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Development of the Minerals Cycle and the Need for Minerals

CRU International

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Development of the minerals cycle and the need for minerals

A report prepared for the International Institute for Environment and Development

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Chapter 1: Portrait of the minerals cycle

1. Volumes of production

Minerals and metals come in all different forms. The volume in which they are used reflects both their scarcity and their value in use. Common metals and minerals can be produced cheaply because their prevalence enables them to be extracted from large deposits where economies of scale can be obtained. Rare metals and minerals are expensive to produce because they tend to occur as trace elements even in those few deposits in which they occur at all. Common metals tend to be produced from ores where the principal recoverable metal constitutes a high proportion of the weight of the ore. Iron ore, for example, contains as much as 67% iron. For rare and precious metals, the volume of the recoverable metal may be measured in grams per tonne.

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Volumes and values of production of metals and minerals vary widely

	Volume (tonnes)	Value ($'000)
Finished steel	762,612,000	228,783,600
Refined copper	14,676,000	26,607,588
Primary aluminium	24,461,000	35,664,138
Primary lead	3,038,000	1,379,252
Refined zinc	8,922,000	10,304,910
Primary nickel	1,107,000	9,565,865
Molybdenum	543,000	3,113,678
Coal	3,400,000,000	136,000,000
Gold	2,574	22,336,854
Platinum	162	2,733,600
Phosphate rock	141,589,000	5,663,560
Titanium minerals	6,580,000	1,460,760
Fluorspar	4,520,000	565,000

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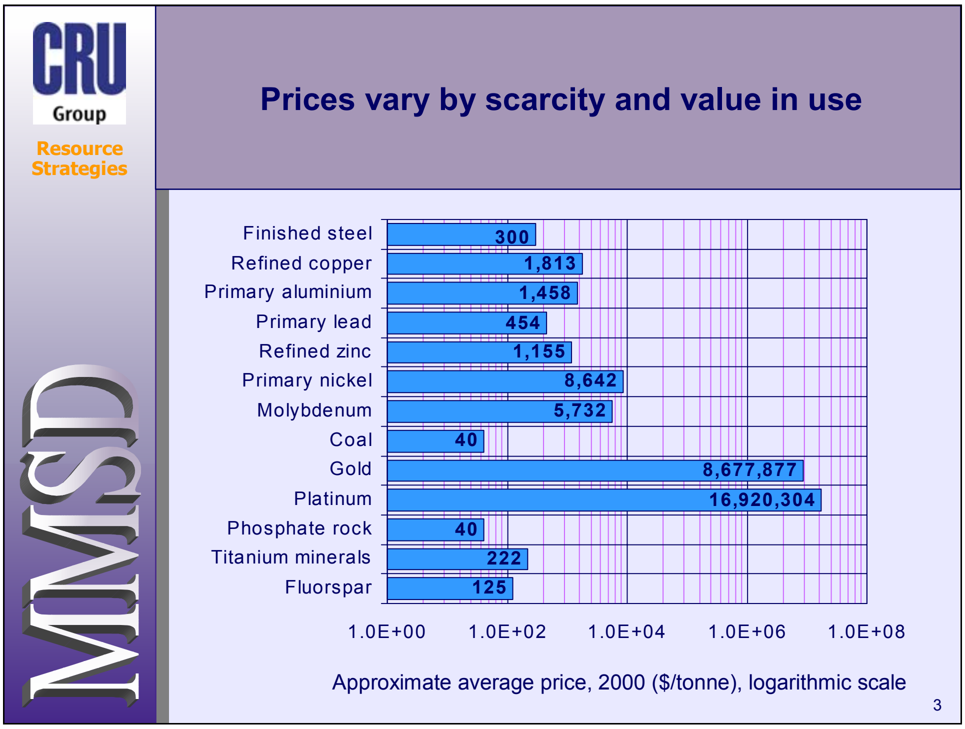
In order to demonstrate the diversity of the mining industry from the point of view of industry size, we have selected some examples, mainly from the world of metals, but also one energy mineral (coal), one fertiliser mineral (phosphate rock) and two industrial minerals (fluorspar and titanium minerals). Among these products, the volume of commercially recoverable metals and minerals ranged in 2000 from 3.4bn tonnes for coal to 162 tonnes for platinum. Among metals, iron, which is recovered mainly in the form of steel, is the largest in volume. Finished steel production was 763m tonnes in 2000, far dwarfing the 24m tonnes of aluminium, the largest non-ferrous metal in terms of volume. Platinum, moreover, is not the smallest in volume of all metals: there are numerous rare metals for which volumes produced are lower still than for platinum.

