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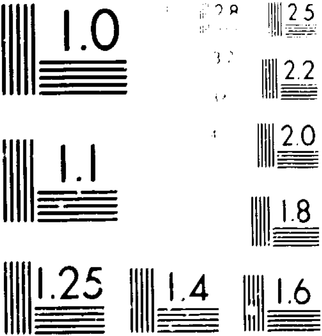
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OPTIONS AND OPPORTUNITIES OF METALLURGICAL PROGRESS IN AFRICA*

by

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Prepared on behalf of the Metallurgical Industries Section,
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for

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0. Executive summary

0.1. General indicators of the African economy

In 1977, Africa without South Africa had 9.7 % of world population; it is expected to have about 12 % in the year 2000.

The African economy is characterized by slow growth from a low base; Africa's share of world manufacturing value added, 0.7 % at present, is not expected to exceed 1.5 to 2.0 % in the year 2000.

Africa North of the Sahara is an entity which, thanks largely to long association with the Mediterranean region and to its rich mineral deposits /oil, gas, phosphates/ is forecast to grow more rapidly from a higher base than Africa South of the Sahara.

0.2. The resource base of metallurgy in Africa

Africa as a whole is rich in ores, fuels and other mineral resources required for metallurgy. The distribution of these riches among the countries of Africa, however, is haphazard: seldom are all the inputs required for a given metallurgy present in one and the same country. The major exception is South Africa. Other countries with substantial metallurgical potential include Nigeria and Egypt and possibly Algeria and Libya for ferrous metallurgy; Zambia, Zaire, Ghana, Guinea and the United Republic of Cameroon for non-ferrous metallurgy. Angola and Mozambique are also rich in potential.

Africa is exceptionally rich in certain steel-alloying elements such as chrome and cobalt.

0.3. Current production and balance between processing stages

Metallurgy in Africa is split up into large export-oriented, enclave-type operations in a few countries, installed by and often operated with the assistance of TNCs, and into small, more or less backward and more or less inadequate operations intended to satisfy domestic markets, present in all but a very few countries. Only in the largest and most populous countries /Egypt, Algeria/ do the two groups merge to some extent.

In view of the logistics of the various stages of processing the ores, relatively high percentages of copper, lead and zinc and tin are smelted and refined in the African mining countries, whereas iron ore, bauxite and manganese are largely exported without further processing.

In each of these metals, Africa as a whole is a net importer, which implies that there is ample scope for the development of metallurgical facilities for satisfying African demand that is uncovered for the time being by offer from within the region.

0.4-0.5. Technological progress in metallurgy and its implications

The technologies required for the specific needs of African development differ according as they are meant for the satisfaction of domestic needs /in which case, given the smallness of the domestic market in most African countries, the emphasis is on economic viability despite a smallish output/ or for export-oriented production, in which case there is as a rule no economic objection to a large plant size.

For the first type of demand, electric steelmaking from scrap or direct reduction of iron and rolling in a mini-mill seems to be the answer in the ferrous field. Cast-rolling or rolling mills fed with imported billet may be the answer in the non-ferrous field. Of course, the subject is a complex one: the above remarks are just the most general pointers.

As regards export-oriented production, the economic forces that favour the siting of new facilities in the various world regions are about evenly balanced between the developing and the developed world. Within the developing world, however, Latin America and Southeast Asia seem to be the preferred regions, with Africa lagging somewhat behind.

0.6. World economic climate for metals in the 1980s

What with the growth rates of the developed world about halved since 1973, the prospects for metals are not bright. There are exceptions such as tin and, to some extent, aluminium. The most rapidly industrialising countries of Africa /the North African ones and perhaps Nigeria/ may embark upon world-market competition in metals nevertheless, but the prospects of their earning adequate returns on such investment are not favourable. Nor are the earning prospects of the established metals majors /Zambia, Zaire/ any better.

0.7. Major recommendations for metallurgical development in Africa

The most important task of all African countries in metallurgy is progress towards the organization and systemization of a hitherto inorganic and immature industry. This requires the preparation of comprehensive development plans including realistic market assessments, the rehabilitation of existing but run-down facilities, progress in well-considered steps up the ladder of metallurgical development as described in Sections 3.4 and 3.7, and serious efforts to expand markets by intra-African /regional and subregional/ market organization.

0.8. UNIDO's involvement in African metallurgical development

UNIDO's metallurgical activities show a strong African bias, with about half of the finance assigned to metallurgical projects currently in the pipeline being earmarked for Africa.

The main thrust of UNIDO's activity is in foundry development. Given adequate financial backing, this should be expanded in the direction, on the one hand, of mini rolling mills, ferro-alloy making, welding electrode manufacture, charcoal-based ferrous metallurgy and, on the other, into non-ferrous metals at large.

It is necessary to enhance the systematic and interdisciplinary aspects of UN activity and the coordination between the different organisms of the UN family.

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1. General economic indicators for Africa

Africa including the surrounding islands, but excluding South Africa is comprised of 52 sovereign states. Total population of those in 1977 was 400 million or 9.7 % of world population. 1/

By the year 2000, Africa /not including South Africa/ is expected to have a population of around 760 million or around 12 % of world population. According to the Lima target of the developing world's industrialisation /UNIDO, loc. cit./, Africa is expected to produce in 2000 a share of 1.5 % of world manufacturing value added. Corresponding shares are to be 13.0 % for Latin America, 9.5 % for South and East Asia and 1.8 % for West Asia.

The only African state with a population exceeding 50 millions is Nigeria /66.6 millions according to the UN Statistical Yearbook; as much as 80 million according to some estimates/. Zaire, Ethiopia and Egypt have populations between 25 and 50 millions; six further countries /Uganda, Kenya, Tanzania, Algeria, Morocco and Sudan/ have populations between 5 and 10 millions, and 16 states between 1 and 5 millions. The rest, including all the islands except Madagascar, have less than one million.

Countries with population densities exceeding one hundred per sq. km are Mauritius /444/, the Seychelles /222/, Rwanda /166/ and Burundi /142/. Countries with population densities between 50 and 100 per sq. km are the Cape Verde Islands /76/, Nigeria /72/, Uganda /52/ and the Sao Tomé group of islands /85/. Countries with a population density less than 10 per sq. km are Algeria, Botswana, the Central African Republic, Chad, Djibouti, Gabon. Mali, Mauritania, Niger, Réunion, Somalia, Sudan, Western Sahara and Zambia.

UNIDO's document "World Industry since 1960: Progress and Prospects" /:ID/CONF.4/2, New York, 1979:/ classes+

as large countries:

Egypt,	South Africa,
Ethiopia,	Zaire,

as small countries with modest resources:

Benin,	Mauritius,
Botswana,	Niger,
Burundi,	Rwanda,
Central African R.,	Sierra Leone,
Chad,	Somalia,
Congo,	Sudan,
Gambia,	Togo,
Guinea,	Tunisia,
Kenya,	Uganda,
Madagascar,	U.R. of Cameroon,
Malawi,	U.R. of Tanzania,
Mali,	Upper Volta and
	Zimbabwe,

1/ The data are from the UN Statistical Yearbook, 1978.

+ This list excludes Djibouti, Equatorial Guinea, Guinea-Bissau, Lesotho, Libya, Western Sahara and all the islands except Madagascar.

as small countries with ample resources and a primary orientation:

Angola,	Liberia,
Gabon,	Mauritania,
Ghana,	Nigeria ** and
	Zambia,

as small countries with ample resources and an industrial orientation:

Algeria,	Mozambique,
Ivory Coast,	Senegal,
Morocco,	Swaziland.

The World Bank+ gives the following GDP per capita ranking for the African countries, in US dollars per year:

middle income countries:

Algeria	1260	Zimbabwe	480
Tunisia	950	Zambia	480
Ivory Coast	840	Liberia	460
Morocco	670	Cameroon, U.R.	460
Nigeria	560	Ghana	390
Congo	540	Egypt	390

low income countries:

Senegal	340	Niger	220
Kenya	330	Zaire	210
Togo	320	Sierra Leone	210
Sudan	320	Guinea	210
Angola	300	Rwanda	180
Lesotho	280	Malawi	180
Uganda	280	Upper Volta	160
Mauritania	270	Mozambique	140
Madagascar	250	Chad	140
Centr. Afr. R.	250	Burundi	140
Tanzania	230	Somalia	130
Benin	230	Mali	120
Ethiopia	120		

Missing from this list are Botswana, Gabon, Swaziland, Djibouti, Equatorial Guinea, Guinea-Bissau, Libya and Western Sahara, also all the islands except Madagascar.

In another classification of developing countries /UNCTAD's Handbook of International Trade and Development Statistics, 1979/, there are in the world 18 developing petroleum exporters, of which

** Nigeria, a large country, was placed here in order to have all the oil producers in one group.

+ IBRD: International Development Report, 1980 five are African /Algeria, Angola, Gabon, Libya and Nigeria/; there are six fast-growing exporters of manufactures, none of which is African; there are 30 least-developed countries, 19 of which are African, and 45 most severely affected countries, 28 of which are African.+

2. Resource base of metallurgy in Africa§

2.1. Resource base of ferrous metallurgy

2.1.1. Iron ore

Table 1 reveals that African reserves/resources of the sort of high-grade iron ore used in iron-making these days are limited to 3.3/4.1 % of world reserves/resources. A large share of these /1.2/1.6 %/ is in the Republic of South Africa.

According to "Mineral Raw Materials in Africa: Iron Ore" /: E/CN.14/MIN.80/3.1, p. 50 :/, the Republic of South Africa leads in iron ore reserves, representing 3[illegible].3 % of the total. It is followed by the Libyan A.J. at 12.5 %, Liberia at 10.2 %, Algeria at 9.2 %, Guinea at 6.9 %, Angola at 6.0 %, Ghana at 3.[illegible] %, Sierra Leone at 2.7 %, Gabon at 2.6 % and Ivory Coast at 2.2 %.

All over intertropical Africa, there are vast expanses of iron-rich laterites, some of which rank as fairly high-grade iron ores. Some of these lend themselves to the making of pig iron or of highly metallized concentrates, but most of them contain alloying elements /Cr, Mn, Ni, Co/ in embarrassing quantities - too high to permit them to be processed into simple mild steel and too low to be extracted on their own merit.

These lateritic iron ores and other iron ores not sufficiently high-grade or abundant for export purposes may nevertheless be expected to serve as viable raw materials of ironmaking for local demand in several countries of Africa.

2.1.2. Coal

Table 2 shows African reserves of bituminous coal. At 3.6 % /of which 1.1 % in South Africa/, they are not significantly more abundant than Africa's iron ore reserves. The reserve distribution exhibits a strong geographical bias in favour of the Southern African countries which possess the Palaeozoic coal-bearing Karroo formation /South Africa, Swaziland, Zimbabwe, Botswana, Zambia,

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+ The most seriously affected African countries are the following /those marked with an asterisk are also least-developed/: *Benin, *Burundi, *Central African Republic, *Chad, Egypt, *Ethiopia, *Gambia, Ghana, *Guinea, Guinea-Bissau, Ivory Coast, Kenya, *Lesotho, Madagascar, *Mali, Mauritania, Mozambique, *Niger, *Rwanda, Senegal, Sierra Leone, *Somalia, *Sudan, *Uganda, U.R. of Cameroon, *U.R. of Tanzania, *Upper Volta and *Cape Verde Is. Botswana and Malawi are least developed but not most seriously affected.

§ South Africa is excluded from all the considerations to follow unless expressly stated otherwise.

Table 1

Iron ore reserves and resources of the world and of Africa
million tons Fe content; percentage

	Reserves+	Others+	Resources+
World, 10^6 t Fe	90 500	105 500	195 500
of which:			
- Africa, %	3.3	4.1	3.7
- Africa without S. Africa, %	2.1	2.5	2.3
- Liberia	0.4	0.3	0.3
- Others	1.7	2.2	2.0

Source: US Bureau of Mines, Mineral Facts and Problems, Bulletin No. 667, 1976

Country	Reserve, Fe content million t	% of world reserve
Algeria	1848	1.6
Libyan A.J.	2514	2.2
Guinea	1394	1.2
Liberia	2055	1.8
Angola	1218	1.0
Total developing Africa	13247	11.3
Total Africa	20175	17.25

Source: UN E/CN.14/MIN.80/3.1

Table 2

Bituminous coal reserves /known, recoverable/ of the world and of Africa
billion tons; percentage

World, 10^9 t	430.1
of which:	
- Africa, %	3.6
- Africa without S. Africa, %	1.1
- Botswana, million tons	506
- Nigeria, " "	180
- Zimbabwe, " "	1390
- Swaziland, " "	1820
- Zaire, " "	720
- Others, " "	324

Source: UN Statistical Yearbook, 197[illegible]

+ Here and in the following, "resources" equal the sum of "reserves" and "others".

