DEMAND PROJECTIONS FOR NON-FERROUS METALS

Two basic factors contribute to the demand for non-ferrous metals: the level of economic activity, especially in the industrialized countries, and the intensity of use of metals in industrial activity. Any projection of demand growth must be based on certain assumptions regarding each of these variables.

The overall level of economic activity, especially in the industrialized countries of the OECD, has been erratic and low over the past decade. In some years, economic activity actually declined, and in all years since the mid-1970s, the growth rate for the OECD as a whole, whether measured in terms of real GDP or industrial production, has been lower than during the preceding two decades. According to UNCTAD estimates, OECD economic growth from 1980 through 1984 will average only 1.5% per year. Along with these generally low levels of economic growth have gone particularly low levels of capital formation, especially in 1982, when private fixed investment actually declined in the United States, Japan and the European Community.

These low growth rates in the industrialized countries have also, as has been widely noted, had a strong impact in restricting the growth of developing countries, by reducing demand for these nations' exports and by contributing to the now-chronic over-supply situation for most non-ferrous metals, a situation that has resulted in metal prices which are currently at or near the lowest point, in real terms, that has been reached in the past 40 to 50 years.

With the exception of aluminium and, to a lesser extent, nickel, the outlook for demand for the major non-ferrous metals is also dampened by the substantial decline in intensity of use which has occurred since the oil price increases of 1973-74, and especially since the second major round of oil price increases in 1979-80. In the case of copper, for example, the use of optical fibers has substantially eroded the potential for growth in copper consumption in communications, one of the metal's major traditional markets. At the same time, copper use in the automotive industry has been substantially cut back, by the use of plastics and other substitutes and by the development of metals-saving technologies, as, for example, in light-weight automobile radiators. Similarly, the use of zinc in automobiles has declined substantially, as weight-saving technologies are adopted in order to provide better fuel economy. And the traditional market for tinplate in beverage cans has been virtually eliminated by the substitution of aluminium, plastic and glass containers.

Table 1 shows worldwide consumption of the six non-ferrous metals included in this study. Even for aluminium, the most buoyant of the metals, the 1970-83 consumption growth rate is only 3% per annum, while copper, nickel and zinc show growth rates between 1% and 2%, and tin actually has a negative consumption growth rate of 0.6%. No compelling reasons have been advanced that would, in the author's view, support predictions of greater growth in the coming decade.

TABLE 1. WORLDWIDE CONSUMPTION OF NON-FERROUS METALS

(thousand tonnes)

	1970	1975	1980	1983 1/	1970-83 Growth Rate (%)
Aluminium	9996	11350	15312	14666	3.0%
Copper	7271	7458	9385	9050	1.7%
Tin	227	219	[illegible]23	210	-0.6%
Nickel	577	576	717	672	1.1%
Zinc	5056	5066	6131	6308	1.7%
Lead	3871	4526	5348	5263	2.4%

1/ Estimated.

Sources: World Metal Statistics; Mining Annual Review 1984.

Aluminium

Despite substantial recovery in demand in 1983 (an increase of consumption over 1982 of 16% in the United States and 9% in the rest of the market-economy countries), most observers agree that the longer-term outlook for aluminium demand is for increases that more or less approximate world economic growth rates. Substantial areas of strong demand include food processing and beverage canning, and the continuing substitution of aluminium in vehicles, replacing other metals, so as to decrease weight and increase fuel efficiency. Growth of demand in such more traditional applications as aircraft and industrial machinery, however, is generally expected to lag behind overall economic growth in the major industrial countries. On balance, assuming continuation of recent OECD growth rates, an aluminium consumption growth of 3-4% per annum appears to be a reasonable estimate.

Copper

The rapid growth in worldwide copper consumption in the 1960s (annual growth rates approaching 6%) was largely the result of the economic reconstruction of Japan and Western Europe. Now that a basic economic infrastructure exists in these areas, and the financial situation of such potential industrializing countries as Brazil, India and China makes it unlikely that they will take the place of Japan and Western Europe as copper consumers, at least in the 1980s, the outlook for copper demand is universally agreed to be pessimistic. The 1970-83 growth rate of 1.7% is a rough approximation of the forecasts for consumption growth over the next decade that are currently being made (once again, assuming a continuation of recent OECD growth rates). To put this rate in perspective, it implies an increase of a little more than 100,000 tonnes per year, or less than one major new mine annually. With some 25-30 already-evaluated mining projects awaiting development around the world, this is not a promising outlook. Moreover, the increasing use of scrap as a source of copper (a growth rate in scrap consumption of 6.5% annually in recent years) further depresses the prospects for new mine development. Demand for copper has also been restricted in communications, as a result of the increasing use of optic fibers, in transportation, where it has been replaced by weight-saving materials, and in electrical transmission, where the continuing scaling-down of electricity demand forecasts has led to a sharp reduction in the need for transmission cables.

Nickel

Nickel demand is largely derived from demand for steel, and has been sharply affected by the depression in this industry, especially since 1980. Nickel consumption in 1983, while still well below the peak level of 1979, was somewhat higher than in 1982, reflecting a modest upturn in steel demand. For the longer term, however, few predictions of nickel demand foresee growth rates much in excess of the 1% per annum level that has been achieved since 1970.

Lead

Although worldwide demand for lead was somewhat stronger than that for copper or nickel in the 1970-83 period, the longer-term outlook appears to be more pessimistic. Recent improvements in electric storage-battery technology require less lead per unit. Similarly, plastic has been substituted for lead in a number of plumbing applications, and a generalized concern with lead's toxic qualities will undoubtedly restrict its use in the future. On the other hand, there has been some increase in lead demand for use in automobiles, especially in corrosion applications. One long-term possibility for substantial use of lead is in the storage and disposal of radioactive material; this is a market that will develop more rapidly as existing nuclear power stayions reach the end of their useful lives and as agreement is reached on appropriate permanent disposal methods for nuclear waste. The size of this market for lead is, however, virtually unpredictable. In any event, a growth rate somewhat less than the overall OECD economic growth rate seems a reasonable forecast for lead demand for the coming decade.

Zinc

The most important determinant of zinc demand is the overall state of the economy in the industrialized countries, since the bulk of zinc use is in applications with relatively little elasticity -- automobiles and construction. Recent technological developments, including the use of zinc alloy coatings, have contradictory effects; on the one hand, they reduce the amount of zinc used in some of the traditional applications, while, on the other hand, they may open up new markets, as, for example, in situations where newly-developed zinc casting alloys can more effectively compete with other materials and processes. A further possible area of increased demand is in the use of zinc for low-value coinage; the United States shifted from copper to zinc as the basis for its lowest-value coin in 1982, and other countries are likely to follow suit:

While few industry analysts foresee demand for zinc rising faster than overall OECD economic growth, some improvement from the growth rates of the 1970-83 period does appear to be a distinct possibility.

Tin

Demand for tin has now been declining for many years; it appears that tin is a fully "mature" metal, and that the development of substantial new areas of use is extremely unlikely. The use of tin in tinplate (which accounts for a third of total tin consumption) has declined by more than 35% in the past decade, reflecting the substitution of aluminium and plastics in beverage containers. In the U.S., for example, 98% of beer cans and 88% of soft drink cans are now made of aluminium, and similar shifts are underway in Europe and Japan. Moreover, even where tinplate is still used, technological advances have substantially reduced the amount of tin metal used in the tinplate.

Tin's other major market, solder for electrical uses, is also threatened by technological change, as electronic equipment is increasingly based on the use of printed circuits and miniaturized components. Thus, tin use per unit of production in the electronics industry has substantially declined, although overall tin use in this sector has not fallen to as large an extent, because of the rapid growth in overall electronic equipment demand.

Summary

While making precise predictions as to future rates of demand growth for the non-ferrous metals would be a somewhat pointless exercise, as these growth rates are so dependent on overall levels of economic activity, one can with reaspnable confidence say that demand growth is unlikely, for the remainder of this century, to reach the high levels that obtained in the 1960s.At best, consumption of metals appears likely to grow no faster than the OECD economies as a whole, and, for most of the metals surveyed, a more defensible prediction would be that consumption growth will lag substantially behind overall economic growth, reflecting the declining intensity of metal use in the maturing industrial economies.

II. MINING AND PROCESSING CAPACITY

As is well known, the basic pattern in the location of mining and processing facilities around the world is that mining operations are considerably more heavily concentrated in the developing countries than are processing installations. Within this general pattern, however, there are significant differences; the bulk of tin refining, for example, is carried out in the developing countries, to take one extreme, while a very large proportion of aluminium smelting capacity is located in the industrial countries and relies on raw materials supplies from developing nations. The specific distribution of production in each of the major non-ferrous metals is described in more detail below.

Aluminium

Table 2 shows world bauxite and aluminium production in 1983. As the table indicates, roughly half of market-economy bauxite production is from developing countries (the principal industrial-country supplier, Australia, alone accounts for 40% of total production), while less than 20% of metal production comes from developing countries. It should be noted, moreover, that the production figures mask an even greater disparity in capacity, as smelters in the industrialized countries were operating at relatively low rates of capacity in 1983 (the capacity utilization rate in Japan, for example, was only 36%.)