By value, the products also vary in magnitude of importance. The largest-value metal or mineral in the chart is finished steel, followed by coal. These are the only metals or minerals for which the volume of sales exceeded $100bn in 2000. Copper, aluminium, zinc and gold were all in the $10-100bn range, while fluorspar, at the other end of the scale, was well below $1bn in value.

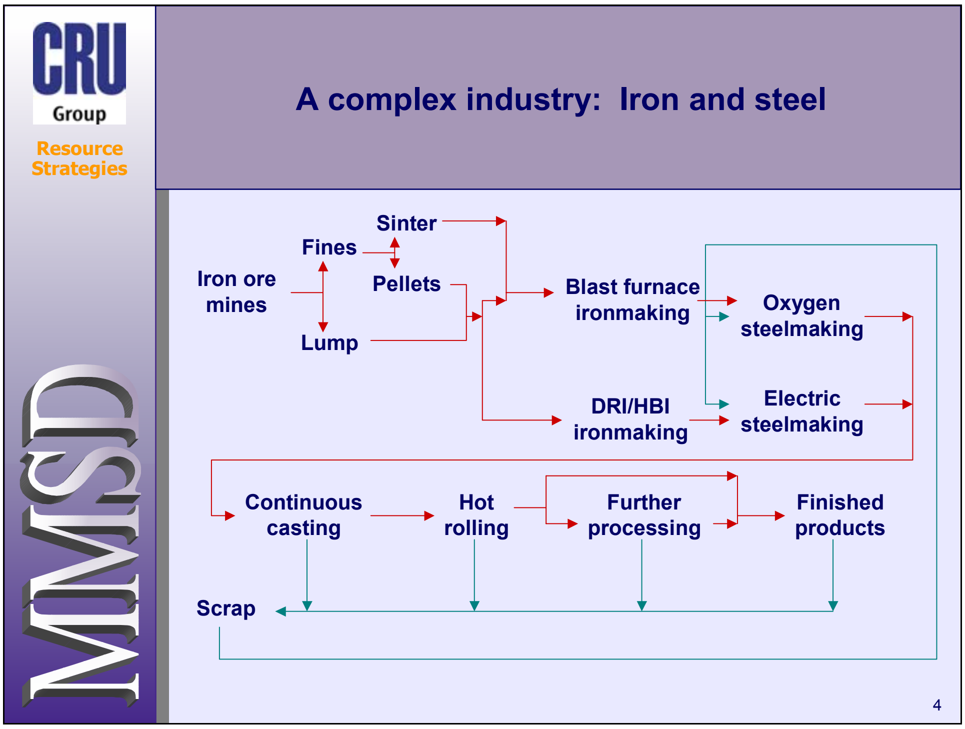


The prices of metals and minerals also vary considerably. Platinum prices averaged nearly $17m/tonne in 2000, while coal and phosphate rock averaged around $40/tonne. The prices of the major non-ferrous and precious metals are evaluated by their average value on commodity exchanges.

There is no terminal market for low-volume, and often heterogeneous, metals and minerals. Because transport costs are high relative to costs of production, moreover, the price of the commodities may vary significantly from one region to the next. The prices for finished steel, coal, phosphate rock, titanium minerals and fluorspar are all notional prices that are quoted merely to show the approximate position of each product in the value hierarchy. Actual prices may have been significantly higher or lower for each of these commodities in 2000, depending on the specification of the product and the location where it was consumed.

2. Mineral processing

There is also significant variation in the processes used to recover minerals. At the most trivial end, building stone can be quarried and used almost directly in its final use. Most metallic minerals must, however, go through a number of processing stages. Most minerals need to be crushed and concentrated. Metals need to be smelted and refined, and fabricated or otherwise converted into products that can be used. Scrap may also be recycled in the production of many metals. The next few slides show the diversity and different degrees of complexity of processing for selected minerals.