Mozambique etc. The exceptions to this rule are minor /Algeria, Egypt, Morocco, Nigeria, Zaire/. Most of the coking coal reserve is in the Southern African deposits.

2.1.3. Natural gas

Natural gas enters the picture as one of the fuels and reductants of iron-making by direct reduction. Table 3 shows African natural gas reserves to be significant, equalling 9 % or so of world reserves. The geographical bias of gas reserve distribution is opposed to that of the coal reserves: as far as it is currently known, none of the Southern African countries possessing significant coal reserves has any significant quantity of gas. Nigeria, situated in the middle and endowed with significant reserves of both coal and gas, seems to be best off.

Table 3

Natural gas reserves /known, recoverable/ of the world and of Africa
billion cubic metres; percentage

World	63 108	or 100.0 %
of which:		
- Africa overall	5 845	9.3
- Algeria	3 468	5.5
- Angola	46	
- Egypt	61	
- Gabon	50	
- Libyan A.J.	807	1.3
- Morocco	2	
- Nigeria	1 462	2.3
- Rwanda	23	
- Zaire	16	

NB. Percentages less than 1.0 not shown.

Source: UN Statistical Yearbook, 1978, updated.

Further important gas reserves have been proved since in Congo /68 billion m^3/, Tunisia /170 billion/ and Nigeria /at least doubling the above figure/. In a general way, African /and world/ gas reserves are on an increase, reflecting the increasing interest in, and viability of, exploiting gas deposits as sources of fuel in their own right.

2.1.4. Steel alloying elements

Chrome ore. Africa is fairly widely known to be a major source of chrome ore to the world /total output in 1978 almost 38 % of world output, of which 13.4 % from outside South Africa/. It is less widely known that Africa possesses more than 90 % of the world reserves and resources of both the high-chrome and the high-iron type of chrome ore, Zimbabwe /with more than 95 %/ being richest in the first and South Africa /with more than 90 %/ in the second /Table 4/.

Cobalt. A major power in cobalt also, Africa possesses 42.5/ /26.0 % of world reserves/resources. Zaire and Zambia have almost

Table 4

Chrome ore reserves and resources of the world and of Africa
million tons; percentage

	High-chrome ores			High-iron ores		
	Reser.	Others	Resou.	Reser.	Others	Resou.
World, 10^6 t of which:	590	590	1180	1090	2090	3180
- Africa overall, %	95.5	95.3	95.4	96.4	98.1	97.1
- without S. Africa	86.9	86.7	86.8	4.7	2.5	3.2
- Madagascar	0.7	0.5	0.6	0.1	0.1	0.1
- Zimbabwe	86.2	86.2	86.2	4.6	2.4	3.1

Chrome production capacities of the world and of Africa
thousand tons; percentage

	1973	1978
World, 10^3 t of which:	2420	3170
- Africa overall, %	36.5	37.8
- Africa without South Africa, %	12.2	13,4
- Madagascar	2.2	2.9
- Zimbabwe	9.4	10.0
- Sudan	0.6	0.6

Source: as for Table 1

Table 5

Cobalt reserves and resources of the world and of Africa
million tons; percentage

	Reserves	Others	Resources
World, 10^6 t	2.45	1.83	4.28
of which:			
- Africa overall, %	42.5	min. 3.9	min. 26.0
- Morocco	0.5	n.a.	0.3
- Zaire	27.8	3.9	17.6
- Zambia	14.2	n.a.	8.1

Cobalt production capacities of the world and of Africa
thousand tons; percentage

	1973	1980
World, 10^3 t	27.7	37.6
of which:		
- Africa overall, %	72.3	66.3
- Morocco	5.1	4.8
- Zaire	55.7	50.7
- Zambia	11.5	10.9

Source: as for Table 7

Table 6

Manganese reserves and resources of the world and of Africa
million tons; percentage

	Reserves	Others	Resources
World, 10^6 t	1800	1450	3250
of which:			
- Africa overall, %	50.2	50.2	50.2
- Africa without S. Africa	5.2	1.4	3.5
- Gabon	5.0	...	2.8

Further countries with minor reserves/resouces include Ghana, Ivory Coast, Morocco, Upper Volta and Zaire.

Manganese production capacities of the world and of Africa
thousand tons; percentage

	1973	1980
World, 10^3 t	9740	13690
of which:		
- Africa overall, %	31.4	25.9
- Africa without S. Africa	13.7	11.3
- Gabon	9.8	9.4
- Ghana	1.3	...
- Zaire	1.7	1.3

Source: as for Table 1

the total reserves; Morocco has a minor quantity. Zaire is about twice as rich as Zambia /Table 5/.

Manganese. Africa has 50 % of both world total reserves and resources, most of it /more than 45 % of the world total/ in South Africa. In developing Africa, Gabon is the only country with reserves/resources of world importance /Table 6/.

Molybdenum. Africa is poor in this steel alloying element, possessing as it does just 0.16 % of the world resources and an insignificant part of the world reserves.

Nickel. Africa possesses 4.8/7.5 % of world total reserves/ /resources, with Zimbabwe and Burundi richest in both /Table 7/.

Vanadium. Africa's vanadium potential /18.7 % of world reserves, 33.9 % of world resources/ is largely concentrated in South Africa /all the reserves and 32.3 % of world resources/.

Titanium. A major power in titanium, Africa possesses 5.4/ /32.7 % of world total reserves/resources; 4.4/16.6 % of those, however, are in South Africa /Table 8/.

Tungsten. Africa is rather poor in ores of this metal /0.6 % of world reserves, 0.5 % of world resources, practically all of them outside South Africa.

2.1.5. Fluxes

Table 9 presents the fluorspar reserves and resources of the world and of Africa, together with the capacities of producing fluorine either out of fluorspar or out of phosphate rock. In fluorspar reserves/resources, Africa /without South Africa/ is important at 6.8/8.1 %. Its low share in production capacity /less than 3 %/ implies that production could be expanded fairly easily.

The most important fluxes used in metallurgy include silica, limestone and dolomite, each of which has to satisfy fairly stringent purity requirements. Limestone and dolomite are not usually a problem in countries which possess extensive calcareous sedimentary series /as most countries of temperate climate do/, but in some countries located on the ancient "shields" of the Earth's crust /as many African countries are/, there may not be enough satisfactory grade limestone or dolomite at all, not even for making mortar, let alone cement or metallurgical flux. Today, African countries lacking limestone/dolomite mostly import it from overseas. There is an important opportunity for regional import substitution here because several countries of North Africa and of the Gulf of Guinea do possess limestone and dolomite deposits of adequate grade. The joint venture of Nigeria and Benin, which intends to produce cement out of the Onigbole limestone deposits in Benin, is a case in point.

2.2. Implications of the ferrous resource base situation

Our concern being with metallurgical development here, we shall not consider the implications of the reserve/resource situation for the exportation of metallurgical raw materials and their immediate derivatives /e.g. pellets/.

Table 7

Nickel ore reserves and resources of the world and of Africa
thousand tons contained Ni; percentage

	Reserves	Others	Resources
World, 10^3 t Ni	82 484	135 800	218 284
of which:			
- Africa, %	7.3	12.0	10.2
- Africa without S. Africa, %	4.9	9.2	7.5
- Burundi	1.8	2.2	2.1
- Zimbabwe	1.9	3.3	2.8
- Ivory Coast	-	2.2	1.4
- Madagascar	0.4	1.1	0.8
- Botswana	0.7	0.1	0.3
- Others	0.0	0.3	0.2

Source: UN E/CN.14/MIN.80/3.7

Nickel mining capacities of the world and of Africa
tons contained Ni; percentage

	1973	1977
World, t Ni	681 400	800 600
of which:		
- Africa, %	4.7	5.9
- Africa without S. Africa, %	1.8	3.2
- Botswana	0.1	1.5
- Morocco	0.0	0.0
- Zimbabwe	1.7	1.6

Source: UN Statistical Yearbook, 1978.

Table 8

Titanium reserves and resources of the world and of Africa
thousand tons contained Ti; percentage

		Reserves	Others	Resources
World, 10^3 t Ti		236 850	465 600	702 450
of which:				
- Africa, %		5.4	32.7	23.5
- Africa without S. Africa, %		1.1	9.8	6.9
- Mozambique	ilmenite	0.0	2.8	1.8
- Egypt	ilmenite	0.4	1.8	1.3
- Senegal	ilmenite	0.0	0.4	0.3
- Tanzania	ilmenite	0.0	0.8	0.5
- Upper Volta	ilmenite	0.0	0.8	0.5
- Sierra Leone	rutile	0.7	3.1	2.3

Source: UN E/CN.14/MIN.80/3.[illegible]

Table 9

Fluorspar reserves and resources of the world and of Africa
thousand tons; percentage

	Reserves	Others	Resources
World, thousand tons	34 250	33 890	68 140
of which:			
- Africa, %	23.7	11.6	17.7
- Africa without S, Africa, %	9.4	6.8	8.1
- Namibia	2.6	2.7	2.7
- Kenya	3.4	1.7	2.6
- Morocco	1.7	1.8	1.7
- Tunisia	1.2	0.3	0.8
- Zimbabwe	0.4	0.3	0.3

Fluorine production capacities from fluorspar and phosphate rock
thousand tons; percentage

	1973	1980
World, thousand tons	2340	2590
of which:		
- Africa, %	7.3	9.8
- Africa without S. Africa, %	1.6	2.5
- Tunisia	1.0	1.4
- Others	0.6	1.1

Source: as for Table 1

There does not seem to exist in any country of Africa a favourable combination of cheap fuel-plus-reductant and iron ore reserves and of a favourable situation as related to the world trade routes that would recommend going in for large-scale export-orientated iron/steel production purely on the merits of the domestic raw materials base. /Possible exceptions include Mozambique and, if hydrocarbons are admitted as a reductant, the Libyan A.J., Algeria and Angola./ This does not mean that, given the right world market situation, some of the metallurgically more developed African countries /such as Egypt/ could not emulate Japan or South Korea in developing export-oriented steel-making largely based on imported raw materials.

In the North African region, and elsewhere where natural gas is abundant, the direct-reduction plus electric-arc-furnace /DR/EF/ route of steelmaking is to be envisaged, primarily for the domestic market, but possibly also to supply subregional groupings. The economics of adopting this route, however, will depend to a considerable extent on the international market price of and demand for natural gas and also on its potential physical outlets /by pipeline or in the liquefied state/: pricing development may well make natural gas too expensive for metallurgical applications.

In the Southern African region, where coal is fairly abundant, the BF/BOF /blast-furnace-cum-basic-oxygen-furnace/ steelmaking route has much to recommend it for those countries which can develop a large enough domestic market or find extensive enough export outlets for the fairly large quantities of iron/steel produced by such units. The use of domestic iron ores, if not too inferior, is to be recommended, and the search for such should be intensified.

In the countries where none of the above applies, charcoal-based iron and steel making out of local iron ores may prove viable.

One fairly obvious implication of the reserve picture is that there is a substantial potential for the preparation of steel-alloying additives such as ferrochrome, ferrocobalt, ferromanganese and ferrovanadium in those countries that are rich in the necessary ores and in energy.

2.3. Resource base of non-ferrous metallurgy

2.3.1. Bauxite

Africa is one of the major bauxite regions of the world, with 33.1/28.7 % of world reserves/resources /Table 10/. The only bauxite giant of the continent is Guinea at 26.0/17.4 % of world reserves/ /resources, but Ghana, Cameroon and a few other African countries are also significant on a world scale.

The world market of bauxite being dominated by very large-scale mines in the more or less immediate proximity of tidewater ports of large or very large throughput, bauxite deposits lying more than a couple of hundreds of kilometres inland tend to be economically unviable because of the overriding cost of haulage to tidewater.