Table 2. Bauxite and Aluminium Production, 1983

(thousand tonnes)

	Bauxite	Aluminium
United Kingdom	...	253
France	1,800	367
Fed. Rep. Germany	...	743
Greece	2,400	136
Italy	...	196
Netherlands	...	234
Norway	...	716
Spain	...	357
Yugoslavia	3,500	248
Other Europe	...	323
Total Europe	7,700	3,573
Cameroon	...	80
Egypt	...	150
Ghana	700	38
Guinea	11,600	...
South Africa	...	162
Total Africa	12,300	430
United States	700	3,353
Canada	...	1,095
Total North America	700	4,448
Brazil	4,200	402
Guyana	1,000	...
Jamaica	7,300	...
Suriname	2,000	35
Venezuela	...	343
Other Latin America		162
Total Latin America/Caribbean	15,200	942
Bahrain	...	160
Dubai	...	151
India	2,000	210
Japan	...	256
Other Asia	2,000	209
Total Asia/Middle East	4,000	986

Table 2 (continued)

	Bauxite	Aluminium
Australia	26,000	475
New Zealand	...	225
Total Australasia	26,000	700
World Total (excluding centrally planned economies)	65,200	11,085

Source: Mining Annual Review 1984.

Among the more important recent developments affecting the location of capacity are: (a) the permanent closure of additional smelters in Japan, reducing that nation's former leading role in the industry; (b) the continuing expansion of all phases of the industry in Australia, including development of at least four new smelters; (c) continuing expansion in Brazil, again at all stages of the industry; (d) the opening of alumina and aluminium plants in Indonesia; and (e) the apparent role of the Caribbean countries -- Jamaica, Guyana and Suriname -- as, increasingly, suppliers of last resort, meeting marginal demand for bauxite. Smelter location appears to be strongly influenced both by the availability of low-cost energy (new facilities are almost universally based on hydro-power, as in Canada and Brazil, or on cheap coal, as in Australia) and by the concern of the major transnational firms in the aluminium industry to diversify away from dependence on one or a few developing countries, in the wake of the imposition of a bauxite levy by Jamaica and other Caribbean producers in the mid-1970s.

A number of recent efforts by developing countries to establish processing facilities have failed. For example, Ghana still lacks an integrated aluminium industry, even though it has both bauxite deposits and hydro-power which supplies an aluminium smelter. More than a decade of effort has not yet resolved the anomaly whereby Ghana's bauxite is exported in raw form, and imported alumina is used in the smelter. Similarly, various efforts by the Jamaican government in the late 1970s and early 1980s to establish an integrated aluminium industry in the Caribbean, in cooperation with Mexico and Trinidad and Tobago, foundered on the inability of the various countries to agree on mutually acceptable terms.

In the light of the very slow development of additional smelting capacity in most developing countries, prospects for the future appear less than bright, particularly in those developing countries that lack a large internal market for aluminium metal. As aluminium is the major non-ferrous metal most strongly controlled by multinational corporations (the traditional Big Six companies still, as of 1981, accounted for 52% of world alumina production capacity and 43% of aluminium metal capacity, these companies' traditional view that developing-country investment is high-risk, and will only be undertaken if prospective profits are higher than those required in the industrialized countries, acts as a substantial barrier to the flow of investment capital into new developing-country processing facilities. This is especially true when, as in the mid-1980s, many developing countries, because of their external debt burden, are effectively cut off from access to commercial bank funds for their own investment projects.

Copper

In contrast to the situation in aluminium, the developing countries have, especially in the past 15 years, made significant gains in establishing national ownership and control over their copper industries. As a result of these efforts, the major developing-country state enterprises, such as Codelco-Chile, Mineroperu and Centromin of Peru, Gecamines of Zaire and the state mining companies of Zambia, have displaced transnational corporations as the leading force in world copper production. Most of the traditional transnational companies, in fact, have either disappeared completely (as, for example, in the case of Anaconda), or have been absorbed into larger firms, where copper mining is only a minor activity (examples include Kennecott's acquisition by Sohio/British Petroleum, and St. Joe Minerals' absorbtion into Fluor Corp.).

In terms of production, developing countries account for more than half of world copper reserves, and for approximately 45% of world mine production of copper contained in ores and concentrates. Table 3 shows world mining and refinery production (excluding the centrally planned economies) in 1983.

Substantial gains have been made in establishing processing

Table 3. World Copper Mine and Refinery Production 1981-1983

(thousand tonnes)

Mine Production	1981	1982	1983
Yugoslavia	[illegible]	119	110
Other Europe	184	186	177
South Africa	211	207	211
Zaire	505	503	503
Zambia	587	581	570
Other Africa	95	113	116
Philippines	302	292	275
Other Asia	210	262	294
Canada	691	612	615
United States	1,538	1,140	1,046
Chile	1,081	1,240	1,257
Mexico	230	239	193
Peru	328	356	317
Other America	18	27	42
Australia	231	245	265
Papua New Guinea	165	170	183
World (excl. CPEs)	6,487	6,292	6,194
Refinery Production			
Belgium	428	458	394
Fed. Rep. Germany	387	394	421
Spain	152	176	159
United Kingdom	136	134	144
Yugoslavia	133	127	124
Other Europe	236	240	252
South Africa	145	143	152
Zaire	151	175	227
Zambia	564	587	575
Other Africa	19	28	26
Japan	1,050	1,075	1,092
South Korea	113	116	126
Other Asia	100	107	148
Canada	477	312	464
United States	1,996	1,683	1,581

Table 3 (continued)

Refinery Production	1981	1982	1983
Chile	776	852	833
Mexico	68	74	76
Peru	209	225	191
Other America	27	45	92
Australia	191	178	202
World (excl. CPEs)	7,358	7,129	7,279

Source: Mining Annual Review 1984, p. 29.

facilities in the more important developing country producers. Zambia, for example, refines virtually all the copper ore it produces, while Chile, Peru and Zaire smelt and refine the large majority of their production. On the other hand, such major ore-producing countries as Papua New Guinea, the Philippines and Indonesia do little or no processing (with the exception of one new smelter in the Philippines); almost all these countries' copper is exported for procesing in Japan and Europe.

A further factor that deserves mention is the location of semi-fabricating facilities. In the past decade, a substantial technological change has occurred, with the development of continuous-casting techniques and increasing utilization of high-grade cathode as the major fabricating feedstock. Because of the difficulty in shipping continuous-cast rod to far-off consumers, most new rod facilities (92%) are located in the industrialized countries. Where developing-country copper producers have moved into this new semi-fabrication technology, they have done so in joint ventures with transnational corporations, located near the major markets. Examples of this approach include Zambia's joint venture with Thomson-Brandt of France, and Codelco's with Duisberger Kupferhutte of the Federal Republic of Germany.

In the light of the near-stagnation of the world copper market (as evidenced by the production statistics in Table 3 above), the outlook for the establishment of new mines or processing facilities in developing countries can only be described as guarded at best. There are at least 30 already-identified and evaluated copper prospects around the world awaiting development; at present consumption growth rates, only one of these new projects would be needed each year to meet increasing demand and replace depleting mines. Thus, the outlook is for a very long wait for some of these prospects — if, indeed, they are ever to be brought into production at all. At present, the only major copper development under active construction is the Ok Tedi mine in Papua New Guinea, and even this project, which is made economically attractive by its high-grade gold ore overburden, has been postponed and may (at least as far as its copper production is concerned) be cancelled altogether.

Nickel

The world nickel industry has historically been highly concentrated, both geographically (in Canada, New Caledonia and Soviet Union) and in terms of corporate control (with Inco of Canada the dominant force). Several recent events, however, have changed this pattern. First, the severe downturn in the world steel industry has drastically affected nickel demand and prices, as the major use of nickel is in steel alloys. Second, the development of techniques for treating laterite (oxide) ores has re-directed production toward developing countries, as most laterite deposits are found in equatorial regions. Table 4 compares mine and metal production in 1971 and 1981 (little change has been evident in 1982 and 1983).

As in the case of copper, few new nickel facilities are under development in market-economy countries. And many of the past decade's projects have either been closed (for example, Falconbridge Dominicana and Inco's Exmibal project in Guatemala) or are continuing to operate only at a huge loss (as in Selebi-Pikwe in Botswana, Marinduque in the Philippines or Greenvale in Australia). The only firm plans for development listed in the 1984 Engineering & Mining Journal survey of new mines and plants, for example, are two replacement mines to maintain production levels in Canada's Sudbury mining district, and the Punta Gorda project being built with the assistance of the Soviet Union in Cuba. The outlook for such identified but still undeveloped prospects as Ramu River in Papua New Guinea or Wadi Qatan in Saudi Arabia is distinctly pessimistic. Moreover, the continuing possibility that deep-ocean nodule mining will contribute an appreciable part of the world's future nickel needs operates as an ongoing barrier to investment in land-based nickel projects. For the foreseeable future, then, the distribution of nickel mining and processing capacity is unlikely to undergo major change.