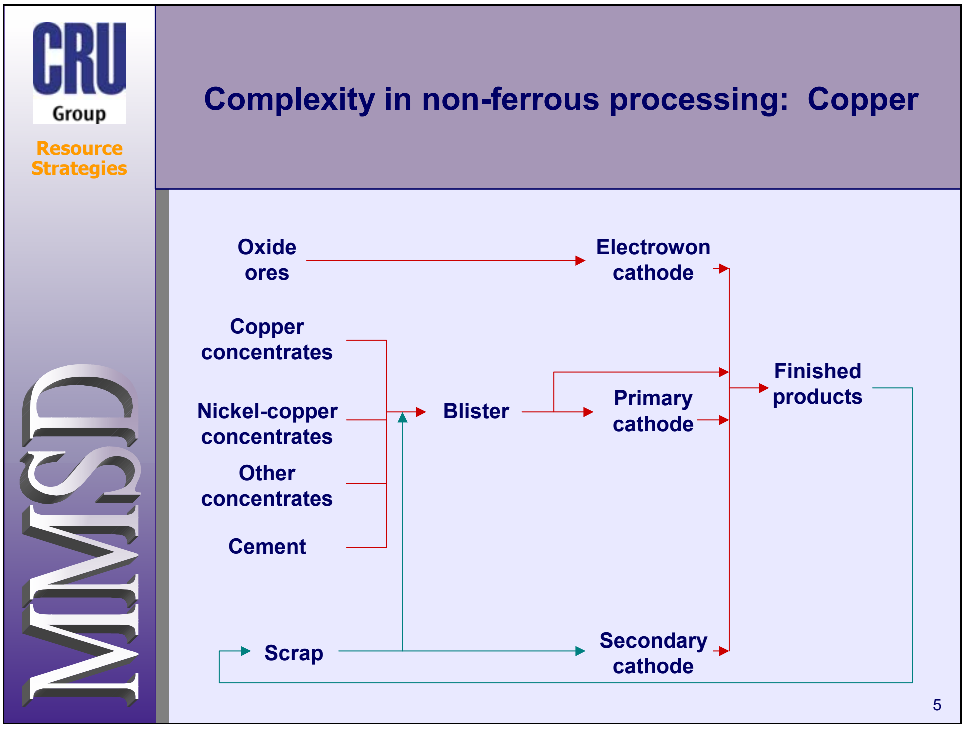
Iron and steel processing is complicated because there are three different grades of iron ore, two different production processes for iron and two different processes for steelmaking. Moreover, there is a long integrated chain of downstream processing from liquid steel, each stage of which generates scrap. This scrap is normally used in nearly all steelmaking operations.

Iron ore is screened into fine and lump ore. The fine ore is unsuitable for most forms of ironmaking without further agglomeration. It is normally converted into one of two agglomerated forms, sinter and pellets.

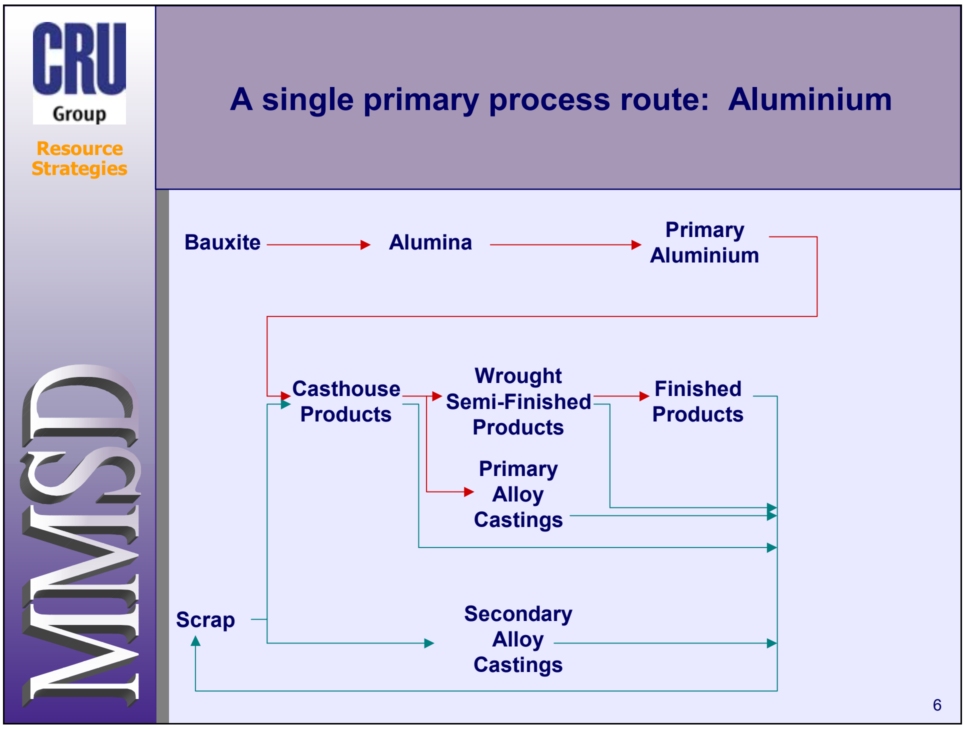
There are two main forms of ironmaking. The more common method is in a blast furnace, which can use sinter, lump and pellets in various blends. Less common is the production of direct reduced iron (DRI), or its briquetted form hot briquetted iron (HBI), which are normally produced from pellets although some lump can be used at times.