Table 10

Bauxite reserves and resources of the world and of Africa
million tons recoverable aluminium content; percentage

	Reserves	Others	Resources
World, 10^6 t	3480	2240	5720
of which:			
- Africa overall, %	33.1	21.9	28.7
- Cameroon, U.R. of	3.9	6.1	4.8
- Ghana	2.0	1.0	1.6
- Guinea	26.0	4.0	17.4
- Other Africa	...	10.5	5.5

For capacities, cf. Table 11/A

Source: as for Table 1

Table 11

Copper reserves and resources of the world and of Africa
million tons; percentage

	Reserves	Others	Resources
World, 10^6 t	410	1450	1860
of which:			
- Africa overall, %	13.3	7.5	8.8
- Zaire	4.4	1.9	2.4
- Zambia	6.7	4.4	4.9
- Others	2.2	1.3	1.5

For capacities, cf. Table 12/A

Source: as for Table 1

This is why the bauxite resources of a number of land-locked African countries have not even been surveyed adequately. A case in point is Mali, whose bauxites, not inferior to some of those being exported out of Guinea on a large scale, have found no takers so far owing to the transportation problem.

One of the possible ways of developing these deposits is the conversion of their bauxite to either alumina or aluminium right next to the mine. We shall discuss the alumina issue farther below; as regards aluminium, its production requires another resource, copious cheap electricity.

2.3.2. Cheap electric power

The standard source of copious cheap electricity for the smelting of aluminium is hydro-power. The three major aluminium smelters of Africa, Tema in Ghana, Edéa in the U.R. of Cameroon and Nag Hamadi in Egypt, are all hooked up to major hydroelectric generating facilities.

In the countries rich in natural gas, the generation of electricity using gas turbines may enter into consideration, provided that no other, more lucrative outlet can be found for the gas. Bahrain Island's ALBA aluminium smelter is an extra-African case in point.

Coal-fired energy is generally regarded as too expensive for the smelting of aluminium, especially if the coal is won underground, as most African coal is.

Of the world's total hydroelectric potential of 2 261 000 MW, Africa at almost 20 % /437 100 MW/ has the greatest share after Asia /excluding the Asian part of the USSR/. As regards developed hydroelectric potential, Africa at 30 000 MW likewise possesses a fairly important 9 % of the world total of 329 400 MW. Still, sites providing sufficient cheap power for metallurgy /electric-furnace steelmaking, aluminium smelting, ferroalloy making etc./ are available in a number of other, so far undeveloped sites: developing those will have to be one of the key activities in the provision of an infrastru ture for metallurgy.

2.3.3. Copper ore

Table 11 shows the copper ore reserves of Africa /those of Zaire and Zambia in particular/ to be significant on a world scale. The same is true of the resources, although less conspicuously so.

Most of the copper ore deposits now being mined in Africa are richer at 3 to 6 % copper content than the very large-scale deposits mined by modern open-cast techniques e.g. in Chile, where the average Cu content of the ore is not above 1.5 %. /This is why many of the African deposits can be mined underground, although more recently their profit margins vis-a-vis a market dominated by opencast producers have been very narrow or, indeed, negative./ The implication is that, in the African Copperbelt or possibly elsewhere in Africa, detailed prospection may yet reveal some large Chilean-type /copper porphyry/ deposits, with or without additional mineralization of lead, zinc, silver, gold, cobalt, nickel, molybdenum etc.

2.3.4. Lead and zinc ore

Lead and zinc are usually, albeit not necessarily, associated in their ores in most parts of the world, but perhaps less so in Africa than elsewhere, as revealed by Tables 12 and 13. The three African countries with the most important lead reserves are Morocco, Namibia and Algeria; those with the most important zinc reserves are Zaire and Zambia /where most of the zinc is mined together with copper/. The zinc reserves of Africa are commensurate, more or less, with the size of the continent, whereas its lead reserves are much less significant.

2.3.5. Tin ore

Table 14 shows Africa to be an important holder of tin reserves/resources, with Nigeria dominant in the first and Zaire in the second.

3. Current production and balance between processing stages

3.1. Introductory remarks

As regards the logistics of their processing, the ores considered in this paper fall into two distinct groups.

The first group includes iron ore, bauxite and manganese ore, each of which typically contains 50 % or more pay metal /Fe, Al, Mn/. These are as a rule exported in bulk /as-mined/ onto the world market or to some captive buyer.

More recently, somewhat enriched products, of a higher value added more often than not /pellets, sinter feed in the case of iron ore; washed bauxite or alumina in the case of bauxite/ are increasingly being exported. As far as the overall economics of bringing the metal to the consumer is concerned, no very strong case can be made for refining these ores to any higher degree next to the mine /or indeed, within the country where the mine is located/. On the other hand, the developing countries that possess such ores or mines are desirous to inject into them the greatest possible value added before exportation, constrained as they are by the need to earn hard currency, in addition /or, indeed, sometimes in contradistinction/ to the criterion of simply making profits in some domestic currency.

The second group includes copper, lead, zinc, tin and all the steel-alloying elements except manganese. The pay metal content of the respective ores is one to five % on average, and only rarely as high as 10 %. Also, overseas mining of these ores was begun as a rule before the advent of large-scale bulk ocean transport /in the days of sail, in fact/. It therefore was and still is the rule to reduce ore weight by concentration /beneficiation/ at or near the mine site. Concentrates usually have a pay metal content of 30 to 40 %.

Table 12

Lead reserves and resources of the world and of Africa
million tons; percentage

	Reserves	Others	Resources
World, 10^6 t	150	150	300
of which:			
- Africa overall, %	3.0	5.4	4.2
- Morocco	0.9	0.9	0.9
- Namibia	0.9	1.5	1.2
- Algeria	0.4	1.4	0.9
- Other Africa	0.8	1.6	1.2

Lead mining capacities of the world and of Africa
thousand tons; percentage

	1973	1980
World, 10^3 t	4080	4400
of which:		
- Africa overall, %	5.6	5.8
- Morocco	2.0	...
- Namibia	1.8	...
- Other Africa	1.8	...

Table 13

Zinc reserves and resources of the world and of Africa
million tons; percentage

	Reserves	Others	Resources
World, 10^6 t	135.1	109.7	244.9
of which:			
- Africa overall, %	4.7	6.6	5.5
- Zaire	1.3	1.7	1.5
- Zambia	0.7	0.9	0.8
- Other Africa	2.7	4.1	3.3

Zinc mining capacities of the world and of Africa
thousand tons; percentage

	1973	1980
World, 10^3 t	6600	7920
of which:		
- Africa overall, %	6.0	5.7
- Zaire	2.7	...
- Zambia	1.2	...
- Other Africa	1.3	...

Source for both tables: as for Table 1

As a later measure, smelting was added at or near the concentrator, and only the last stage, that of refining the primary metal, was retained for the countries where the final markets lay. In recent times, even this stage has been moved in many instances to the mining country /cf. the tin refining industry of Malaysia/. Hence, although the smelting and refining capacities of the developing countries, including those of Africa, are less as a rule than their mining and concentrating capacities, they are much greater, relatively speaking, than their processing capacities for bauxite, iron ore or manganese.

3.2. Ferrous metallurgy: production capacities

Table 15 shows iron ore production in Africa to have been 7.7 % of world production in 1977 with South Africa included and 4.3 % with South Africa excluded. The only African iron ore producers important on a world scale are South Africa, Liberia and Mauritania, in that order.

Further mining capacities that might be realized by 1985 could add some 22.5 million tpy /tons per year/ as a minimum and up to 80 million tpy as a maximum to African iron ore mining capacity. Given the difficult situation of the world steel industry, the lower figure is the more probable /cf. UNIDO/IOD 236, 13 December 1978/.

The only pelletizing capacities currently in existence in Africa seem to be 4 million tpy in Liberia /2 million tpy each at Bong and at Buchanan, both for export/ and 0.85 million tpy at Sheferif-Nador in Morocco. Some 22 million tpy of further pelletizing capacity might be realized by 1985 as a minimum /of which 10 million tpy in Liberia and 12 million tpy in Ivory Coast/ and some 40 million tpy as a maximum /UNIDO, ibid./.

The increase in iron ore mining and pelletizing capacities in Africa /and the world over, for that matter/ will be limited by market availability rather than by the availability of viable ore deposits.

The current iron and steel capacities of Africa and those forecast for 1984 are shown in Table 16. Disregarding South Africa, the following picture emerges.

- All the North African countries except Morocco have some crude steel capacity; all except Tunisia have important expansion projects in hand.
- The only country with a significant steel capacity elsewhere in Africa is Zimbabwe. Nigeria has important iron and steel projects in hand; Zimbabwe has not. UNIDO is assisting Angola in the preparation of an iron/steel study.
- Both the present production pattern and the expansion projects in hand reveal a set of disjointed production centres with little or no progress towards a regionalization of markets: the countries with no production facilities of their own will in the foreseeable future have to rely on the world market for their purchases of basic iron/steel inputs.

Table 14

Tin reserves and resources of the world and of Africa
million tons; percentage

	Reserves	Others	Resources
World, 10^6 t	10.104	27.490	37.630
of which:			
- Africa, %	7.1	10.9	9.9
- Nigeria	2.8	2.2	2.4
- Zaire	2.0	7.4	5.9
- Other Africa	2.3	1.3	1.6

Tin mining and smelting capacities of the world and of Africa
thousand tons of contained tin; percentage

	1973	1980
Mining capacity		
World, 10^3 t	295	341
of which:		
- Africa, %	9.0	8.3
- Nigeria	3.4	
- Zaire	2.8	
Smelting capacity		
World, 10^3 t	341	394
of which:		
- Africa, %	8.3	6.0
- Nigeria	3.4	
- Zaire	1.1	

Source: as in Table 1

Table 15

Iron ore production of the world and of Africa
million tons contained Fe; percentages

	1968 tonnage	1968 %	1973 tonnage	1973 %	1977 tonnage	1977 %
World, 10^6 t Fe	371.7	100.0	467.8	100.0	482.8	100.0
of which:						
- Africa,	32.9	8.9	37.5	8.0	37.4	7.7
- Africa without S. Africa	27.7	7.5	30.6	6.5	20.8	4.3
- Algeria	1.66		1.70		1.72	
- Angola	2.00		3.75		-	
- Egypt	0.22		0.32		0.70	
- Guinea	0.94		-		-	
- Liberia	11.29	3.8	14.36	3.1	11.96	2.5
- Mauritania	5.01	1.4	6.58	1.4	4.73	1.0
- Morocco	0.49		0.21		0.24	
- Sierra Leone	1.54		1.51		-	
- South Africa	5.30	1.4	6.91	1.5	16.58	3.4
- Zimbabwe	0.46		0.35		0.33	
- Sudan	0.01		-		-	
- Swaziland	1.50		1.37		0.92	
- Tunisia	0.55		0.43		0.18	

NB. Percentages are stated only where they exceed one per cent of world output.

Source: UN Statistical Yearbook, 1978.

Table 15

Iron and steel capacities of Africa by type: fact /1978/ and forecast /1984/

Country/region	crude steel capacity, million tons		percentage of world crude steel capacity	basic oxygen capacity as percentage of country's/ region's total crude steel capacity		open-hearth capacity as percentage of country's/ region's total crude steel capacity		electric-furnace capacity as percentage of country's/ region's total crude steel capacity		blast-furnace pig capacity, million tons		direct reduction capacity, million tons	
	1978	1984	1984	1978	1984	1978	1984	1978	1984	1978	1984	1978	1984
Africa total	12.93	19.94	2.0	61.9	55.5	14.5	9.2	23.6	25.2	9.32	12.21	0.90	5.10
		23.68	2.3		58.6		7.8		33.6		13.31		5.70
South Africa	9.45	9.72	0.9	65.5	64.5	9.5	9.3	24.9	26.2	7.00	7.00	0.90	1.15
		11.46	1.1		67.8		7.9		24.3		7.00		1.25
Egypt, A.R. of	1.26	2.66	0.03	47.6	45.1	37.7	17.9	14.7	37.0	0.96	1.75	-	0.8
		2.66	0.03		45.1		17.9		37.0		1.75		0.8
Zimbabwe	1.00	1.00	0.1	53.0	53.0	47.0	47.0			0.70	0.70		
		1.00	0.1		53.0		47.0				0.70		
Algeria	0.63	3.00	0.3	79.4	63.3	4.8		15.9	36.7	0.50	1.70	-	1.20
		3.00	0.3		63.3				36.7		1.70		1.20
Tunesia	0.20	0.24	0.0	85.0	70.8			15.0	29.2	0.16	0.16		
		0.24	0.0		70.8				29.2		0.16		
Nigeria	0.16	1.19	0.1					100.0	100.0				1.0
		2.49	0.2		52.2				47.8		1.00		1.0
Libyan A.J.	0.02	0.52	0.1					100.0	100.0				0.4
		1.22	0.1						100.0				1.0

Note. For each country/region, the top line figures for 1984 represent a "conservative" forecast; the bottom line figures represent an "optimistic" one.