Table 4. World Nickel Production 1971-81

(per cent)

	Mine Prod.		Metal Prod.	
	1971	1981	1971	1981
South Africa	1.8	3.6	1.8	2.4
Japan	...	...	16.6	13.7
Finland	0.5	1.0	0.6	1.9
France	...	...	1.6	1.4
Greece	1.5	1.7	1.7	1.6
Norway	0.1	0.1	6.7	5.3
United Kingdom	...	...	6.2	3.6
Canada	39.2	22.0	28.5	15.4
United States	2.1	1.6	2.3	6.2
Australia	5.2	10.6	2.4	6.0
Total DMEs	50.4	40.8	68.4	57.5
Botswana	...	2.6	...	...
Zimbabwe	1.7	2.2	1.3	1.8
Indonesia	2.2	6.4	...	0.7
Philippines	0.1	4.2	...	2.7
Brazil	0.5	0.4	0.4	0.3
Dominican Rep.	0.1	2.6	...	2.7
New Caledonia	22.2	11.1	5.2	4.0
Total LDCs	26.7	29.5	6.9	12.2
China	...	1.6	...	1.7
Cuba	5.4	5.7	2.9	3.0
Soviet Union	16.1	20.6	20.3	24.1
Other CPEs	1.4	3.4	1.5	3.2
Total CPEs	22.9	29.7	24.7	30.3
World Total (kt metal content)	681	703	620	704

Source: Annuaire Statistique Minemet 1982.

Lead

In contrast to bauxite, copper or nickel, the production of lead is very largely determined by demand for the other metals -- principally zinc and silver -- with which lead is typically associated in commercial deposits. Even though lead use in such traditional applications as storage batteries is decreasing, the strong demand for zinc in recent years has kept lead production at relatively higher levels than could be expected based on an analysis of supply and demand for lead itself.

The major producers of lead are the United States, Australia and Canada. Among developing countries, Mexico, Peru and Morocco are the most important suppliers, and all these countries have plans for expansion of both their mining and processing industries. Table 5 shows world mine and metal production of lead in 1981-83.

In contrast to the situation in nickel, a substantial number of lead/zinc/silver projects are either under construction or well advanced in the planning stages. The 1984 Engineering & Mining Journal investment survey, for example, list some 15 lead prospects under active development, including projects in Peru, Morocco, Tunisia, India and Thailand, as well as in Canada, Yugoslavia and Australia. In virtually all cases, these new developments will produce zinc and silver as well as lead.

Table 5. World Lead Mine and Metal Production 1981-83

(thousand tonnes)

	Mine Prod.		Metal Prod.	
	1981	1983	1981	1983
Austria	4	4	16	17
Belgium	...	...	102	125
Denmark	27[1]	20[1]	27	10
France	19	2	228	198
Fed. Rep. Germany	29	30	348	352
Greece	23	21	21	...
Ireland	29	34	10	8
Italy	21	24	133	131
Netherlands	...	...	20	38
Spain	84	84	120	135
Sweden	85	79	29	53
United Kingdom	7	2	333	314
Yugoslavia	119	118	126	123
Total Europe	452	424	1,532	1,522
Morocco	118	111	52	58
South Africa	147	128	67	65
Total Africa	298	268	154	157
Brazil	22	31	66	49
Canada	332	252	238	242
Mexico	150	172	166	179
Peru	187	207	85	66
United States	455	456	1,067	1,006
Total America	1,208	1,176	1,676	1,598
Japan	47	47	317	322
Total Asia	125	143	420	437
Australia	380	450	252	229
World (excl. CPEs)	2,463	2,461	4,034	3,943

Source: International Lead/Zinc Study Group.

A notable feature of the lead processing industry, in contrast to copper, aluminium or nickel, is the very high proportion of metal supply which is produced from scrap. Nearly 40% of the world's lead consumption is secondary (scrap) production, reflecting the metal's maturity and the large stock available for recycling. As the more energy-efficient recycling techniques continue to extend their cost advantages over energy-intensive primary smelting, the share of mine ore in final lead metal supply can be expected to continue to decline, further limiting opportunities for the addition of processing capacity in the developing countries.

Zinc

As noted above, zinc production is closely linked with that of lead. The most significant producing countries are Canada, Peru and Australia, although production is fairly widely distributed. Table 6 show world zinc mine and metal production for 1981-83.

Unlike the market for lead, that for zinc has been moderately strong in recent years, as new galvanizing applications have been developed, replacing the declining markets for traditional zinc die castings. A potentially significant development is the introduction of zinc for coinage in the United States, replacing copper. An important regional market is the use of zinc in construction in France.

Table 6. World Zinc Mine and Metal Production 1981-83

(thousand tonnes)

	Mine Prod.		Metal Prod.	
	1981	1983	1981	1983
Austria	18	19	23	23
Belgium	...	...	235	263
Denmark	79[1]	73[1]	...	...
Finland	54	56	140	155
France	37	31	257	249
Fed. Rep. Germany	111	113	366	357
Greece	27	22	...	...
Ireland	117	186	...	...
Italy	42	44	181	154
Netherlands	...	...	177	187
Norway	28	32	80	90
Portugal	...	...	5	4
Spain	182	171	189	195
Sweden	181	203	...	...
United Kingdom	11	9	82	88
Yugoslavia	89	90	96	88
Total Europe	976	1,049	1,831	1,853
South Africa	123	137	81	82
Zaire	76	81	58	62
Zambia	40	42	33	38
Total Africa	275	296	203	212
Brazil	71	73	92	100
Canada	1,096	1,069	619	617
Mexico	216	241	127	179
Peru	497	560	126	154
United States	343	302	393	294
Total America	2,330	2,369	1,384	1,376
Japan	242	256	670	701
Total Asia	403	418	827	873
Australia	485	647	301	301
World (excl. CPEs)	4,469	4,779	4,546	4,615

Source: International Lead/Zinc Study Group

Tin

Although mine production of tin reached its lowest level in 17 years in 1983, there remained a substantial surplus on the market, inhibiting plans for future mine and plant development. Tin is a fully mature metal, with little or no growth in demand likely for the foreseeable future, and so existing patterns of production are likely to change little, if at all.

In contrast to most of the other non-ferrous metals, production of tin, both at the mine and smelter stages, is heavily concentrated in the developing countries. Among the industrialized countries, only the United Kingdom and Australia each account for as much as 2% of world mine production, while Malaysia supplies 30% of world supplies and Bolivia, Indonesia and Thailand each account for more than 15% of production. Table 7 shows world mine production of tin in 1972-82.

The relatively small expansion plans in the world tin industry (only three projects are listed by Engineering & Mining Journal) are concentrated in already-producing countries, although it appears that what little investment interest exists favors the United Kingdom and Australia over developing-country producers. At the processing stage, it should be noted that the vast majority of developing countries' tin production is already smelted locally; the recent completion of smelter facilities by Bolivia removes the last case in which a major tin producer depended on smelting facilities in the industrialized countries.

Table 7. World Tin Mine Production 1972-83

(thousand tonnes)

	1972	1983
Int'l Tin Council Members		
Australia	12.0	9.6
Indonesia	21.8	26.6
Malaysia	76.8	41.4
Nigeria	6.7	1.4
Thailand	22.0	20.0
Zaire	6.0	2.0
Total ITC Members	145.4	101.0
Non-Member Producers		
Bolivia	32.4	25.0
Brazil	2.8	13.1
United Kingdom	3.3	4.1
Total Non-Members	50.9	71.4
World Total (excl. CPEs)	196.3	172.4

Source: Mining Annual Review 1984, p. 42.

Note: Discrepancies in the totals in the above table reflect illegal tin trade, primarily in Southeast Asia.

III. SUPPLY AND DEMAND BALANCES

Although the general market situation for the major non-ferrous metals has already been alluded to, this section of the report brings together views obtained from industry analysts regarding the near- and medium-term outlook for supply and demand balances.

Aluminium

Compared to the very low operating rates recorded in the last several years, most existing aluminium producers expect to be operating at higher levels of capacity in 1984-85. Growth projections for aluminium demand both in the U.S. and in the European and Japanese markets were for increases on the order of 9% in 1984, over 1983 levels; if this increase is realized, the high level of producers' inventories should decline somewhat. Even so, the 83% of capacity that major industry analysts see as a likely operating level for 1983 still leaves substantial slack and will deter immediate investment in new facilities. The postponement or cancellation of several planned smelters in Australia is a concrete indication of the continuing slackness in the world aluminium market.