There are also two main forms of steelmaking. Basic oxygen steelmaking uses a mixture containing mainly hot metal (liquid iron) from a blast furnace, but also some cold metal, usually in the form of scrap, for temperature control. Electric furnace steelmaking uses DRI/HBI or scrap, or sometimes a combination of the two.

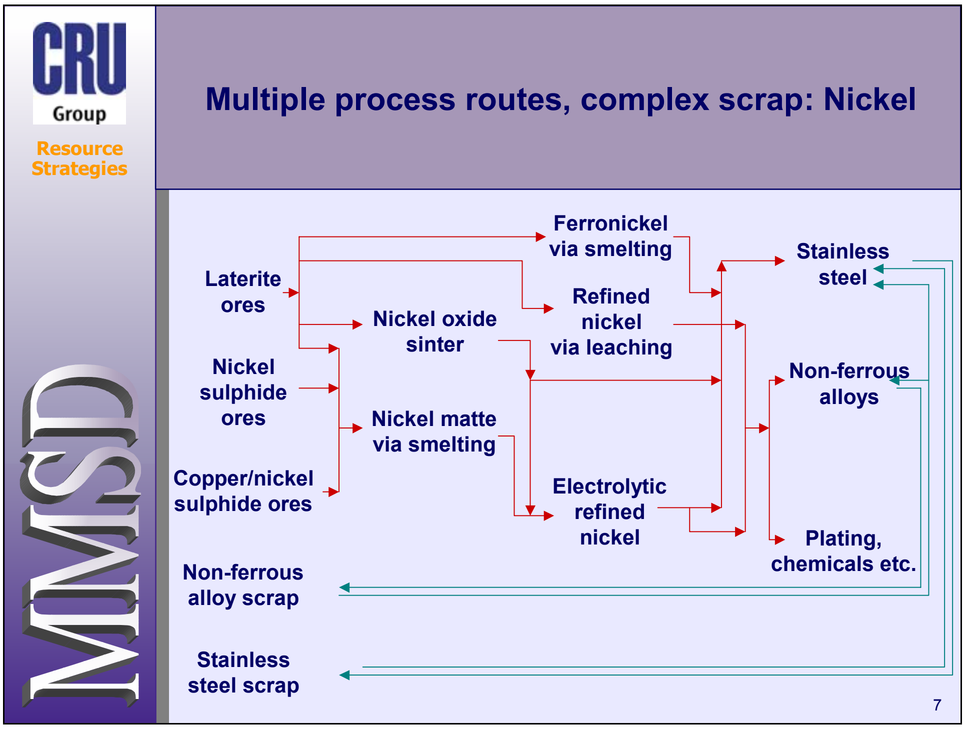
Scrap is generated at each subsequent stage of processing: continuous casting, hot rolling, further processing and fabrication. The scrap can be collected and used in steelmaking furnaces of both main types. In addition, steel scrap is collected for recycling from steel-containing goods that are no longer in use.



Copper can be obtained from a variety of mineral sources. The most common sources are copper concentrates and other sulphide ores. These can be smelted, sometimes along with low-grade scrap, to form an impure copper intermediate called blister. Small volumes of blister may be consumed directly in finished products, but most is electrolytically refined to produce primary cathode. Another route to cathode comes from oxide ores, which can be processed by solvent extraction into electrowon cathode. Scrap generated from fabrication or finished products can be recycled to smelters, if low-grade, to produce blister or directly to secondary refineries, if high-grade, to produce secondary cathode.