Source: Marcus, P.F. - Kirsis, K.M.: World Steel Dynamics, Paine Webber Mitchell Hutchins Inc., June 1980.

The current iron and steel capacities of Africa are highly inadequate, as revealed by the fact that /Table 17/ Africa without South Africa in 1978 imported 4.8 million tons of semifinished and finished steel products, roughly equivalent to 6.3 million tons of crude steel, almost double the 3.48 million tons of crude steel produced in the region: also, the largest importers were Algeria, Nigeria, Morocco, Libya, Kenya and Tunisia, in that order: that is, some of the most important producers were the greatest importers. There is thus ample scope for iron and steel expansion into the markets of the continent proper, although it will probably be reasonable to go on importing from overseas for some time the steel types that are more difficult to make /special steels, stainless steels, special pipe etc./.

Table 17

Total imports of semifinished and finished steel products
thousand tons

	1965	1970	1975	1978
World total	60 502.3	88 277.1	109 931.9	124 044.8
African total	2 734.1	3 174.7	4 885.1	4 847.1
Africa without South Africa, Botswana, Lesotho, Namibia and Swaziland:	1 878.9	2 731.7	4 034.6	4 709.8

Source: Metal Bulletin Handbook, 12th Ed., 1979.

For a comparison with the other developing regions of the world, in 1978, Latin America had 3.6 % of world gross crude steel capacity; the Far East excluding Japan had 2.8 %; the Middle East had 0.4 %; Africa without South Africa also had 0.4 %. In 1984, Africa is expected to have a share of 1.1 to 1.2 %; Latin America, 5.4 to 6.1 %; the Middle East, 0.7 %; the Far East without Japan, 4.1 to 4.4 %. The implied growth rates in percentage shares are 46 to 57 % for the Far East without Japan, 50 to 69 % for Latin America, 75 % starting from a very low base in the Middle East and 175 to 200 % for Africa /Marcus and Kirsis, l.c./. That is, crude steel growth is to be relatively fastest in Africa of all the developing regions, albeit also from a fairly low base.

3.3. Ferrous metallurgy: case histories of some African countries

The discussion below is far from complete: in fact, a number of countries providing important examples, either positive or negative, have been left out. The only point in the author's mind was to present a broad enough range of examples to permit the drawing of a few fairly general, albeit of necessity somewhat tentative, conclusions.

In Lesotho[1/], even simple iron and steel semis such as bars, shapes, plate, sheet, pipes, tubes etc. are being imported. Recent

1/ ECA: Country Report of the ECA/UNIDO Basic Metals and Engineering Industries Development Programme Mission, Kingdom of Lesotho.

government thinking has been towards self-reliance in simple metal products, but at present Lesotho has no proven indigenous raw materials to support any basic metal industries. Scrap utilization seems the only obvious possibility, but even scrap availability remains unproven.

In Mali[1/], ferrous metallurgy in the strict sense is confined to foundry work. Even some of the scrap and broken cast iron used to feed the foundries is being imported. Under a policy of strong import restraint, imports of all forms of iron and steel are less than 6000 tpy. A small steel mill using local raw materials, of 40 000 tpy output, is being planned, probably to use the DR/EF route. A rolling mill for small profiles is to be set up at the capital, Bamako. Such scrap as can be collected locally is also to be introduced into the iron-steel circuit. No dates have been fixed for these projects.

In Ethiopia[2/], cast iron products are made out of scrap in small foundries; steel ingots made in an electric-arc furnace are converted into rolled steel, largely rebar and sections. No steel castings are being produced. High-priority projects for the basic metal industries include prospection for iron ores, for coal /lignite/ and also for the steel alloying elements manganese and nickel. Feasibility studies are being envisaged for the production of sponge iron by direct reduction using domestic lignite and for the conversion of lignite into a form of coke.

In Senegal[3/], the company Sénémétallurgie produces castings of iron and steel. Some local scrap is being used, but as there is not enough of it, some iron for casting has to be imported. There are some other foundries also /at the Railways Workshop and at the workshops of the Navy and Merchant Marine/. An electric-furnace steelmaking plant to be based on local scrap is being envisaged. It is to feed a mini rolling mill to produce some 30 000 tpy of long products and a wire-drawing plant of some 10 000 tpy output. The country has important and fairly high-grade reserves of iron ore along its border with Mali, i.e. far removed from tidewater. Their exploitation could be economically viable if transportation on the Senegal River could be arranged. This in turn presupposes a substantial and fairly costly improvement of the navigability of that river.

Zambia[4/] has proven iron ore reserves of 30 million tons and probable ones of 150 million tons. There are known resources of coal and cobalt and potential ones of manganese and nickel. At present, there is no industry producing commercial iron and steel intermediates. Steel products are being imported. Most of the repair and maintenance workshops and a number of engineering establishments have foundries; some have forging facilities. The fore-

1/ Commission Mixte CEA/ONUDI de l'Industrie: Rapport de la mission sur le programme de développement des industries métallurgiques de base et mécaniques du Mali. June 13, 1979.

2/ ECA: Country report of the ECA/UNIDO Basic Metal and Engineering Industries Development Programme: The Provisional Military Government of Socialist Ethiopia.

3/ Idem, Republic of Senegal.

4/ Idem, Republic of Zambia.

cast demand for steel products is on the order of 80 000 tpy in 1985. Projects include an integrated iron and steel plant of 20 000 to 30 000 tpy iron and steel capacity, using coal as a reductant, and a mini steel plant of 60 000 tpy capacity, to use scrap in addition to the output of the integrated plant, and to produce bars, angles and light sections, mainly for building construction.

In Uganda1/, the Steel Manufactures of East Africa Ltd. at Jinja produces liquid steel from scrap, converting it into rebars, angles and flats. At Lugazi, the same company produces ferrous and non-ferrous castings. The capacity of the Jinja works is 24 000 tpy of ingots and 30 000 tpy of rolled steel. The works is underutilized. Scrap supply seems to be inadequate. An expansion programme involving a 30 000 tpy addition to the steel plant is being envisaged.

In Tunisia2/, the El Fouladh integrated iron and steel plant uses local iron ore and imported coal. It includes a pelletising plant, a blast furnace, two top-blown LD converters, an electric-arc furnace, three continuous-casting machines and rolling equipment. It began commercial production in 1966. It has a 180 000 tpy installed capacity for pig iron, and 215 000 tpy for iron and steel products. The works is operating at roughly 3/4 rated capacity. There are two iron and steel foundries with an output of 5000 tpy of cast iron and 2000 tpy of cast steel. A study has been prepared for the expansion of steelmaking by the installation of a new electric furnace.

In Egypt3/, the Helwan works of the Egyptian Iron and Steel Co. comprises a BF/OH /blast-furnace-cum-open-hearth/ and a BF/BOF unit with ingot casting, built in 1958, and a BF/BOF unit using continuous casting, the first half of which was blown in in 1979. The works uses 100 % sinter charge made of Egyptian iron ore and coke made of Egyptian coal. There is a cold and hot rolling mill, a strip mill and sections mill.

A natural-gas-based direct reduction unit of 160 000 tpy output is expected to come onstream in 1983.

A DR/EF route steel mill of 800 000 tpy output, integrated with a bar mill to produce 720 000 tpy of bar, has been envisaged for El Dekheila. It is to use Brazilian iron ore.

Sudan4/ has an efficient foundry working for the railways and a few smaller foundries. Sudanese Steel Products Ltd. uses imported sheet to prepare corrugated roofing sheet and imported billet to roll rods and bars. The capacity of the rolling mill is 70 000 tpy, but actual output is much less. At the same time, steel imports have reached about 250 000 tpy, and a domestic market of some 350 000 tpy of steel is reckoned to exist. It has been concluded by Italian consultants Italimpianti that an iron and steel installation "could utilize indigenous iron ores, charcoal, limestone and other domestic inputs, and electrical energy from the Roseiri

1/ ECA: Country report of the ECA/UNIDO Basic Metal and Engineering Industries Development Programme: Republic of Uganda.

2/ Idem, Tunisia.

3/ Idem, Arab Republic of Egypt.

4/ Idem, Democratic Republic of Sudan

facility". More recently, the idea of a mini steel mill of 50 000 to 100 000 tpy capacity has emerged.

The only iron and steel company of Algeria[1/] is the Société Nationale de Sidérurgie. Its current BF pig iron capacity is 500 000 tpy at El Hadjar; this is to be expanded to 1.7 million tpy by 1980. BOF capacity is to be expanded in step, from 0.6 to 2.0 million tpy. A DR/EF route steel plant is to be built at Jijal, to come onstream in 1984 with a capacity of 1.2 million tpy. It is to feed a special-steel plant at Ain Melilla which, it is hoped, will come onstream in 1985. An even more ambitious plan involves the building of a 10 million tpy BF/BOF plant or two 5 million tpy units at La Macta. No date has been fixed as yet for this latter project.

In Nigeria[2/], there are at present three small scrap-based electric-furnace steelmakers. Iron and steel industry expansion is to be based on domestic iron ore /Itakpe Hills/, coal /Lafia and Enugu/ and natural gas. At Warri, a gas-based DR/EF route steel plant of one million tpy output is to come onstream in 1982. At Ajaokuta, a BF/BOF route integrated steel mill is to start rolling in 1981 and making crude steel in 1983. Its initial capacity is to be 1.3 million tons of crude steel, with a possibility of expanding it to five million tpy. The first stage is expected to produce 1 185 000 tons of rolled products including 560 000 tons of sections, 400 000 tons of rounds and squares and 110 000 tons of wire rods.

3.4. Ferrous metallurgy: an African pattern of past development

Out of the above concise "case histories", a fairly clear-cut pattern of metallurgical development emerges:

Step 1: No noteworthy iron and steel industry; no proven raw materials base.

Step 2: There are only foundries, typically at the railways workshops.

Step 3: There are foundries plus a mini rolling facility for long products, typically using imported steel billet.

Step 4: In addition, there is scrap-based electric-furnace steelmaking, its output feeding a mini rolling facility for long products.

Step 5: There is iron-making based on domestic iron ore, probably using the direct-reduction route. Rolling mills may produce flat products also.

Step 6: There is an integrated iron and steel plant, typically of the BF/BOF type, less seldom of the DR/EF type.

The above list represents at the same time the steps of progress by which a developing country can attain self-sufficiency in

1/ Marcus and Kirsis, World Steel Dynamics, l.c.

2/ ECA: Country Report of the ECA/UNIDO Basic Metals and Engineering Industries Development Programme Mission, The Federal Republic of Nigeria.

ferrous metallurgy.

It is to be pointed out that, up to step 4, the domestic market of most developing countries is likely to absorb the iron and steel produced; steps 5 and 6, however, are likely to be economically viable only if the country is

- either relatively industrialized /such as the North African countries/
- or fairly large /such as Nigeria/,

or, alternatively, if the works can operate into a sizeable regional market, on the basis of a more or less firm regional production and marketing agreement.

3.5. Non-ferrous metallurgy: current production and balance between stages of processing

The current non-ferrous metallurgical capacities of Africa are quite unbalanced, with some refined-metal capacities far exceeding domestic or even regional demand, whereas semis capacities are quite inadequate as a rule. The situation is illustrated by the fact that, in 1977, the African continent exporting 833 900 tons of refined copper had to import 40 000 tons of copper and copper-alloy semi-manufactures from overseas. The situation is much the same in aluminium: even Ghana, a large producer of primary aluminium, has to import aluminium semis from overseas for want of a domestic semis facility.