Copper

Copper stocks, particularly those held on the metal exchanges, have declined in 1984, but prices remain at very low levels in real terms (the lowest, adjusted for inflation, since the Depression of the 1930s). Moreover, very large amounts of capacity have been closed, either temporarily or permanently. As of mid-1984, Mining Annual Review reported the following tonnages of shut-in capacity:

Australia	18,000 tonnes
Canada	248,000 tonnes
Philippines	110,000 tonnes
South Africa	2,000 tonnes
United States	762,000 tonnes
Zimbabwe	5,000 tonnes
Total	1,145,000 tonnes

This shut-in capacity amounts to more than 15% of total world mine production. In addition, many other mines are operating at well under full capacity. Thus, even with the drawdown of short-term stocks, the copper market still faces substantial over-supply, and most analysts expect this situation to continue into the late 1980s. The result of continuing technological change -- the substitution of satellite, microwave and fiber-optics communications facilities for traditional copper wire, for example -- makes it unlikely that demand will grow at more than 1-2% per year, compared to the 3-4% rates achieved in the 1960s and early 1970s.

Nickel

While nickel consumption growth rates of more than 4% per annum were predicted a few years ago, most current forecasts see demand increasing at 2-2.5% per year through the 1980s. The expected recovery in 1984 brought capacity utilization in the industry up to about 80%, but this figure reflects the permanent closure of some nickel mines that could not operate profitably at prices of $3.00 per pound or less.

In the near term, over-capacity will continue to be a feature of the world nickel market, and there appears to be little room for development of new projects. A number of existing producers, in fact, continue to operate either because they receive government subsidies (e.g., Selebi-Pikwe) or because they have preferential trade arrangements for their production (e.g., the Cuban state enterprises). On a purely commercial basis, it would be difficult to justify investment in a new nickel venture.

Lead

Most lead consumption forecasts see demand increasing at 2-2.5% per year through the remainder of the 1980s. As the supply of lead is not wholly responsive to market forces (because lead is produced in conjunction with zinc and silver), it is difficult to predict whether the world lead market will be in balance. For the past several years, there has been a small but persistent over-supply situation, but stocks began to decline somewhat in 1984. The medium-term outlook is uncertain.

Zinc

Prices and market balance in zinc were maintain in past years through the concerted action of the major producers, acting as a cartel in the European market; this arrangement apparently persisted from 1964 through 1979 and involved price fixing, market-sharing arrangements, restrictions on resale by consumers, refusal to sell to dealers and direct intervention on the London market. Since the discovery of the cartel, concerted action has obviously not been a viable alternative, and there has been considerable disarray in the zinc markets. A recent increase in demand, reflecting new uses for galvanizing processes, may, however, prove strong enough to support a relatively stable market over the next several years.

Tin

As noted above, tin is a fully mature metal, and demand is unlikely to increase by more than 1% per year. The existing producers have, through the mechanism of the International Tin

Agreements, long attempted to support the market through a combination of production and export restrictions, on the one hand, and direct market intervention, using a buffer stock mechanism, on the other hand. In the long term, these machanisms only provide a device for cushioning the impact of market forces; there is general agreement that prices will remain at relatively low real levels for the near term.

IV. PROSPECTS FOR FURTHER PROCESSING

Increased processing of minerals has become a key element in developing countries' proposals for a New International Economic Order. The primary reasons that daveloping-country governments have advocated increased local mineral processing include: industrialization strategies based on the use of local raw materials; reduction of dependence on the industrialized countries; creation of opportunities for the training of nationals and the development of skills which can be used in other sectors of the economy; limitation of transnational corporations' ability to engage in transfer pricing; capture of a greater share of the economic rent from mineral production; and the hope of obtaining access to capital which might not otherwise be available.

In view of the limited success of import-substitution strategies for industrialization and the limited number of countries which have been able successfully to pursue an export-oriented strategy based on manufacturing or assembly operations, strategies of resource-based industrialization have been claiming increasing attention from developing-country planners. Two variations of such strategies have been tried. One, which could be called "primary export processing," is based on the assumption that more processing of, and, hence, more value-added from, primary product exports will speed the overall development of an economy. Success in pursuing such a strategy depends on the ability of the processed materials to compete in world markets, although it may be possible for a producer-country government to subsidize processing by making inputs, such as energy or infrastructure, available at less than market price.

The second strategy, which can be called "basic goods production," concentrates on the use of agricultural and natural-resource products not primarily for export, but rather for domestic consumption. This approach is in direct contrast to the typical post-colonial trade pattern in much of the Third World, where primary-product exports are used as a means of generating foreign exchange to pay for the import of intermediate and capital goods for import-substitution industries. In its most complete form, this basic goods strategy has been attempted for considerable periods by China and North Korea. In non-socialist countries, a comparable approach has sometimes been advocated, but never wholly put into practice.

Many resource-rich developing countries have pursued a combination of the two strategies. Chile and Venezuela, for example, have sought increased domestic processing of copper and iron ore, respectively, both for export and for use in domestic industries. Countries with a smaller domestic industrial base, such as Jamaica in the case of bauxite, have vigorously pursued further processing as a means of adding value to exports, while countries with greater domestic opportunities, such as Mexico, have emphasized the basic goods production aspect of mineral processing. Many of the petroleum-producing countries have adopted ambitious industrialization plans based on export-oriented refining and the use of natural gas as a feedstock for petrochemical production.

One of the major arguments for increased domestic processing of natural resources, even where a basic goods production strategy is not immediately feasible, concerns the supposed linkage, or "ripple" effects of such processing. These effects are often said to be of two kinds:

(a) linked downstream processing of the same product, for domestic and regional use as well as for export, and linked upstream activities, where local processing makes possible the primary production of another product (for example, where establishment of processing facilities for phosphate rock generates a demand for sulphuric acid which could be produced from local gypsum); and

(b) indirect effects outside the primary-product sector itself, in the use of infrastructure, supply of equipment, construction, fiscal impacts, etc.

Whether any particular mineral processing project actually produces the desired effect is a factual question; one needs to be especially careful in considering the possibility of establishing large-scale processing facilities in small Third World countries not to overestimate linkage effects. It is unlikely, for example, that a very small economy would ever support a well-rounded capital-goods industry, simply because the domestic market involved is too small. Thus, care should be taken in assessing the feasibility of mineral processing projects to limit any quantification of expected benefits to those linkages which can be demonstrated as sure to occur, rather than including all those linkages which are merely thought to be possible or desirable.

B. Reducing Dependence

Further processing of natural resources is often seen as a means of reducing a developing country's dependence, either on the outside world in general or on particular countries or transnational corporations. In broad terms, five different types of dependence can be identified: (a) trade dependence, in which a developing country's ability to import desired consumer and capital goods is a function of that country's exports of primary products; (b) financial dependence, in which the exploitation of raw materials for export and the construction of the infrastructure associated with that exploitation are financed by large flows of capital from the industrialized countries; (c) technological dependence, in which capital goods embodying foreign technologies are imported for purposes of natural resource exploitation; (d) managerial dependence, resulting both from the lack, in the developing country, of adequate education for and experience with industrialization and from the need to import foreign technologies with which local managers and technicians are not familiar; and (e) market dependence, in which control is exercised over a country's export markets or import sources by a few integrated transnational corporations, and in which export sales and/or import purchases are concentrated in a few foreign countries.

The impact on these various forms of dependence of a strategy that emphasizes the further processing of natural resources is not clear-cut. For example, additional processing may well improve a country's balance of payments, by adding value to exports, but at the same time will tend to intensify the lopsided structure of the economy by increasing dependence on export earnings to finance the capital goods and materials needed for the processing industry. This kind of dependence will be reduced, in all but the largest developing countries, only if processing can be done in small units, using relatively accessible technologies, so that a steady demand can be generated over a long period of time for processing inputs which can be supplied domestically. Such a pattern is possible for sawmilling and vegetable oil processing, for example, but may not be achievable in the cases of minerals, pulp and paper, rubber, or many other natural resources.

Similarly, because most resource-processing activities are large-scale and capital-intensive, their immediate impact in many developing countries may be to deepen financial dependence. In addition, technological and managerial dependence are likely to be increased where a country must import processing techniques, equipment and management from transnational corporations, as is generally the case in mineral processing. Forward linkages (i.e., into semi-fabricated products) may also increase a country's risk of technological obsolescence; once a country is committed to processing a commodity into a specific product, using a particular technology, it exposes itself to the risk that competing producers will develop more efficient technologies, leaving the exporting country with an unprofitable investment. The relatively recent development of continuous casting in the metals industries is a good example of this type of risk. [illegible] The same kind of technological risk exists, of course, in the extraction of raw materials, but may be less severe, because extraction techniques are somewhat more stable than processing techniques.

The impact of further processing on market dependence varies according to the commodity involved and the extent of processing. In some cases (e.g., production of refined copper or aluminum ingot), processing will widen the market options of producer countries, since there are many more metal fabricating enterprises than there are smelters and refiners. Integration into forward processing may also, in the case of some metals, be useful in creating brand loyalty among consumers.

C. Development of National Capacity

Although mining and mineral processing produce relatively little direct employment, because of their high capital intensity, these industries may provide valuable training and development of skills which are related to, but nonetheless distinct from, those directly required in the mineral industries. Thus, the construction of large-scale mineral processing facilities can stimulate the training of nationals in construction industry skills and can generate demand for transport and business services and hence contribute to the development of skills needed in those sectors.