Primary aluminium, by contrast, is produced almost universally by a single simple process: refining bauxite to alumina and reducing the alumina to aluminium metal at a smelter. The only complexity in the flowsheet comes from the generation of scrap, which is generated at various downstream stages. Scrap may be blended with liquid aluminium from the smelter to produce primary casthouse products, or it may be used on its own to produce secondary castings.

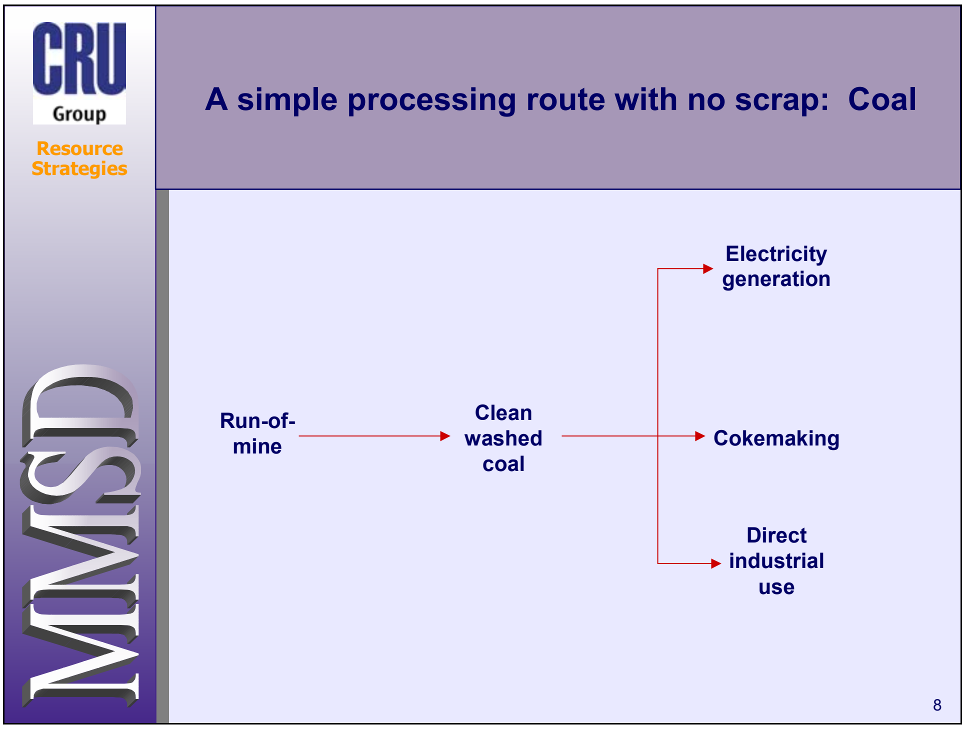


Nickel has a more complex flowsheet. Ores may be either laterites or sulphides, and finished products may take the form of refined nickel of various purities, of nickel oxide sinter or an iron-nickel alloy called ferronickel. Each nickel plant has its own unique flowsheet, so that the scheme shown here is perhaps over-simplified.

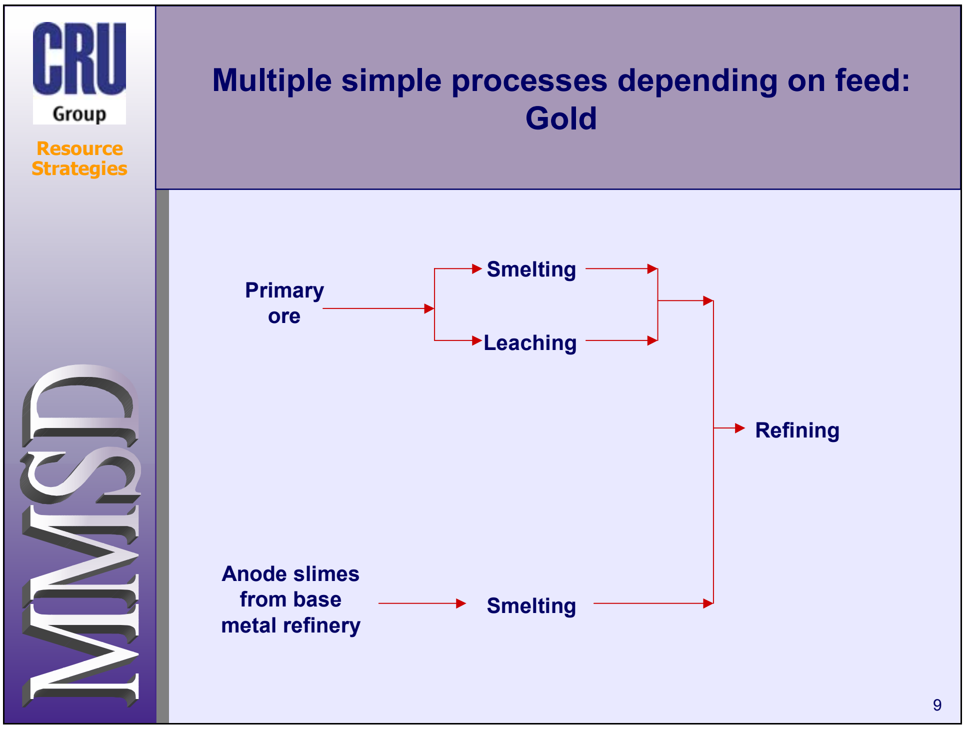
Laterite ores can be smelted into ferronickel, leached into refined nickel, converted into nickel sulphide matte or smelted into a nickel oxide sinter. Sulphide ores are usually converted into a sulphide matte and then refined electrolytically. Nickel oxide sinter may be consumed directly or refined electrolytically.