The relative capacities of the different processing stages of the various non-ferrous metals and the plans to expand them /as far as they are known/ are shown in Tables 18, 19 and 20.

In bauxite mining, Africa with almost 30 % of expected world total increment between 1978 and 1984 is in a strong second position in the world, overshadowed only by Latin America which is to have almost half of world total increment.

In alumina refining, Africa in 1978 had a minute share of 2.3 % of world capacity /700 000 tpy/, entirely out of proportion to its 16.3 % share of world bauxite output. No expansion is being planned to come onstream up to 1984. The alumina/bauxite capacity factor of Africa, at 0.14 in 1978, is the lowest by far of all regions, and is slated for a further decline /to 0.10 by 1984/.+

In aluminium smelting, Africa's expected capacity increment at 4.9 % of world increment is also the lowest of all regions, especially in the light of Africa's very low base-year share /3.3 % of world capacity in 1978/. Remarkably enough, the aluminium/alumina capacity factor exceeds unity /1.43 in 1978; 1.97 in 1984/, because alumina produced outside Africa is being smelted at Tema, Ghana and is to be smelted at M'Sila, Algeria. The aluminium/bauxite capacity factor is very low again at 0.20 declining to 0.19; true, both Latin America's and Oceania's capacity factor was lower in 1978 at 0.14 and 0.09, re-

+ The capacity factors referred to are obtained by taking the ratio of world output of a downstream product to that of an upstream product /say, world aluminium output divided by world bauxite output/ as unity and relating the outputs of the individual continents, world regions or countries to the ratio thus defined.

Bauxite mining and processing capacities, 1978;
expected increments up to 1984;
relative capacities of processing stages, 1978-1984

Region	Bauxite mining			Alumina vs. bauxite capacity ratios		Alumina refining			Aluminium vs. alumina capacity ratios		Aluminium smelting			Aluminium vs. bauxite capacity ratios	
	Capacity 1978 '000 t	Increment up to 1984 '000 t	Percent of world incrmt.	1978	1984	capacity 1978 '000 t	Incrmt. up to 1984 '000 t	Percent of world incrmt.	1978	1984	Capacity 1978 '000 t	Incrmt. up to 1984 '000 t	Percent of world incrmt.	1978	1984
World	87 297	23 523	100.0	1.00	1.00	30 195	7 220	100.0	1.00	1.00	13 286	3 893	100.0	1.00	1.00
Africa 1/	14 262	6 945	29.5	0.14	0.10	700	0	0.0	1.43	1.97	442	191	4.9	0.20	0.19
Non-Japan Asia	3 756	105	0.4	0.86	1.27	1 120	540	7.5	1.34	2.10	662	941	24.2	1.15	2.67
Japan	0	0	0	∞	∞	2 580	0	0	1.45	1.25	1 645	1 483	-4.2	∞	∞
Latin America	30 449	11 200	47.6	0.47	0.49	4 990	1 882	26.1	0.29	0.46	631	825	21.2	0.14	0.23
Oceania	28 000	3 245	13.8	0.70	0.81	6 800	1 700	23.5	0.13	0.36	399	989	25.4	0.09	0.29
Europe	8 680	2 040	8.7	1.89	2.39	5 675	2 963	41.0	1.49	1.10	3 730	622	16.0	2.82	2.62
North America	2 150	0	0	11.20	11.66	8 330	135	1.9	1.58	1.61	5 777	487	12.5	17.65	18.80

1/ South Africa's 80 000 ton smelter capacity, no expansion of which is being planned, does not affect the picture significantly. South Africa has no existing or scheduled bauxite mine or alumina plant.

Source: For capacities and increments: Chase Econometrics: Metals Investment in the Eighties - Supporting Volume 1 (Light Metals)

The rest are the author's calculations.

Copper mining and processing capacities, 1978;
expected increments up to 1984;
relative capacities of processing stages, 1978-1984

Region	Copper mining			Smelter vs. mine capacity ratios		Copper smelting			Refinery vs. smelter capacity ratios		Copper refining			Refinery vs. mine capacity ratios	
	Capacity 1978 '000 t	Increment up to 1984 '000 t	Percent of world increment	1978	1984	Capacity 1978 '000t	Incrmt. up to 1984 '000t	Percent of world increment	1978	1984	Capacity 1978 '000t	Incrmt. up to 1984 '000t	Percent of world incrmt.	1978	1984
World	7 327	1 302	100.00	1.00	1.00	7 408	828	100.0	1.00	1.00	9 123	734	100.00	1.00	1.00
Africa without South Africa	1 445	68	5.2	0.64	0.73	932	125	15.1	0.97	0.88	1 110	0	0	0.62	0.64
South Africa	227	-5	-0.4	0.80	0.87	185	0	0	0.63	0.84	144	42	5.7	0.50	0.74
Non-Japan Asia	148	225	17.3	1.20	1.31	180	288	24.8	0.87	0.85	193	285	38.8	1.05	1.12
Japan	90	-15	-1.2	12.22	15.44	1 112	0	0	0.88	0.91	1 207	0	0	10.78	14.03
Latin America	1 722	497	38.2	0.77	0.77	1 341	295	35.6	0.67	0.75	1 106	364	49.6	0.52	0.58
Oceania	816	157	12.1	0.24	0.27	198	50	6.0	0.90	1.01	220	300	10.9	0.22	0.27
Europe	346	87	6.7	2.61	2.21	914	0	0	1.69	1.76	1 904	20	2.7	4.42	3.89
North America	2 533	288	22.1	0.99	0.97	2 546	70	8.5	1.03	1.02	3 239	-57	-7.8	1.02	0.99

Source: For capacities and increments: Chase Econometrics: Metals Investment in the Eighties - Supporting Volume 2 (Base Metals)

The rest are the author's calculations.

Table 20

Lead metal production capacities in 1978 and 1984
thousand tons per year

	1978	1984	Increment 1978-1984 tonnage	Increment 1978-1984 % of world increment
Africa without South Africa	133	133	0	-
South Africa	0	30	30	42.3
Asia without Japan	100	100	0	-
Japan	277	289	12	16.9
Latin America	439	468	29	40.8
Oceania	282	282	0	-
Europe	1746	1746	0	-
North America	922	922	0	-
World	3899	3970	71	100.0

Zinc metal production capacities in 1978 and 1984

	1978	1984	Increment 1978-1984 tonnage	Increment 1978-1984 % of world increment
Africa without South Africa	173	173	0	-
South Africa	85	85	0	-
Asia without Japan	171	241	70	30.0
Japan	962	962	0	-
Latin America	390	681	291	124.9
Oceania	328	328	0	-
Europe	2286	2297	11	4.7
North America	1279	1140	-139	-60.0
World	5674	5907	233	100.0

Source: Chase Econometrics: Metal Investment in the Eighties - Supporting Volume 2 /base metals/ for both tables spectively, but both regions will have overtaken Africa by 1984 /at 0.29 and 0.23, respectively/.

In copper mining, Africa has the least planned capacity increment of all world regions: at 5.2 %, it is less than Africa's share of planned smelter expansion /15.1 %/. In base year 1978, African copper mining capacity was second only to Latin America's.

In copper smelting, Africa's expansion at 15.1 % of world increment is third after Latin America's and Asia's. The smelter/mine capacity factor in 1978, at 0.64, was much less wildly out of line than in the case of aluminium, and it is to improve to 0.73 by 1984 /this being largely due to the difference in logistics between copper and aluminium, pointed out in Section 3.1/.

In copper refining, the expected African increment is nil. The refinery/smelter capacity ratio, tolerable at 0.9 in 1978, is to decline to a still acceptable 0.88 by 1984. The refinery/mine capacity ratio is to remain near-constant at about 0.60.

In lead, the largest increment /42.3 %/ is planned in South Africa; no other capacity increment is to come onstream elsewhere in Africa.

In zinc, no capacity increment at all is to materialize in the whole of Africa up to and including the year 1984. In both lead and zinc, a shift towards more substantial growth in Latin America is apparent.

3.6. Non-ferrous metallurgy: case histories of some African countries

As regards the purpose of presenting these case histories, and for the relevant background documents, the reader is referred to Section 3.3, on case histories for ferrous metals.

In Lesotho, Clifford Trading, a company employing some 30 workmen, is the only sizeable metalworking undertaking. It produces window and door frames and similar products. Most other metalworking is artisanal, carried out by men who have gained experience and set aside money to start a business during years of work in South Africa. The materials used by them are also imported from South Africa.

In Mauritius, there are no known non-ferrous ore reserves; the small works that produce items of brass /sanitary fittings/ and aluminium /holloware, doors and windows/ rely on imported metal.

In Ethiopia, the East African Aluminium Co. produces doors, windows and household holloware out of imported metal and shapes. It is hoped that copper, zinc and nickel deposits, now being surveyed, will turn out to be economically viable.

In Mali, the private company Entreprise Malienne de Fonderie makes castings of aluminium and bronze in addition to iron and steel. There is a works with the capacity of turning out some 20 000 aluminium-framed windows per year: it currently produces only some 5000 units per year, however. The country has a fairly high-grade bauxite reserve, adequately prospected and important even on a world scale. A project for its mining and conversion into alumina on a large scale has been studied with UNIDO assistance. The condition for making the project viable seems to be the improvement of the navigability of the Senegal River /as mentioned under Senegal in Section 3.3/, involving the construction of a dam at Manantali in Mali. The electricity produced by the dam could then be used, among other things, to supply a minor /25 000 tpy/ aluminium smelter whose output would satisfy domestic demand and leave an exportable surplus. Given the current insufficiency of finance for the Senegal River project, the Malian bauxite-aluminium project does not look immediately hopeful.

Tunesia has a number of artisanal-type small foundries, mostly for copper. The larger iron and steel foundries Sofoméca and Fonderies réunies do some non-ferrous work as well. At Hoknine, a copper foundry of 500 to 600 tpy output is to be started up soon. All supplies for foundries, including coke and scrap, are being imported. There is an important lead refinery, La Fonderie de Megrine, belonging in part /?/ to the French company Peñarroya. It treats 15 000 tpy of domestically produced lead and 30 000 tpy brought in from Morocco, and produces some 30 000 tpy of 99.99 % purity lead and 7 to 8 tpy of silver.

In Uganda, copper is being produced. Concentrate from the mine at Kilembe is converted to blister at the Jinja smelter, whose capacity is 1500 tpy but whose output is just 400 to 600 tpy. It is planned to rehabilitate both the mine and the smelter by sizeable infusions of investment. At the copper mine, there is a stockpile of iron pyrites from which the extraction of cobalt and sulphur is being planned.

In Senegal, the Société Africaine de Fonderie d'Aluminium specialises largely in the making of household utensils. Three other foundries, doing mostly iron and steel casting work, also have non-ferrous casting facilities and experience. The operation of these shops is regarded as an important import-substituting activity which permits to avoid delays due to the unavailability of spares or protracted procedures of procurement subsequent to the breakage of cast metal parts.

In Nigeria, the only domestically produced non-ferrous metal is tin. Its output is declining for a variety of reasons, including the exhaustion of the known deposits and a mass movement of labour away from mining. Alcan Aluminium of Nigeria Ltd. produces aluminium sheet, plate, coil etc. from imported metal at Lagos. It is owned as to 72 % by the Canadian company Alcan Aluminium. There is a Nigerian project for the manufacturing of aluminium door and window frames. A UN feasibility study on the setting up of a public-sector non-ferrous metal industry has been recommended: it is to serve as a master plan for non-ferrous metals development.

Zambia is well known to be one of the major copper-producing countries of the world. Its current output is on the order of 600 000 tpy of copper, 28 000 tpy of zinc, 10 000 tpy of lead, 1800 tpy of cobalt /of which it is likewise a major world producer/, 40 tpy of selenium, 45 tpy of silver and some 350 kg per year of gold. Zambia's may well be called a mining-dominated economy. The country has some further copper potential /with two projects of copper capacity expansion in hand/ and tin and nickel potential also. Another cobalt plant was to come onstream in 1979. Much of the copper being mined in the country is also being refined there, but semis production is confined to some wire-making /there is a wire and cable plant of 2000 tpy capacity/. On the other hand, Zambia is co-proprietor of a continuous rod-casting /contirod/ facility in Western Europe, and party to two intra-African copper cooperation schemes /one with Nigeria and the other with Egypt, both proceeding with assistance from UNIDO/.