It should be kept in mind, however, that the employment effects of mineral processing industries are not always positive. Direct employment in the mineral processing industries themselves is quite limited. The UNIDO study cited earlier estimated, for example, that the amounts of capital investment shown in Table 8 were required to create each job in mineral processing.

Even if a Third World government wished to increase employment in mineral-processing industries, there is little scope for substituting labor for capital. Most technological change in processing has been aimed at increasing the efficiency of raw material use. Given the high share represented by raw material costs, and the relatively low share of labor costs, in the value of finished metal products, Table

Employment in Mineral Processing

Process	Output per Man-year (tonnes)	Capital Cost per Job (1980 dollars)[a]
Alumina refining	800	667,000
Aluminium smelting	90	312,000
Copper smelting/refining	140	450,000
Steelmaking	200	210,000
Lead smelting/refining	225	202,000
Nickel processing (sulphides)	150	1,540,000
Tin smelting	20	205,000
Zinc smelting	200	410,000

Source: UNIDO, Mineral Processing In Developing Countries, P.76.

Note: (a) Costs adjusted to 1980 basis by using Marshall and Swift index of mining and milling costs, as published in Chemical Engineering.

especially in developing countries where wage rates are low, there is little incentive for corporate managers to focus on labor-capital substitution. The available evidence suggests that, since most innovations in copper and aluminum processing, at least, have significantly increased resource recovery rates as well as increasing the capital-labor ratio, there is probably little scope for a plant to operate using older technology in order to generate greater employment per unit of output. This conclusion is reinforced by the past decade's increases in energy costs, since the older processing technologies are considerably more energy-intensive than new processes.

Moreover, employment in mineral processing, as well as in mining, may reinforce tendencies in small economies that favor creation of a small, highly paid elite segment of the working class. The relatively high productivity of labor in these industries, combined with the low share of wages in total product costs, have often made mining and mineral processing enterprises willing to concede to workers' pressure for high hourly wages. The creation of such high-wage enclaves in a small developing economy has been shown to lead to continuing unemployment and undesirable rural-urban migration, as workers leave their traditional agricultural jobs to seek work in the high-wage mining sector, even if in so doing they run the risk of a considerable period of unemployment.

D. Curbing of Transfer-Pricing Abuses

Where both mining and mineral-processing operations are under the same corporate ownership, the establishment of processing facilities in the country where the raw materials are produced can benefit the host government by reducing the company's opportunity to manipulate profits and tax liabilities through transfer pricing. In the bauxite-aluminum industry, for example, the six largest transnational corporations account for 65 per cent of worldwide alumina refining capacity and 55 per cent of smelting capacity. In this situation, the price paid to bauxite mines by refineries is often a purely notional one, established by the corporations in order to minimize their worldwide tax liability (i.e., to adjust prices so that profits are concentrated in low-tax jurisdictions). No "free market" can be said to exist, on a worldwide basis, for bauxite or alumina, even though there are a few arm's length sales. Similarly, in the cases of copper and iron ore, a significant amount of trade in unprocessed and partially processed material has traditionally been conducted between units of large transnational corporations, although the degree of concentration in these industries has decreased in the past two decades and is significantly less than in bauxite-aluminum.

E. Capture of Economic Rents

A producer of refined metal has, typically, a wider range of potential customers than does a producer of unprocessed or semi-processed material. Most markets where unprocessed minerals are bought are highly concentrated. Non-ferrous metal smelters and steelworks, as indicated below, have important economy-of-scale factors. Often their large size dictates the purchase of supplies from several different mines. The limited number of such processing facilities, dealing with a large number of raw-material sellers, might reasonably be expected to create possibilities for monopsony gains by the processors. In contrast, refined metals are typically bought by a large number of customers, and the concentration among buyers of, say, copper cathode or aluminum ingot is much less than among buyers of copper concentrate, bauxite or alumina.

For example, in the case of copper, there are fewer than two dozen independent copper smelters in the world which are prepared to buy significant tonnages of concentrate from independent mines. Concentrate sales contracts with these smelters are usually based on the London Metal Exchange price for refined copper, but actual payments are arrived at only after subtraction of complicated and often ambiguously defined deductions for smelting and refining charges, impurities, etc. The smelters' powerful market position often gives them the opportunity to shift contract terms in their favor. In contrast, the producers of refined copper in international trade have a great number of potential customers to choose from. Trade in refined copper is normally on the basis of a relatively straightforward contract, which specifies quantities, chemical specifications, and delivery and payment terms, usually on the basis of London or New York metal exchange prices. If a supplier of refined copper is unable to find a customer, it can usually dispose of the product directly on these exchanges, an option not available to producers of concentrate.

The above argument does not imply that refined metal prices would be likely to increase if additional processing facilities were located in developing countries, but only that such facilities could help Third World countries to capture some of the monopsony gains which may currently be accruing to processors. It should, however, be kept in mind that the available literature does not suggest that such gains are very large. In addition, there is little substance to the argument which is sometimes made that processing through to refined metal will help to stabilize the export earnings of developing countries. It is well documented that the major cause of price instability in mineral markets is variation in demand, induced by business-cycle fluctuations. This variation in demand, in turn, results from changes in the demand for mineral-containing finished consumer goods and capital equipment. Producers, whether of raw materials, refined metal or finished goods, can react to these changes in demand either by continuing to produce at full capacity and accepting the likely decline in prices, or by cutting back production and attempting to maintain price levels, or through a strategy containing elements of both actions. There is little evidence, however, to show that these business-cycle-induced fluctuations are less severe in the case of refined metal than in the case of ores and concentrates.

F. Access to Capital

A final reason for a developing country to pursue downstream processing of mineral may be that foreign capital for such a project is easier to obtain than other kinds of funds. Certain industrialized nations which are heavily dependent on mineral imports are prepared, for example, to provide government funds for projects which help to assure their long-term materials-supply needs. The governments of Japan, West Germany and France, among others, have subsidized mining and mineral-processing investment in Third World countries, provided that such projects included a long-term sales contract or other mechanism for assuring a mineral supply to the capital-exporting country. Foreign investors in such ventures may be willing, as a condition of obtaining access to a developing country's raw materials, to accept the host government's demands for establishment of local processing facilities, especially where the companies benefit from their home governments' offers of tax concessions and subsidies. In contrast, a developing country is unlikely to have similar leverage when trying to obtain foreign capital for other sectors of the economy. It should be kept in mind, however, that the bargaining advantage which Third World nations have because of industrial countries' desire to assure mineral supplies may be considerably less in the 1980s than it was in the mid-1970s, at the height of international concern over raw materials shortages.

V. BARRIERS TO LOCAL MINERAL PROCESSING

A good deal of the discussion of mineral processing in developing countries has focussed on "barriers" or obstacles to the development of processing facilities. These barriers are seen to be policy distortions or market imperfections which have resulted in a lesser amount of processing in Third World countries than would have resulted from the unimpeded operation of competitive market forces. In the literature on this issue, barriers to processing are often classified as either "artificial" or "natural." The artificial barriers are said to include trade-distorting policies introduced by the industrialized countries, restrictive business practices of transnational corporations, and production-distorting policies of the developing countries themselves. The natural barriers, on the other hand, are said to be the underlying economic characteristics of particular Third World countries. These latter factors are more properly considered in the context of an overall economic analysis of processing projects, in the following section of this article. This section discusses some of the more commonly cited "artificial" barriers to processing.

A. Tariffs and Other Trade Limitations

The tariff structures of the industrialized countries frequently impose higher rates of duty on the import of processed materials than on unprocessed ores. This situation can, in theory, result in a very high rate of effective protection for processing operations, with the result that further processing in developing countries is discouraged. In practice, however, it is not clear that many developing countries are significantly affected by this tariff escalation, at least in respect of smelting and refining operations. The combined effect of the tariff-reducing negotiations of the General Agreement on Tariffs and Trade (GATT), the Generalized System of Preferences which is applied by most Western countries to Third World exports, and the preferential-access provisions of the Lome Convention in respect of exports to the European Economic Community have, taken together, reduced tariff barriers on imports of refined metal from developing countries to insignificant levels. One recent study of the impact of tariffs on mineral processing concludes that "the reduction or removal of developed countries' tariffs on processed raw materials originating in developing countries may not, by itself, do much for the level of processing activity in the Third World." It remains to be seen whether the current worldwide recession, which has produced serious overcapacity in many industrialized nations' mineral-processing industries, will lead to a re-introduction of tariff obstacles to Third World metal sales.

Similarly, while non-tariff barriers to trade, such as the quantitative import restrictions imposed by certain industrialized countries, can, in theory, have a deterrent effect on developing-country processing, there is little concrete evidence to show that such non-tariff barriers do in fact have such an effect in the specific case of non-fuel minerals.