All main finished products can be consumed in the production of stainless steel, which is the most important single application for nickel. Only refined nickel can be consumed in non-ferrous alloys, plating, chemicals and other finished products.

There is also an indirect scrap cycle for nickel. There is little recycling of nickel as such. However, stainless steel may be recycled back into stainless steel, and non-ferrous alloys likewise into non-ferrous alloys. Some of the nickel in non-ferrous alloys, especially post-consumer scrap, may instead be recycled into stainless steel.



Coal has a simple flowsheet. Run-of-mine ore is typically washed at a preparation plant to remove ash and other undesirable compounds, and then shipped directly to power stations, coke plants or industrial consumers. Since the coal is either burnt or carbonised in use, there is obviously no recycling.



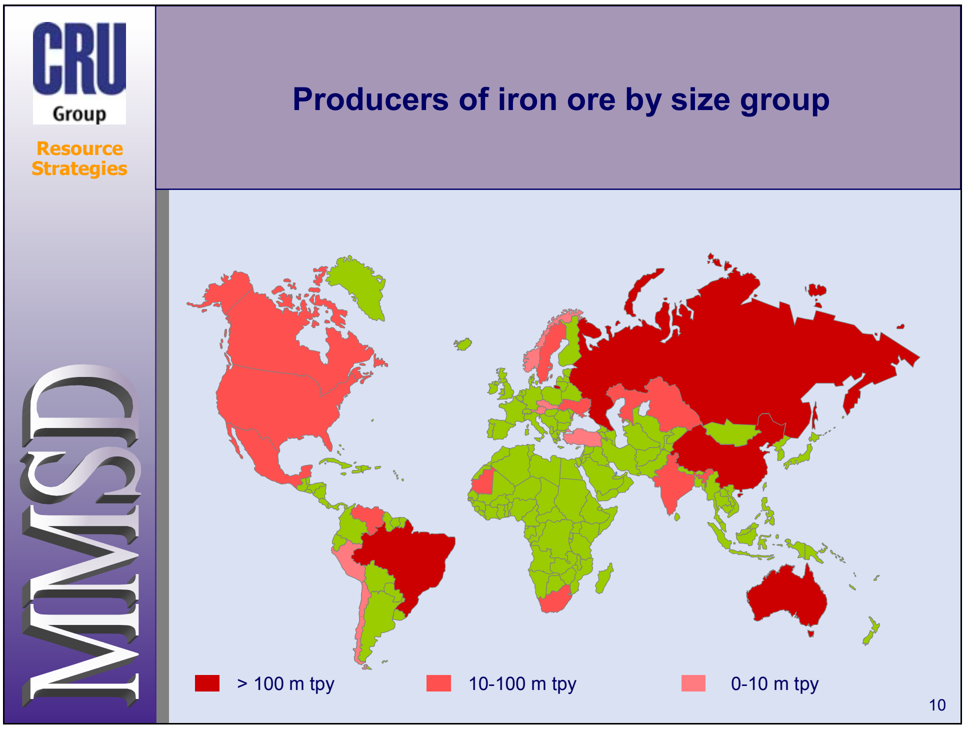
Gold production consists of a few simple processes but the flowsheet used depends mainly on the raw material feed. Primary gold ore is normally smelted or leached and then sent to a refinery. Alternatively, gold may be recovered from the anode slimes generated as a by-product of base metal production in an electrolytic refinery. These slimes are always smelted and the intermediate product is then refined. Although there exist secondary refineries for the recovery of metal from unwanted jewellery, coins and so on, most gold tends not to require recycling.