In Egypt, the Nag Hamadi aluminium smelter of 100 000 tpy output, expan able to 160 000 tpy as demand increases, is based on Aswan High Dam electricity. This is the major non-ferrous base metals operation of Egypt; 70 % of its output is being exported to Europe, but all of it will be needed domestically by 2000 if not sooner. There is a small electrolytic copper refinery using imported blister. Cable, wire, rod, sheet and strip of copper and aluminium are being rolled, at a total output of some 25 000 tpy. Aluminium, copper, bronze and brass is processed by The Egyptian Copper Works Co.; lead, zinc, copper and aluminium by the General Metals Co. The Egyptian electrical industry is fairly well supplied with wire, cable and bus bar of domestic make. Projects include the electrolytic tinning of sheet steel /can stock, 50 000 tpy/, the expansion of lead oxide production /2400 tpy/ and certain joint ventures with other African countries /a joint copper-aluminium venture with Zambia and a joint bauxite venture in Guinea together with some other countries, both in the feasibility study stage/.

3.7. Non-ferrous metallurgy: an African pattern of past development

In the non-ferrous field also, the above "case histories" permit to derive a fairly clear-cut pattern of metallurgical development.

1. Of the countries discussed, practically only Egypt has the "developed-country approach" of satisfying a large share of domestic demand using imported metal, refined or unrefined, which is further processed within the country.

2. Intra-African cooperation projects tend to have Egypt or Nigeria as one of the partners.

3. Other countries have acquired significance by exploiting ore deposits of world-wide importance. Most of these countries, however /practically all of them except Zambia and Zaire/ exploit one metal only /tin in the case of Nigeria, bauxite in the case of Guinea, etc./.

4. None of these countries possesses full vertical integration up to semis, let alone finished goods. In copper and tin, the

situation is fair enough, as explained in Section 3.1 on logistics. In aluminium, on the other hand, the situation is as bad as it can be, with the bauxite-producing countries having practically no alumina refineries /the Friguia plant in Guinea treats only a minor fraction of Guinean bauxite output/ and no smelters at all, whereas the smelter countries Ghana, Cameroon and Egypt have no bauxite mines /although the first two do have viable bauxite reserves/. In fact, the Ghanaian smelter is being supplied from alumina from overseas and the Cameroon smelter from Guinea.

5. The countries that possess no non-ferrous ore production facilities or produce minor quantities only must rely partly or entirely on imported metal as the availability of non-ferrous scrap is even worse as a rule than that of ferrous scrap. In the countries of this group, there are, depending more or less on the size of the domestic market,

- artisanal metalworking shops, or
- those plus foundries, or
- the above plus works making simple products such as door and window frames, or
- at the top end of the range - also a small rolling facility or two.

6. One of the most widespread ills of metallurgy, both ferrous and non-ferrous, in Africa today is the underutilization of existing capacities, output being fairly often less than half the rated capacity. The problem is a complex one, due to some or all of the following factors:

- outdated equipment; lack of finance for replacement;
- inadequacy of maintenance for lack of spares, know-how, skilled personnel etc.; lack of finance for spares that have to be imported;
- lack of inputs /raw and basic materials, fuels, energy/;
- lack of operating experience and/or of skilled operating and management personnel;
- or sheer lack of demand.

In cases such as these, the rehabilitation of existing facilities, possibly including their conversion with a view to a better adaptation to existing demand, is to be seriously considered before proceeding to the setting up of any new facilities.

4. Technological progress in ferrous metallurgy and its influence on the economics of works siting and operation

In iron making, the most important deviation from the traditional blast furnace process of pig iron production is the group of processes generically known as direct reduction processes.

"Direct reduction" is something of a misnomer because a blast furnace converts iron ore into pig iron in a single stage just as much as a direct-reduction device converts it into sponge iron. The essential difference, as far as our purpose here is concerned, is that

- direct reduction does not require coking coal as a reducing agent: it can use as reducing agents
  - -- either natural gas or gas of a similar composition,
  - -- or coal of a non-coking variety, cheaper and more widely available as a rule than coking coal,
  - -- or some other available hydrocarbon, e.g. fuel oil:
- on the other hand, direct reduction requires a fairly high-grade iron ore:
  - -- preferably so-called first class iron ore, with a

    $$\frac{SiO_2 + Al_2O_3}{Fe}$$

    ratio less than 5 % and a phosphorus content less than 0.05 %, or
  - -- at least so-called second-class ore in which the above ratio is not higher than 9 % and the phosphorus content is likewise less than 0.05 %.

There are large reserves of such ores in Africa, although most of the ore currently being shipped does not fall in either category. The only first-class ore now being produced is that of Sishen in South Africa. Lamco and Bong Mining Co. of Liberia and Miferma of Mauritania produce second-class ore. Of the projects in hand, the Mifergui mine of Guinea is expected to produce first-class ore; the Man project in Ivory Coast, the Wologisi project in Liberia and the Cassala-Kitungo project in Angola are expected to furnish second-class ore.+

The use of gas as a reductant in the direct reduction process used to be regarded as a substantial advantage in those countries which have no coking coal but are rich in natural gas. The economics of natural gas having been profoundly affected by the oil price explosion, however, that advantage is by no means all that clear-cut today. In fact, wherever a world market outlet can be

+ Direct Reduction of Iron Ore, a Bibliographical Survey. The Metals Society, London, 1979.

found for the gas, a gas-based direct reduction operation may well turn out to be economically unviable. Where no such outlet can be found, the price will depend to a large extent on accounting practice /expensive if costed at a hypothetical world market price, cheap if costed on a cost-plus basis, and indifferent or cheapish if costed somewhere in between/. Costing practice will tend to depend also on alternative domestic uses envisaged /e.g. fertilizer manufacturing/ as well as on the priority that the owner of the gas /the state in the gas-producing countries of Africa/ assigns to iron production by the direct-reduction route.

Direct reduction using non-coking coal seems to be a second-best alternative but, in Africa, those countries which have deposits of such coal /e.g. Nigeria/ tend to have gas also.

Sponge iron made by the direct reduction route has two types of outlets. In the great steelmaking countries, it is used as a replacement for scrap wherever and whenever scrap is in short supply. Elsewhere, it is used as electric-furnace feed. The direct-reduction-plus-electric-furnace /DR/EF/ route to crude steel has, for developing countries producing, or having the potential to produce, low-cost electricity in sufficient quantities, the advantage that it can be economically viable without requiring the huge sizes associated with the blast-furnace-plus-basic-oxygen-furnace /BF/BOF/ route.

Low-cost electricity, on the other hand, has become a rarity these days. Wherever natural gas is available, electricity generation using gas turbines is a viable option, but the economics of the process are beset with the same question marks as the process of direct reduction. Hydroelectric power is the obvious alternative in those countries where sufficient generating capacity exists or is being planned, provided its metallurgical use does not starve the rest of the economy of the electric power that it needs. Also, the development of hydroelectric generating potential tends to require huge sums for investment with a very long repayment period because, for attaining anything like a wholesome cash flow, the entire generating potential has to be loaded down with comparatively high-return consumers: if this is done practically simultaneously with the construction of the hydroelectric facility, a juggernaut of a combined investment project results, far beyond the capacity of financement of most developing countries; if it is done step by step, or if some of the power is diverted for non-return uses such as street lighting or low-return uses such as agriculture, then the first few industrial consumers tend to be overloaded financially by the need to generate the cash flow for the entire credit servicing. In sum, hydro power might be cheap, but it also has its own problems.

Continuous casting of steel and the rolling in a strip mill of the continuous-cast slabs and billets, with no cooling phase inserted, is a highly efficient and energy-saving process whose only drawback for many developing countries being the immense outputs it is usually designed for. In fact, it is the strip mill supplied by a continuous casting shop that has been responsible for the recent gigantization of integrated steelworks where works capacities in excess of 10 million tpy of rolled-product output still seem to yield economies of scale. Let us recall here that the entire African consumption forecast by Professor Malenbaum for the year 2000 /cf. Table 23/ could be supplied by a single giant integrated steelworks of 15 million tpy output. Accordingly, the giant integrated steelworks of today may be viable in an African context only if aimed at markets outside the continent. In view of recent developments in steelmaking in some of the rapidly industrializing developing countries such as the Republic of Korea /or, for that matter, in view of the post-World War II steel revolution of Japan/, which took place without the benefit of a substantial domestic raw materials base, such an export-orientated development is by no means inconceivable for certain African countries, those of North Africa above all, but it should certainly not be expected to materialize before the late 1990s.

The best option for supplying the domestic markets of all but the smallest African countries seems to be the so-called mini steelmaking mill. Unintegrated, making simple products for local or regional markets, flexible in their operating schedules and giving prompt service, these mills are usually scrap-based, employing electric furnaces and sometimes small continuous casting shops to serve their finishing mills. Typical capacities are between 50 000 tpy and 200 000 tpy of long products or between 100 000 tpy and 500 000 tpy of flats.+

There has recently been a renewal of interest in a modified version of one of the oldest ironmaking technologies, that which uses charcoal as a reducing agent. This process has experienced rapid development in Brazil, but similar projects have been envisaged also in Africa /Cameroon, Uganda/. The important point to be made in this context is that, in order to avoid environmental damage /most of it irreversible/, charcoal-based industries must treat the forest as a renewable resource /i.e. one that must be renewed/; they must plant fast-growing trees such as eucalyptus or take some other measures to avoid deforestation and/or the degradation of the forest. In view of the ecological damage that excessive deforestation is liable to wreak, the use of domestic charcoal for industry is largely out of the question in the arid, semiarid and savannah countries of Africa where, even without industrial consumption, a chronic shortage of firewood tends to result in deforestation and/or forest degradation. This largely confines the feasibility of charcoal-based industries to the humid zones of Africa. Even there, however, the forestry effort required introduces a fairly high excess cost element if conditions of reforestation are less than optimal.

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In countries whose domestic iron and steel market is small, steelmaking out of scrap is likely to arise as an obvious option. There is, however, one critical constraint, the availability of scrap. In the African countryside, many objects that would go into scrap elsewhere /such as empty tins/ are put to good use. Losses

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+ Kenneth Warren: World Steel - An Economic Geography; David and Charles, Newton Abbot, 1975.

due to corrosion /rusting/ are also high. Collection over extensive, sparsely inhabited areas may not be economical. In view of all this, when planning a scrap-based metallurgical industry, the availability of scrap and the cost of its collecting must be examined just as scrupulously as the availability and cost of any other natural resource required. In fact, the underutilization of metallurgical capacities in a number of African countries is being attributed, among other causes, to scrap shortage.

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One of the handiest steelworking technologies, very widespread in the developing world at the artisanal level as well as in its more sophisticated forms, is the welding of steel plate, sheet and shapes, mostly imported, using welding electrodes, also imported in their vast majority. The domestic production of welding electrodes has for these reasons been envisaged in a number of countries /including Nigeria, Zambia, Ethiopia, to name just a few/.

5. Technological progress in non-ferrous metallurgy and its influence on the economics of works siting and operation

5.1. Aluminium

As already stated, the only major bauxite producer in Africa is Guinea. Bauxite and alumina make up rather more than three quarters of that country's exports.