B. Market Distortion by Transnational Corporations

For a number of reasons, transnational corporations in the minerals sector tend to avoid locating processing facilities in developing countries, even if all purely economic factors appear, at first analysis, to support such a location. A TNC will normally attempt to reduce risk by diversifying its investments, and in particular will attempt to avoid a concentration of investment in countries thought to be prone to nationalization. TNCs may also be subject to pressure from their home governments, whose defense and strategic interests or whose concern with maintaining domestic employment levels may favor expansion, or at least maintenance, of their home processing capacities. These non-economic reasons are in addition to such purely economic considerations as the fact that a TNC may have different factor costs than a developing country, because the corporation has easier access to world capital and raw materials markets, or that the TNC may face, within its own vertically integrated operations, a set of marginal costs that differ from the world prices or the costs faced by the producing country.

The extent to which these factors limit a mineral-producing country's ability to establish processing facilities depends greatly on the extent of corporate concentration in the particular mineral industry. For example, company concentration ratios are very high in aluminum, while the copper and iron-and-steel industries are considerably less concentrated. All other things being equal, a developing country would probably have a better chance of negotiating the establishment of domestic processing arrangements in copper than in aluminum.

TNCs can restrict developing countries' processing potential through the use of export-restraining business practices. Such practices include restrictions on exports from developing-country plants or even complete refusal by the TNC to permit such exports. In the case of most minerals, however, there is little clear evidence that TNCs have used such monopoly power to restrict developing-country exports, at least in the past decade, although worldwide apportionment of markets for metals has been a feature of past cartel arrangements, such as the short-lived copper cartels of the late 1880s, 1899-1901 and 1936-39.

A more specific use of monopoly power which is sometimes cited as a barrier to Third World processing is the tendency of shipping conferences to increase freight rates for processed products solely because of the shipowners' superior bargaining power vis-a-vis the exporting countries, and without any justification based on the increased cost of handling processed material. While unit freight rates are normally higher for materials such as copper cathodes, aluminum ingots or steel shapes than for bulk cargoes like copper concentrate, bauxite, alumina or iron ore, these differences may merely reflect specific conditions in the world markets for ships of different types (e.g., for the past few years there has been a persistent over-supply of large bulk carriers, as compared to a more balanced supply-demand situation for smaller cargo liners). There is little significant evidence to show that differences in ocean freight rates for different degrees of processing can be attributed to shipowners' monopoly power.

A final aspect of monopoly power sometimes cited as a barrier to developing-country processing is the use of massive advertising by TNCs to create brand-name loyalty that is not necessarily justified on the basis of product quality differences. In the case of minerals, however, advertising is of relatively little importance, since quality standards for refined metals are normally set by the various materials testing organizations or by the metal exchanges themselves. Once a producer has its brand certified as good for delivery on the relevant metal exchange, little further assurance of basic quality is required. Some customers may prefer deliveries from industrial-country suppliers, either because transportation and delivery are thought to be more reliable or because the buyer prefers a specific brand for particular end-uses (e.g., the use of high-silver fire-refined copper in certain electrical applications), but it appears unlikely that mere advertising significantly affects mineral buyers' preferences.

C. Marketing Problems

While the use of advertising by TNCs may not, in itself, constitute a major barrier to further processing in developing countries, there are some objective difficulties for Third World producers in the marketing of refined and semi-fabricated mineral products. The actual selling of mineral products requires a reasonably extensive marketing organization; this can be supplied, at a price, by a state enterprise in the mineral-producing country, perhaps using foreign firms as agents in specific geographical markets -- the strategy followed, for example, by the state copper company, Codelco-Chile -- or by a foreign investor. In any event, marketing will involve certain costs, such as travel to establish and maintain sales and distribution outlets, the negotiation of shipping, insurance and documentation, and after-sales service to customers. The level of such costs can be such that, even though a developing country might have a competitive cost advantage in the actual production of minerals, it may not be able to achieve market entry in some or all of its potential markets because of marketing costs. The marketing problem is likely to be more severe in the case of metals like aluminum, where markets are highly concentrated and the market of last resort - the metal exchange - is not a significant factor. But all producers of refined metals usually see a need for some marketing effort.

D. the Effect of Technology

The lack of availability of industrial technology is often seen as a barrier to further industrialization in developing countries; hence, the concern of Third World nations with efforts to secure effective transfer of technology. In the case of mineral smelting and refining, however, the fundamental technology is widely available from a variety of sources, and almost no cases are known in which a developing country was unable to purchase the required technology, provided the country had adequate financing.

The knowledge required for efficient mineral processing, however, is not only a matter of obtaining the equipment needed to carry out particular operations. Such equipment, and instructions for its use, can be obtained, but many developing countries lack the "know--how" which comes from actual experience. This know-how is often internalized within TNCs, and hence is difficult to obtain unless a TNC is a partner in the processing venture. Lack of management experience, lack of knowledge of industrial operations, and lack of group know-how built up over time in an ongoing organization are likely to be more of a constraint on the ability of developing countries to process their raw materials than is the lack of merely theoretical knowledge.

The rapid technological change occurring in some mineral processing industries also has implications for developing countries' ability to establish processing facilities. On the one hand, certain developments, such as the use of direct-reduction/electric arc furnace technology for steelmaking, permit the construction of plants on a much smaller scale than was previously thought economical, opening the way for processing for the domestic market in many countries.

On the other hand, new developments such as continuous casting in copper have the effect of making it more difficult for producers located at considerable distances from major markets to compete effectively.

E. Economies of Scale

A final issue often cited as a barrier to increased processing activity in developing countries concerns economies of scale and minimum efficient plant sizes. To a large extent, this issue is simply one of basic economic analysis: can a plant of a given size in a particular location produce at a cost which is competitive? It does appear, however, that there are certain basic efficiencies in the standard mineral processing technologies, and that the choice of a plant size below these minima will likely lead to higher unit costs. In the case of many Third World countries, this factor is reinforced by requirements for large amounts of infrastructure development to support any processing industry at all, and by the real economies of scale in certain infrastructure facilities (e.g., hydroelectric power plants).

The apparent advantages in constructing an optimum-size plant are often, however, not realized in developing countries. Among the specific difficulties which often arise in such projects are the following:

(a) large plants often experience longer construction times, higher costs and greater difficulties in arranging utilities, ancillary facilities and infrastructure than small plants;

(b) large plants tend to experience more technical operating problems than small plants, maintenance may be more problematic, and technological rigidities are more likely to occur; and

(c) operating rates tend to be lower in large plants than in smaller units, thus increasing average fixed costs.

As a general rule, it would probably not be too far off to estimate that unit costs associated with large mineral processing plants in developing countries could be as much as 40 per cent higher than the equivalent cost if the same plant, with the same factor availability (i.e., energy, complementary inputs, labor, etc.) were located in an already industrialized country.

The "barriers" to further processing of minerals in developing countries cited in the preceding section are not so much impenetrable roadblocks as they are factors which tend to have a stronger impact on developing-country projects than on those in industrialized countries. Rather, however, than say that such barriers are either so important that one cannot think at all about further processing in Third World countries, or, on the other hand, that the barriers are of little or no importance, a more fruitful approach may be to consider in detail the economics of specific processing facilities. The following paragraphs discuss in general terms the major headings under which economic analysis of mineral processing projects can proceed.

A. Capital Costs

Capital costs are typically a high proportion of total costs in mineral processing (with the partial exception of aluminum smelting, where energy and labor costs dominate). For most processing industries, capital costs account for 40 per cent or more of total processing costs and dominate the non-raw-materials share of the cost structure. It is not entirely clear whether the dominance of capital costs in processing favors or hampers developing countries. On the one hand, capital goods will tend to be cheaper in industrialized countries, and the poor conditions under which many Third World plants are built tends to inflate capital charges for those locations. On the other hand, the initial cost of buying and preparing sites for new plants is rising more rapidly in most industrialized countries than in the Third World, and developing countries may also have access to relatively low-cost sources of finance, through the World Bank or other public international agencies or through bilateral assistance arrangements, that have the effect of reducing the impact on a project of high initial capital costs. It is clear, however, that capital costs are likely to be the most significant single element affecting the feasibility of a proposed processing venture, and that, therefore, every effort must be made to obtain estimates of those costs that are as accurate and realistic as possible and to assemble a package of financing that minimizes the annual capital charge to the project.

B. Transport Costs

A reduction in transport costs appears to be an obvious reason for locating processing facilities in the country or region where the mineral is extracted. Frequently, minerals are consumed in countries at great distances from the mine, and transport costs of shipping unprocessed ore, with a metal content of only a few per cent, would be prohibitive. Thus, the transport savings from undertaking at least initial concentration of low-metal-content ores near the mine are essential, and such concentration is virtually always carried out in the mineral-producing country in the case of ıickel and similar ores.

the other hand, long-distance transport is quite common for s with slightly higher metal content, such as bauxite er cent aluminum content), copper concentrates (25-30 per r iron ore (35-65 per cent). The advent of large-tonnage bulk shipping has made transport of these commodities relatively cheap and hence has discouraged further processing in the countries where the material is mined.

etheless, there is often some possibility of achieving transport savings through additional processing. For exam- the case of bauxite, if shipping costs are $12 per ton essing costs to convert five tons of bauxite to two tons of are $100, then the transport savings from conversion will ughly one-third of the total processing costs, a very con- e savings. In the case of copper, if conversion of four concentrate to one ton of blister copper through smelting 40 (i.e., 20 cents per pound) and shipping costs are $12 per ton, then the transport saving through smelting shipping would theoretically be $36, or 8.2 per cent of essing cost. One should note, however, that this latter may not be realized in practice, because of a differential ht rates which sets lower charges for bulk materials like , alumina and copper concentrate, as compared to metal There may also be a possibility that shipping services will be available only from a limited number of suppliers, especially in the case of cargo liner services for handling smelted or refined metal, and that shippers may use their monopoly or oligopoly position to capture some of the transport savings achieved through processing.