3. Location of minerals production

The location of minerals production depends on where the minerals are found. Before the development of modern transport methods, minerals were most commonly produced in deposits in or near the main consuming regions. Sometimes, they were high-grade deposits, and sometimes low-grade. Nowadays, relatively cheap transport makes possible the globalisation of most mineral production, except for ores and minerals with an exceptionally low value in use relative to the transport cost.

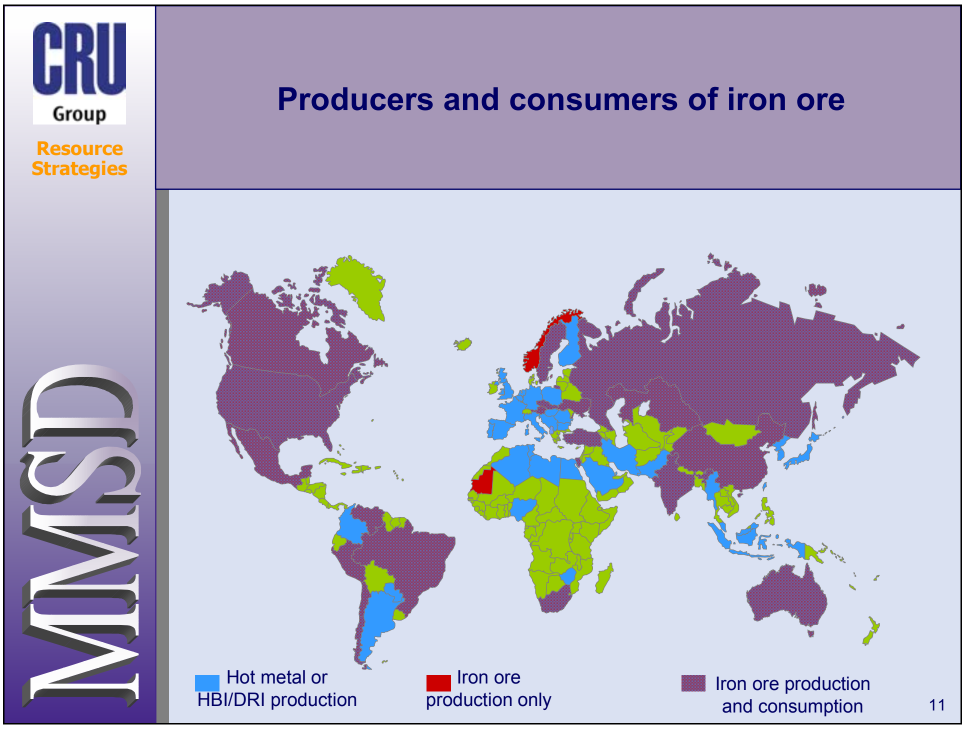
The major consuming countries can still be competitive in mineral production if they have ample deposits of high-grade ores. However, the high-grade ores in these countries typically have been the first to be depleted. As a result, there has been a gradual migration of the sources of ores from the main consuming countries to more distant producing countries.

In general, countries that have a large surface area tend to have high levels of mineral production, if only because the size of the country increases the probability of finding economically recoverable mineral deposits. However, large deposits of minerals can often be found in smaller countries, as well.