The fact that aluminium is smelted electrically, at a consumption of some 15 000 kWh per ton of metal, makes for a peculiar cost structure of aluminium making. Mining accounts for only about 10 % of the cost of producing the metal; the making of alumina accounts for 20 to 25 %; the rest /60 to 65 %/ is added by the smelting operation. In smelting, the cost of power is becoming more and more crucial as energy prices rise. Hence, not only is efficient smelting essential to competitive production, but relatively low power costs are also essential to efficient smelting. 1/

It has been calculated that the weighted average cost of electricity furnished to aluminium smelters today is about 1.5 to 2 US cents /15 to 20 mills/ per kWh, that is, about US$ 230 to 300 per ton of metal, but the full range of energy costs is much broader, from US$ 50 to 550 per ton. Power contracts for new smelters or for deliveries from new generating facilities may carry prices as high as 9.5 to 10.5 US cents per kWh, that is, up to $ 1250 per ton. 2/ All this reveals clearly enough the importance to the aluminium industry of finding sites of cheap electricity. Accordingly, a shift of aluminium smelting capacities into developing countries, including those of Africa, has been predicted. There has so far been, however, no breakthrough in smelter technology that would have reduced the minimum economically viable smelter size, which today is about 100 000 tpy metal output rather than the 50 000 tpy or so that it used to be just one or two decades ago. Economies of scale in smelting are quite significant: the unit cost of aluminium may be reduced by 8 to 9 % by building a 100 000-ton rather than a 30 000-ton smelter. Such economies may continue up to 200 000 tpy and beyond. This implies that, in order to compete in the export markets, developing-country producers must turn out so large quantities of either alumina or metal as already tend to give rise to considerable marketing difficulties. Also in fabrication, the hot rolling of metal /to produce plate, sheet, bars and rod/ is highly capital-intensive and requires large mills. Other processes /including e.g. the cast-rolling of rod and cold rolling/ are feasible on a smaller scale, however. Can stock and can ends have also been made recently using such processes.

Alumina plants have in the past been located in the major bauxite-importing countries, but there is nowadays a fairly strong case

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1/ UNIDO: World industry since 1960: Progress and prospects. Much of the argument of this chapter has been updated from that publication.

2/ S.J. Ross-MacDonald /Bahrain Aluminium/: Aluminium, in Future Metal Strategy, The Metals Society, London, 19 0.

for locating them as near to the bauxite mine as possible. Alumina making consumes relatively little energy, and the alumina plant can be a self-contained unit supplied by its own steam-and-thermal-power plant. The cost patterns of shipping bauxite, alumina and aluminium metal to overseas consumers also seem to favour the location of the alumina plant near the bauxite source. The country that, on present showing, is likely to profit most by these shifts in transport logistics is Australia, however. 1/

In the case of alumina, economies of scale are even greater than in the case of aluminium: the least viable size of alumina plant today is considered to be 300 000 tpy, i.e. 1.5 times as much as is needed to supply a 100 000 tpy smelter. Hence, even if the construction of a minimum-size smelter is justified in a given country, it is necessary to find an export market for some of the alumina if it is desired to add an alumina plant also. /This is one of the reasons why the siting patterns of alumina plants and aluminium smelters tend to diverge, the availability of bauxite being the prime criterion these days in deciding alumina plant siting and the availability of cheap electricity in deciding smelter siting./ It is only those countries which are fortunate enough to have both /Australia; in Africa, Guinea, Ghana or the United Republic of Cameroon/ that can expect to develop an industry integrated from mining at least to smelting, but all those integrated industries will have to be export-orientated owing to the sheer size of even the smallest competitive operation.

At present, two lines of research are being carried on that may affect the industry pattern. Firstly, there is a search for ways and means permitting to reduce the inputs, especially of energy, per ton of metal output. In smelting, developments in cell design, current density and improved conductivity of both the cathode and the electrolyte might reduce both power consumption and unit investment costs. Existing smelters could be retrofitted, which would increase their output and reduce the demand for new plant. Secondly, the aluminium companies are on a permanent search for processes that can make aluminium out of clays and other raw materials available in quantity in the developed countries. The primary intention of that search is to liberate the transnational corporations from their dependence on overseas sources of bauxite; nevertheless, given today's energy prices, bauxite stands a fair chance of remaining the cheapest ore of aluminium by far.

In fabrication, the major change may be continuous casting /cast-rolling/: it is rather simple and not too expensive to add cast-rolling facilities to existing smelters, but the transport costs of cast-rolled products to overseas markets tend to be higher than those of ingot, slab or billet. /Import duties are quite high enough for each./

5.2. Copper

Copper is one of the principal export commodities of the world economy. It accounts for more than two thirds of the export earnings

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1/ Australian aluminium: At what price? The Economist, February 7, 1981, p. 74.

of Zaire and Zambia. A major share of copper smelting and refining being carried out in the copper mining countries, among them also in Zaire and Zambia, the logical and entirely feasible next step would be to proceed to fabrication of some products, wire in particular. In fact, Zaire and, more recently, Zambia have begun to manufacture wire and cable, largely for domestic consumption and to a smaller extent for export to neighbouring countries. None of the developing-country producers have, however, penetrated so far the copper-product or even the copper-semis markets of the developed countries in any important way.

Economies of scale perhaps play less of a role in copper smelting and refining than in the processing of other metal ores. The minimum economic copper smelter size may be around 40 000 tpy, and 100 000 tpy is sometimes regarded as the optimum plant size. Local conditions, however, may render also smaller facilities profitable. In fact, numerous projects with capacities of 30 000 to 50 000 tpy have been undertaken in recent years.

Although copper refining technology has been stable enough to enable the developing exporter countries to gain control of smelters and refineries, technological changes may well frustrate their hopes of downstream expansion. Wire manufactured from continuous-cast refined copper cathodes /so-called contirods = continuous-cast rods/ seems to command a premium over wire conventionally made of wirebar. The process, however, requires a carefully controlled cathode production. Continuous casting has been estimated to be chosen for 70 to 80 % of new mill capacity over the next several years. Here just as elsewhere, rapid change of technology may constitute a barrier to new entrants into the copper-refining industry, or to the construction of new facilities in the traditional developing copper-producing countries: the recent trend has been to locate contirod plants in the developed market-economy countries, with some of the ownership being held by developing-country producers /Zambia, Chile/.

For the most part, exports of refined copper from developing to developed market-economy countries do not face high tariff barriers in the latter. On the other hand, all major metal importers provide a substantial tariff protection to their own producers of fabricated copper. In the case of Zambia, e.g., a 10 % duty on wire and cable means that Zambia has to face a 50 % effective rate of protection. The recent trend, referred to in the previous paragraph, of locating semis plants partly owned by the developing-country producers in the developed market-economy countries may reflect an effort to avoid these heavy tariffs.

The trade barriers erected by the developed market-economy countries, however, are only one of the problems facing the potential exporters of fabricated copper products. Others include the need for scrap and for residues not available in the country, for imports of alloying elements such as zinc and nickel, the need for foreign expertise, the considerable investment finance involved and the broad ranges of products and sizes demanded by the markets.

Intra-African cooperation especially in the fabrication of copper, such as the negotiations now underway with UNIDO assistance between Zambia and Nigeria on the one hand and Zambia and Egypt on the other, seem one of the best means of expanding the market potential of metals-rich African countries.

5.3. Lead and zinc

Of the three major developing-country producers of lead /Peru, Mexico and Morocco/, only Morocco smelts none of the concentrate produced in the country. Of the five major developing-country producers of zinc, on the other hand /Peru, Mexico, Zaire, Zambia and Bolivia/, Zaire and Zambia refine the highest percentage, 77 and 74 %, respectively.

Technological progress relative to the smelting and refining of these two metals seems to concentrate upon reducing the environmental offensiveness of their smelters so as not to have to increase the smallest economically viable smelter size. New developments usually hinge on the capture and, if possible, the profitable use or marketing, of certain noxious associated products such as sulphur. This opens up for the developing-country producers an opportunity of attracting smelters of the old type, provided that they are ready to accept the offensive emissions of those, which many of them seem reluctant to do. The more complex technological circuits and marketing patterns of the new types of smelters, on the other hand, seem to favour location in the developed countries. The technological innovation that seems to make progress everywhere is flash smelting in its many forms.

5.4. Tin

The major uses of tin can be conveniently divided into three categories, tinplate, tin alloys /including solders and bearing alloys/ and other uses. In each of these, the quantity of tin in the finished product tends to be rather small tonnagewise and mostly also percentagewise /the tin content of tinplate produced by the electrolytic process can be as low as 0.25 weight percent/. Hence, in considerations whether or not a given product incorporating tin is to be manufactured for export in a developing or a developed country, it is almost invariably the other components present /steel in tinplate; lead in solder; copper in bronze, gunmetal and brass; antimony, copper and lead in bearing alloys/ that have the decisive word to say. Products to be recommended for export by developing-country producers of tin are those with a high tin content /solder and certain other tin alloys/. There is, on the other hand, a substantial need for tinplate in many African countries, most of which produce large quantities of tinned foods for export or for domestic consumption. Satisfying this need with tinplate produced in Africa could be a fairly obvious item of collective self-reliance.

5.5. Some general considerations

It is clearest in the case of copper and aluminium that tariffs in the developed market-economy countries still play a major role in determining that point of the technological chain at which it becomes more profitable to locate downstream operations in the developed importing rather than in the developing exporting country.

By implication, African producers, and developing-country producers at large, of semifinished non-ferrous metal products can well become competitive in markets which erect no such tariff barriers. By corollary, there is a major case for an all-African or at least subregional trade policy which permits to boost intra-African movements of metals and semis. By extension, similar policies could open up other developing countries' markets for metals and semis produced in Africa.

6. World economic climate for metals in the 1980s

6.1. General

Direct demand for metals /e.g. for aluminium in housing/ and most of derived demand /e.g. the demand for tinplate, which is controlled by the demand for certain types of food/ is overwhelmingly influenced in the current world economic situation by economic climate in the developed countries in the world and, more specifically, in the developed market-economy countries because the centrally planned economies are rather more self-sufficient in metals.

It is a matter of near-general consensus that the outlook for economic growth in the developed market-economy countries is far from bright, and that the growth rates in the vicinity of 5 % per year, chalked up in the 1960s and 1970s, will be replaced in the foreseeable future by growth rates of 2.5 % per year or less. The downward adjustments in metallurgical investment following this realization have not by far been fully put into effect as yet: the result has been a wide disparity between capacity and demand at one time or another for most metals. Copper seems to emerge from the doldrums of this adjustment process, while iron and steel are beset by grave problems which can be expected to get considerably worse before they get better. Only tin and, to some extent, aluminium have been spared so far, for specific reasons that it would take too long to examine here. These days, however, "for the first time in more than five years the tin price is within sight of the tin agreement's lower range /M$27.28-30.01 a kilo/, where the buffer stock manager has to defend the floor." 1/

The overall pattern thus characterized is made up of a number of major and minor components, some of them conflicting. It is worth our while to consider the major ones in more detail.

1. Despite demand constriction, a great deal of capacity expansion may be taking place. In iron and steel e.g., the major problem plaguing the traditional developed-country producers is competitior by recently built, superior facilities in Japan and in some developing countries such as South Korea.

2. There has been a substantial profits squeeze almost everywhere in metallurgy, what with inputs /ores and energy and, in many instances, labour/ becoming more expensive and markets remaining sluggish. Profits are therefore largely confined to the downstream sectors, such as semifabrication in copper and aluminium, machinery and equipment in iron and steel etc. This is one of the reasons for the dwindling resistance in the developed market-economy countries to the location /"redeployment"/ of new metallurgical facilities in the developing world.

3. What with the gigantic size new facilities have to be to stand a fair chance of competitiveness world-wide, smaller incre-

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1/ Flat tin. Key indicators: Commodity prices. The Economist, January 24, 1981, p. 83.

ments in mining and metallurgical capacities come increasingly from the expansion of existing facilities, conferring better economies of scale on those and, making better use of their existing infrastructure, costing much less investmentwise. This is a factor that, opposed to the foregoing one, tends to increase rather than to decrease concentration in metallurgy.

4. Fear of the "commodity power" of the developing countries, on the wane recently, and the persistent fear of expropriation and "creeping nationalisation" /of changing the terms of an agreement unilaterally once the facility to which it relates has come onstream/ have redirected the main thrust of prospection and exploration for ores towards the countries of the "capitalist fringe" /Australia, Canada, the US, to some extent South Africa/ and the developing countries that seem to offer the best security of investment /e.g. Brazil/.

5. The financing of new facilities is being done at greatly increased debt/equity ratios: where 40 or 50 % debt was the rule only a decade ago, 85 % debt is not uncommon today. Together with the increase in international liquidity due to the necessity of petrodollar recycling, this has given banks and other sources of finance a greater say in deciding upon new investment than before, reducing thereby the role of the specialized mining and metals transnationals.