Even if transport cost savings through processing are small in absolute terms, they may still provide some competitive advantage in specific markets. For example, in supplying Japanese markets, the Pacific Island countries could combine processing with shorter transport routes to gain some advantage over, say, African copper suppliers. African suppliers, in turn, might have a similar advantage in shipping to European markets. This locational advantage would exist even though the overall ratio of transport costs to total production and processing costs is relatively low.

C. Environmental Costs

A factor of fairly recent origin which may favor the establishment of processing facilities in developing countries is the question of environmental protection and pollution control. Many mineral-processing activities, such as alumina refining or copper smelting, are potentially highly polluting. In most developed countries, where sensitivity to environmental issues has increased significantly in the past two decades, complex and costly regulations have been imposed on these processing operations. In the US, for example, it has been estimated that pollution control costs in copper smelting may have increased total costs by from 30 to 50 per cent.

The situation is potentially different in many developing countries, Only a few Third World countries have elaborate environmental legislation. In addition, because developing countries, by definition, do not have as much industry as the developed countries, the former may have less existing pollution-causing activity to which the effects of mineral processing would be added, and thus a greater pollution-absorbing capacity, especially if processing facilities can be located in relatively unpopulated areas.

Even assuming, however, that some developing countries may wish to utilize this cost advantage, there are certain potential obstacles. First, the industrialized countries, responding to pressure from domestic industries, may impose environmental tariffs on goods from countries where environmental restrictions are not so severe. Such a policy would be consistent with the fairly common "sweated labor" tariffs that are imposed by industrial countries on goods from low-wage countries. US copper producers, for example, have been advocating such a tariff for some time.

Second, many international financial institutions are themselves insisting on the application of strict environmental controls. The World Bank and the regional development banks, for example, have issued a joint statement requiring environmental considerations to be taken into account in any project in which they are involved as lenders. Such a policy may have the effect of forcing Third World countries to adopt environmental standards based on those of the industrialized countries, and so remove the possibility of the former countries' gaining a competitive advantage in this respect.

D. Energy Costs

Where a developing country has access to relatively low-cost sources of energy, that country may have a significant competitive advantage in certain energy-intensive mineral processing activities. More than half of aluminum smelting costs, and perhaps one-quarter of copper smelting and refining costs, consist of energy. Thus, the availability of fixed sources of low-cost energy (hydro-electric potential, small natural gas fields, or even geothermal energy) can make metal processing competitive where energy is important in the total cost structure. Table 9, for example, shows the effect of changes in energy prices on the cost of aluminum ingot.

It can be seen from Table 9 that the availability of low-cost power represents a very significant cost advantage and, moreover, that the absence of a source of low-cost energy, when combined with the other cost disadvantages typically faced by developing countries, may well make it impossible to establish a competitive pro-

Table 9

Energy Costs in Aluminium Smelting

Power Source	Cost per kwh (U.S. cents)	Cost per pound Al (U.S. cents)[a]
1. Hydroelectric (established - Iceland, Ghana)	.6 - 1.4	3.8 - 8.9
2. Hydroelectric (new)[b]	.75 - 3.0	4.8 - 19.0
3. Coal (Australia)	2.1	13.3
4. Oil[c] (Japan)	4.5	28.6
5. Oil[c] (New)	6.0 - 8.0	38.1 - 50.8

Source: Trade journal reports.

Notes:

(a) based on 14,000 kwh per metric tonne Al.

(b) based on capital cost of US$500-2000 per kilowatt, 12.5 percent annual capital charge, 75 percent availability.

(c) based on fuel oil @ US$35/bbl.

cessing plant.

There is a substantial variation in capital costs for power plants, particularly in developing countries. Typical ranges of costs per installed kilowatt of electric-power capacity might be (in 1981 dollars) as follows:

Type of Plant	Cost per KW (US$)
hydro	500 - 2000
geothermal	600 - 1500
oil/diesel	500 - 1200
natural gas	800 - 1500
coal	1000 - 1500
nuclear	1500 - 2500 (65)

These costs could be increased by up to 40 per cent for plants in particularly unfavorable locations, including many developing--country sites, and by up to $500/KW for coal-fired plants if all available pollution-control equipment is installed.

The effect of power plant capital costs on the ultimate cost of power to mineral-processing plants is shown in Figure 1. As the figure indicates, at a moderate level of profitability, corresponding to the 12 per cent capital charge in the figure, it would be necessary for a hydroelectric plant to be built at a cost of well under $2000 per installed kilowatt if the power is to be available at a competitive cost.

E. Complementary Inputs

In addition to energy, a variety of other complementary inputs are usually required in mineral processing. Alumina refining, for example, requires caustic soda and lime, while aluminum smelting requires cryolite, aluminum fluoride and calcium fluoride. Copper smelting requires silica, while refining requires sulphuric acid, itself a byproduct of smelting. Depending on the particular process being used, a specific form of energy (e.g., natural gas) may be desirable. In some cases, the location of complementary inputs is the deciding factor in locating processing facilities; in traditional steel-making, for example, coking coal availability has often been more important than iron ore or energy costs in determining where steelworks were located.

Most developing countries do not have the various complementary inputs for mineral processing readily available. This means that they will need to import the required materials, and presumably will have to pay a higher price for such imports than the price which facilities in already industrialized countries will have to pay for locally produced materials.

F. Labor Costs

In view of the relatively low share of labor costs in the to-

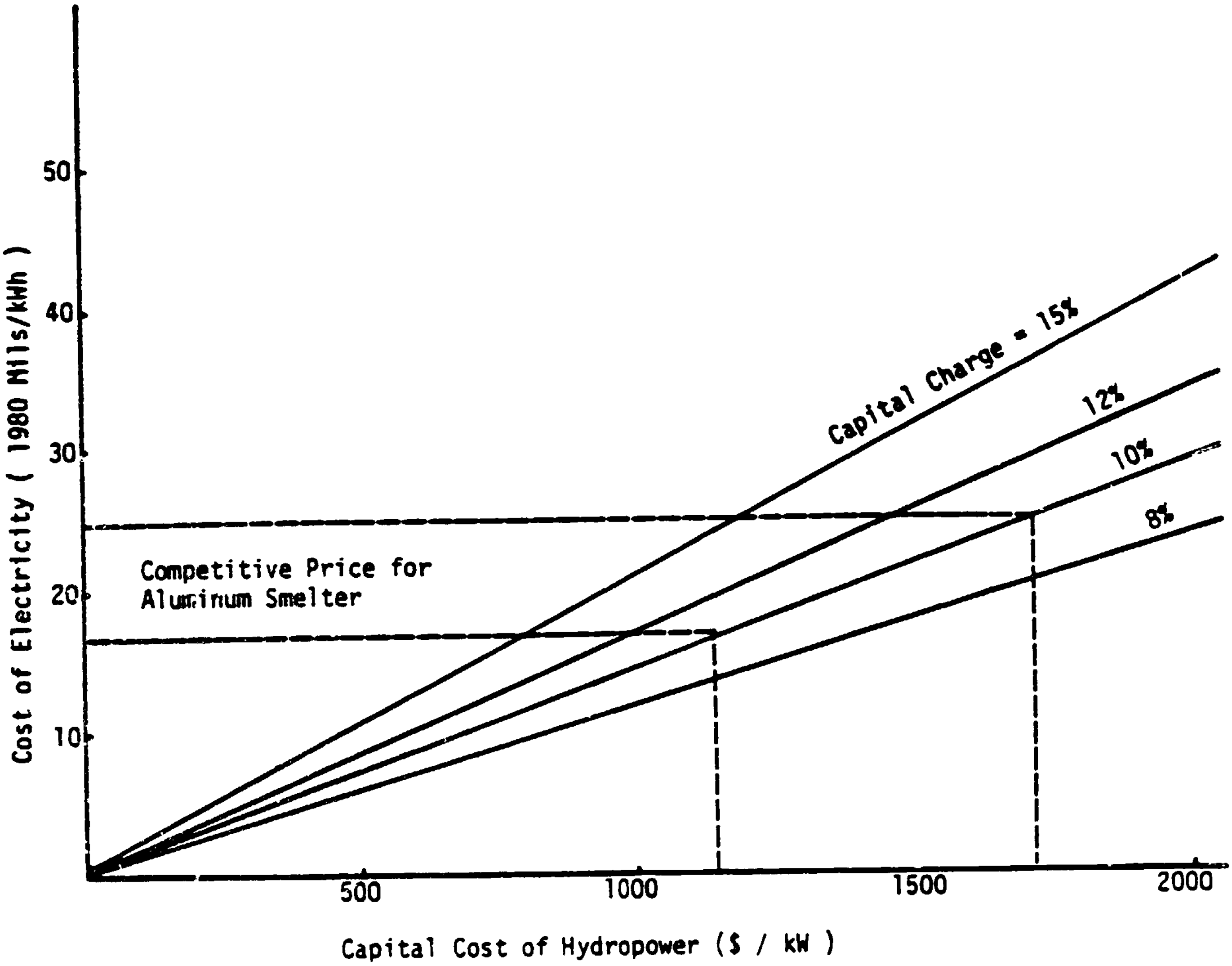

Figure 1. Cost of Electricity from Hydropower ($ / kWh)

Assumptions: Capital charge calculated on basis of 30-year investment recovery

Annual plant utilization factor-- 90%

Taxes not included

Operating and maintenance = 2% of capital cost / year tal cost structure of mineral processing (see Table 10) it is unlikely that developing countries in general possess a major competitive advantage as a result of low labor costs. This is particularly true where domestic wage rates, while lower than those in the industrialized countries, are still higher than in such developing-country manufacturing centers as South Korea, Taiwan or Singapore, or where a significant number of skilled, managerial and technical employees would need to be brought in from other countries because the requisite skills are not available domestically. In addition, processing facilities in developing countries tend to have higher levels of staffing per ton of capacity than similar facilities in the industrialized countries. This fsctor alone cancels out much of the potential advantage that would result from low labor costs.

G. Infrastructure

It is becoming increasingly common for develoing countries to insist that the cost of infrastructure required by mining projects to be paid for directly by the mining enterprise. This can be accomplished either by having the mining company directly supply the capital for infrastructure development or by the state's constructing the infrastructure facilities subject to a prior agreement of the mining company under which the latter undertakes to make annual payments sufficient to meet operating costs and to pay off the ca-

Table 10

Labor Share in Processing Costs

	Approximate Share (%) of Total Cost Due to:			
		Value Added		
	Raw Material	Labor	Other[a]	Capital[b]
Aluminium (input)				
Alumina (bauxite)	30	10	12	48
Aluminium ingot				
(alumina)	31	16	21	32
(bauxite)[c]	9	19	25	47
Copper (input)				
Blister (concentrate)	68	6	7	19
Refined				
(blister)	89	3	4	4
(concentrate)[c]	60	8	10	21
Nickel				
Laterite	65	2	12	21
Sulphide	60	4	12	24

Source: calculated from UNIDO, Mineral Processing in Developing Countries, pp. 124-39.

Notes: (a) includes complementary inputs and energy.

(b) 12.5 percent annual capital change (equal to 10.9 percent real rate of return over 20 years).

(c) capital, labor, and other cost shares at previous stage (alumina and blister copper) are included under those headings rather than as part of raw material cost at metal ingot stage.

pital cost, including interest, over an agreed period of time. Naturally, from the point of view of the mining company, such expenses are a deterrent to investment. In the case of mineral processing projects, as opposed to mining, a company will likely prefer to establish processing facilities where major items of infrastructure, such as transportation systems, ports and power supply, are already in place, or can be made suitable for the project at minimal cost, as opposed to supplying a full range of infrastructure at a "greenfields" site.

To the extent that developing-country governments have access to low-cost sources of finance through aid arrangements or international-agency loans, these countries may be in a position to provide certain items of infrastructure, while at the same time obtaining facilities which can be used for purposes other than those of the mining and mineral-processing project. In general, however, the relative lack of infrastructure in such countries can be expected to act as a disincentive to investment in processing in Third World countries.

H. Externalities

A variety of economic side effects or externalities are important in the analysis of processing projects. For example, one reason why a copper smelter for some developing-country mines may be considered uneconomic is the lack of a local market for by-product sulfuric acid. Similarly, a number of US alumina refineries were built in Louisiana because of the existence of chemical industries which could supply necessary inputs and could purchase by-products of the refining process, even though other factors, such as shipping costs, favored locating the refineries near the source of bauxite in Jamaica.

In a country with a variety of natural resources and a relatively large domestic market, it may be possible to think of establishing "territorial production complexes" in which a number of facilities are located close together so they can supply each other with necessary inputs. It is not clear, however, whether such massive industrial developments could be justified, even on the basis of supplying regional markets, for very small developing countries.

The argument concerning externalities and economic linkages can, however, be turned around and used to justify establishment of processing facilities in mineral-exporting countries to stimulate the growth of related industries. The linkage from mining of ore through smelting and refining to fabrication of metal products and finally to capital-goods production is one of the basic patterns of successful industrialization. A recent study shows that the basic metals are among the highest-ranking industrial sectors in terms of ability to generate economic linkages and promote growth. Once again, however, the linkage argument has somewhat less force in very small economies, where development of a well-rounded industrial economy may in any event be impossible.

I. New vs. Expansion Projects

A further factor in favor of locating additional mineral processing in the industrialized countries, as opposed to developing mineral-producing countries, is that in the former, significant additional capacity can often be added through expansion of existing plants, rather than construction of entirely new facilities. In virtually all cases, expansion capacity can be supplied at a lower capital cost than the same amount of new "greenfields" capacity. Table 11 shows capital costs per annual ton of capacity for alumina refineries and aluminum smelters currently under construction or in the planning stsges. As the table shows, expansion capacity in alumina can be brought onstream at about 20 per cent less than the cost of new capacity, while for smelters, expansion projects have a 35 per cent cost advantage over new facilities.

Exceptions to the general cost trends shown in Table 11 will generally result only when pollution-control requirements in the industrialized countries are so stringent that they increase expansion costs by significant levels.

J. Summary of Economic Factors

The various economic factors discussed in the preceding paragraphs do not always interact so as to produce an entirely predic-

Table 11

Capital Cost of New Alumina Refineries and Aluminium Smelters

	Refineries		Smelters	
	number	capital cost ($ per ton)	number	capital cost ($ per ton)
All projects	11	647	28	4547
New plants	6	676	16	4892
Expansions	5	541	12	3152
Developing Country - new projects	4	580	9	6873
Developing Country - expansions	2	540	2	2750
Industrial Country - new projects	2	959	7	3068
Industrial Country - expansions	3	543	10	3220

Source: "Mining Investment 1981," Engineering and Mining Journal, January 1981, pp. 59-81.

table result. Some developing-country mineral processing projects will show a high rate of return or will have a significant competitive advantage in a particular product market, while other proposed projects will clearly be uneconomical and will result in high-cost production and a possible loss of the economic rents earned at the mining stage. The history of a number of ill-fated processing ventures in developing countries suggests that it is essential for any Third World government contemplating a procesing project to carry out a realistic and comprehensive feasibility study which quantifies the various factors discussed above, considers realistic technological options, and which is carried out with a clear understanding of the market situation for the specific commodity involved.

VI. GOVERNMENT STRATEGIES FOR PROCESSING

In what has become the conventional wisdom of the New International Economic Order, the further processing of natural resources in producing countries is an essential element in national development strategies. Much of this conventional wisdom, however, appears to be based on the idea that developing countries can simply assume a place within the existing world market economy. Instead of being suppliers of crude materials, they will become suppliers of semi-processed goods, with consequent improvements, it is argued, in their trade balances and industrial capabilities.

But, nonetheless, they will still be integrated into a world-wide economic system which has not been notable in the past for its enrichment of the periphery.

This paper has presented evidence that, in many cases, it will be difficult to justify the establishment of mineral-processing facilities in the developing countries on the basis of conventional economic analysis. In these terms, developing countries may often be better off, at least in the short term, by continuing to function purely as raw materials suppliers, and extracting, to the best of their ability, a major share of the economic rent associated with mining.

It should be clear, however, that such an approach cannot, in the longer term, provide a basis for autonomous industrialization and development. Therefore, it would appear logical for those developing countries which wish to pursue workable national development strategies to examine alternative approaches to the mineral processing issue. Such approaches could involve, for example, co-operative efforts among developing countries, using raw materials from one, energy from another, and capital from a third to produce products required in all three countries. Or they could involve regional planning efforts, so as to permit comstruction of economical-scale processing plants to serve regional markets where national markets are not large enough. Or they could involve strategies of reducing mineral production and waiting for further development which would permit the establishment of processing facilities on a national basis.

None of these strategies are easy. The pressures for rapid mineral production to generate revenue are severe in many countries, and the difficulties in making cooperative or regional arrangements have already been well demonstrated in practice, in the Andean Pact, the association of Southeast Asian Nations (ASEAN), and elsewhere. But such new approaches do deserve further analysis, as they offer what may be the only means by which many developing countries may effectively build on their mineral resources and avoid the fate of being forever nothing more than crude materials suppliers, dependent on the decisions made in Western markets and boardrooms.