6. The profound changes in the criteria defining the world economic optimum of an operation /the greatly increased cost of energy and of pollution control, where applicable/ have created a need for changes in technology, required to maintain competitiveness. As before, such technology is largely available from the most advanced countries/corporations only. This and the need for increasing volumes of investment finance make it practically impossible for the developing countries to dispense with the TNCs and banks of the developed market-economy countries in export-orientated metallurgical investment, and the situation of investment projects aimed at the domestic or regional-subregional markets is not much better, either. 1/

As a prominent feature of recent evolution in metallurgy, there has been a constriction of profits, especially in ferrous metallurgy, which has tended to deflect private-sector enterprise and finance from some, although of course not all, metallurgical projects. But since metals are indispensable inputs to most other industrial and non-industrial projects, including those in which private-sector finance continues to be invested, it has become one of the major concerns of the state to assure the availability of such inputs - as witness the nationalization, or construction under state ownership to start with, of ferrous metallurgy facilities in more and more countries of the world. We call this phenomenon, analogous to what happened to the railroads in the late 19th and early 20th century, <u>the infrastructurization of metallurgy</u>. The fact that metallurgy in Africa is growing up and coming of age as a state /government/ concern is in keeping with this overall tendency.

1/ The CMEA countries offer the only alternative source of a full range of mining and metallurgical know-how.

In sum, the climate for metallurgical investment in the developing countries looks perhaps less clement for the decade ahead than it has over the past couple of decades. Within this gloomy overall picture, more hope can be seen for individual metals such as tin or aluminium, and for individual countries /the most rapidly industrializing and the most developed developing countries with their larger domestic markets and greater capacities for absorbing technology and investment/. This implies that there is no reason for giving any sort of blanket encouragement to world-market-orientated metallurgical development in the developing countries: every case, every project will have to be judged strictly on its own merits. But this is hardly a novel feature.

6.2. The African setting

Forecasters agree as a rule that Africa's economic development up to 2000, starting from a low base in 1975, is going to be relatively slow as compared with the rest of the developing world.

Each of UNIDO's three forecasts implies Africa to have the smallest share of world manufacturing value added /MVA/ of all the developing regions.

Table 21

	1975	2000		
		historical	Lima target	high-growth
	per cent of world total			
Developed countries	91.5	86.1	74.3	76.2
South and East Asia	2.4	5.1	9.5	7.4
West Asia	0.5	1.0	1.8	1.7
Latin America	4.9	7.1	13.0	13.2
Africa	0.7	0.7	1.5	1.5

Source: UNIDO: World Industry since 1960: Progress and Prospects.

As regards growth rates and rates of industrialization, Africa splits up in two major regions: Africa North and South of the Sahara. In Africa North of the Sahara, growth rates and rates of industrialization are forecast to be higher, not least owing to the oil and gas wealth of several countries of that sub-region.

Table 22 reveals how small today's per capita consumption of most metals in Africa is, in relation to the other world regions.

Table 23 implies that African demand in the year 2000 can be satisfied by adding two or three of the largest-sized production units in use today to the capacities now existing and being built; three five-million-ton or five three-million-ton integrated steelworks, one 150 000-ton aluminium smelter complex or three 50 000-ton ones, one 100 000-ton copper refinery etc. The obvious implication is that, given the size of the continent and the logistics of metal transportation, reinforced by national strivings towards self-reliance /to the extent that this makes sense/ in the principal basic materials of industry, technological developments permit-

Table 22

Consumption of selected metals by world region
kilograms per capita

	world average	USA	Japan	UK	South America	Africa
steel	250	650	650	450	50	20
aluminium	13.5	20	10.5	9.6	0.4	0.02
copper	2.4	10.8	8.8	11.5	1.0	0.02
lead	1.0	5.7	...	6.9	1.0	1.5
zinc	1.2	5.9	...	7.0	0.6	2.4
tin	0.06	0.25	0.26	0.40	0.02	0.01
nickel	0.02	0.70	...	0.62	0.01	0.02

Source: G.J.S. Govett - M.H. Govett: World Minerals Supplies - Assessment and Perspective. Developments in Economic Geology 3, Elsevier 1976.

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ting economic viability at smaller plant sizes than the above-named will be of particular interest for metallurgical development in Africa; alternatively, strivings for autarky or misjudgement of domestic or subregional markets may give rise to oversized and therefore unviable investment projects.

African demand for metals in the past and in the future

	1951-55	1956-60	1961-65	1966-70	1971-75	1985*	2000*
	historical figures					forecast	
Crude steel, million tons/year	1.29	1.87	2.49	3.12	4.90	15.0	15.0-16.0
per cent of world consumption	0.6	0.6	0.6	0.6	0.8	0.8	1.0-1.2
Aluminium, primary, thousand tons/year	0.96	1.92	7.06	19.12	39.92	65.0	160.0-167.0
per cent of world consumption	0.04	0.05	0.1	0.2	0.3	0.3	0.4
Copper, refined, thousand tons/year	5.70	7.68	11.54	9.46	20.80	38.0	71.0-111.0
per cent of world consumption	0.2	0.1	0.2	0.1	0.3	0.3	0.4-0.6
Zinc, thousand tons/year	0.60	1.68	5.28	16.18	24.48	38.0	46.0-71.0
per cent of world consumption	0.02	0.06	0.1	0.1	0.4	0.5	0.3-0.6
Tin, thousand tons/year	1.22	1.34	1.68	1.52	1.78	7.0	10.0
per cent of world consumption	0.8	0.7	0.8	0.7	0.8	2.3	2.5

*) The 1985 forecast is from Malenbaum 1978. The forecast range for 2000 has been derived by combining Malenbaum 1978 and Malenbaum et al. 1973.

Source: Malenbaum, W., World Demand for Raw Materials in 1985 and 2000, E/MJ Mining Informational Services, McGraw-Hill, Inc., New York, 1978, and Malenbaum, W. et al., Material Requirements in the United States and Abroad in the Year 2000, Washington, National Commission on Materials Policy, 1973.

Table 23

7. Major recommendations for metallurgical development in Africa

It is very important to emphasize, as it has in fact been done tacitly or outspokenly in the development plans of some African countries, that metallurgy is a system and that, therefore, planning its development must use the systems approach. This is self-evident for each metal in itself, but there is more to it than just that. In fact, the different metals are more or less linked together, even if one of them is produced by a huge enclave industry /such as, e.g., the copper industry in Zambia/. A country which has a sizeable market for iron and steel will of necessity require tinplating, copper wire and cable, lead for battery regeneration, zinc for die-casting etc. The demand for non-ferrous metals can even be predicted more or less confidently by taking as a basis the size of iron and steel consumption. Also, the metallurgies of the various metals are tied together in that they require similar training in professions and skills, similar backstopping facilities such as workshops, procurement or domestic production of investment goods, similar siting and transport patterns, laboratory and testing facilities, much the same investment per ton of output, similar approaches to planning and marketing, etc. This gives rise, among other things, to the important converse implication that no metallurgical giant should be created, if it is at all avoidable, in a country where there is no background industry in other metals. The cases where this has been done in the past have led to distortions in economic structure, to enclave-type and monoculture-type economies with all the attendant problems.

The systems approach must be followed also in linking up metallurgical projects with the relevant infrastructural and other necessities. On the one hand, a land-locked country which happens to be far away from tidewater may find it difficult if not impossible to find takers for its ores and other raw materials, even though they might be no worse or in fact better as to grade than those currently being traded in the world markets. On the other hand, in such a geographical setting, there is a strong incentive for import substitution because the delivered price of steel and metal ingots, semis and finished products can be twice as high or more as their prices cif the nearest seaport. That is, distance from tidewater promotes import substitution as much as it hampers export orientation. In such a setting, then, an import-substituting metallurgical operation may save a great deal on local currency and, what is even more important, also a great deal on the hard currency account.

Another issue where the systems aspect comes to the fore is the regionalization of markets. It was pointed out above that the markets of most African countries are not large enough to provide outlets for even the least viable sizes of metallurgical plant, and that only the largest and/or most industrialized African countries do in fact have markets of the required size. The answer is the joining of several countries into subregional groupings, so as to constitute markets that are already large enough. It is, however, imperative that the advantages of doing so be realistically assessed and that false hopes be avoided. An African country importing, say, copper semis from another African country which is producing them for export cannot expect to pay less than the ruling world market price, the price that it would pay to any overseas supplier, whether developed or developing. There exists, however, the possibility in any region to pay for such deliveries in goods as the buyer of the copper has and the seller of the copper wants. In this way, some hard-currency expenditure can be short-circuited, and the intra-subregional exchange of goods will reduce the overall hard currency expenditure of the subregional grouping. There is, of course, also an economy-of-scale advantage: a larger plant working into a more extensive market can produce a unit of output more cheaply. Some freight cost may also be saved, and mutual tariff advantages may be secured. In this, as in many other respects, African countries may be recommended to study the experience of the CMEA group of countries.

It is precisely the systems aspect of the basic metals industries that tends to be immature in most developing countries, and perhaps more so in the developing countries of Africa than elsewhere. One obvious and much-publicized aspect of this state of facts is the mismatch between mining output and the output of the higher value-added stages of processing, often to the extent where the basic metals demand of an important metal mining country must be met by imports from the developed world. A less familiar but just as important aspect is the mismatch between the available development potential in metals on the one hand and the available investment finance, market capacity, human resources etc. on the other.

The underlying tendency in the development of basic metals industries in Africa must therefore be an organization and systemization of hitherto inorganic and unsystemic /immature/ industries. From this basic statement, a number of important conclusions and recommendations follow.

An issue of major relevance is the shortage of development finance in most African countries, due partly to insufficient finance-generating capacity in the domestic economies, partly to the inadequacy of aid, and partly to world market inflation and the steeply rising prices of some commodities, petroleum and refinery products in particular. Extreme austerity is therefore the password in most developing countries. This has two implications:

- in metallurgical development, the simple and straightforward must be preferred to the costly and fancy; waste resulting from underutilization of capacity due to an erroneous market assessment or to the non-availability of inputs must be avoided at all costs;

- the construction of new capacity must be preceded, wherever it is at all feasible and reasonable, by the rehabilitation of existing capacities, by the elimination of the bottlenecks giving rise to underutilization.

8. UNIDO's involvement in metallurgical development in Africa

UNIDO's metallurgical activities show a strong bias in favour of Africa. Projects currently in the pipeline involve finance to the tune of US$ 21.8 million, roughly twice as much as for Latin America and four times as much as for Asia and the Pacific or for Europe and the Middle East.

Of the 42 projects in the pipeline, 16 are foundry projects: two of these are associated with rolling mills and one with a forge. One project is concerned with charcoal-based iron-making; one with a mini rolling mill; four with the minerals base of a metallurgical project; the rest are of a more comprehensive nature, such as the preparation of master plans for metallurgical development, covering several countries of a subregion.

Whereas the above effort represents what is feasible given the current financial endowment of the Metallurgical Industries Section, and may be characterized as offering help where the shoe pinches most, there are several obvious ways in which this activity might be broadened, notably by placing more emphasis on

- charcoal-based iron-making,
- mini rolling mills,
- ferroalloy making,
- the making of welding electrodes, and
- non-ferrous metals at large.

As regards UN activity as a whole, it may be recommended that it, too, be rendered more organic and systemic. Currently, mineral prospecting and beneficiation activities are the responsibility of UNDP and UNRFNRE, also DTCD /the Department of Technological Cooperation for Development/ and to some extent of Unesco, whereas metallurgy and basic transformation is the responsibility of UNIDO. The first three reside in New York, the fourth in Paris and the fifth in Vienna. Even with the best of will, this situation is liable to result in insufficient coordination, lack of information, waste and missed opportunities. If we stop to consider that, moreover, any project must be initiated by host governments and cleared through local resident UN personnel, we must realize how extended the chain of information and decision-taking really is. There must be room for much improvement here.

Even more progress, however, can be expected of UN-sponsored <u>complex programmes</u> of basic metals industry development, such as:

- comprehensive government-level planning assistance covering the entire basic metals field,
- identification of the main thrusts of geological activity and UN-sponsored assistance thereto,
- assistance in the planning, projecting and running of metallurgical operations at all levels, including the better utilization of existing capacities and the construction of new ones;

- assistance in market research including the forecasting of the behaviour of domestic and foreign /also subregional/ basic-metal markets,
- assistance in decision-taking concerning development priorities; more specially, in decisions involving choice between import substitution and export-orientated growth.