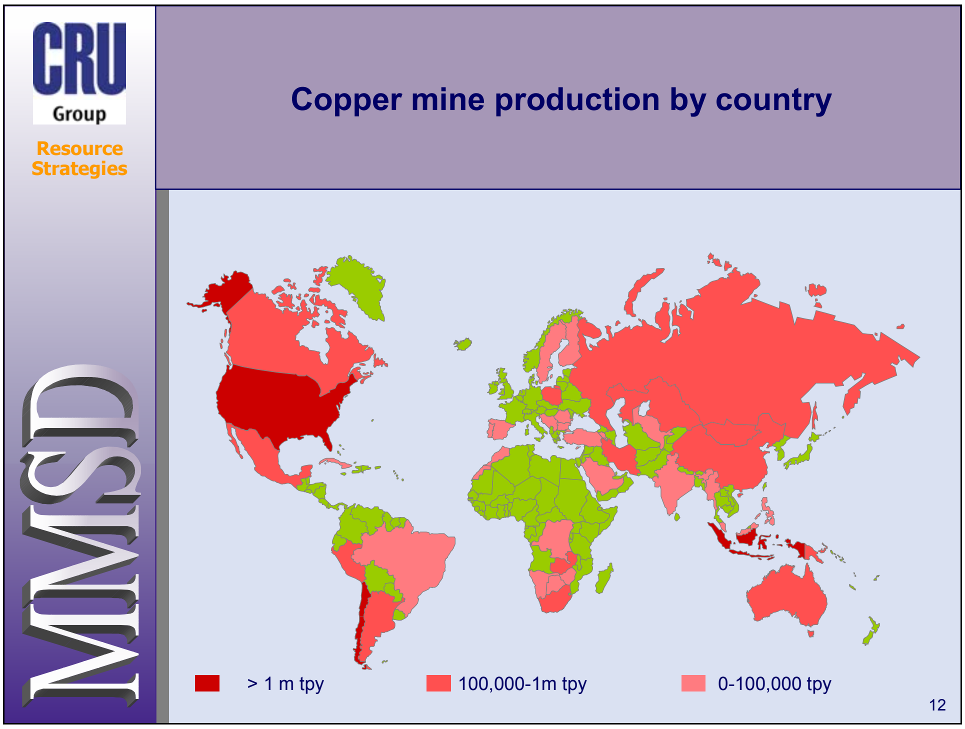


The big producers of iron ore are Brazil, Australia, Russia and China. Brazil and Australia are big export producers, while China and Russia tend to produce mainly for domestic consumption.

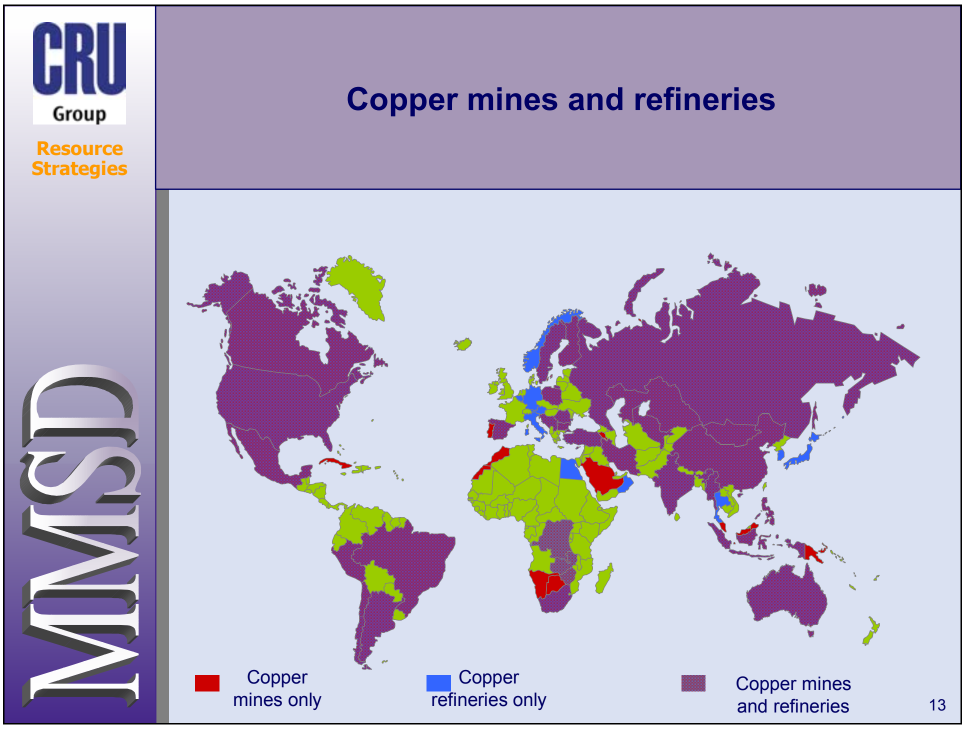
Production in Africa is confined to Mauritania and South Africa, while there is little production in South Asia apart from India. Sweden is the big producer in Europe. There is significant production in North America. In South America, production occurs in Venezuela, Peru and Chile in addition to Brazil.



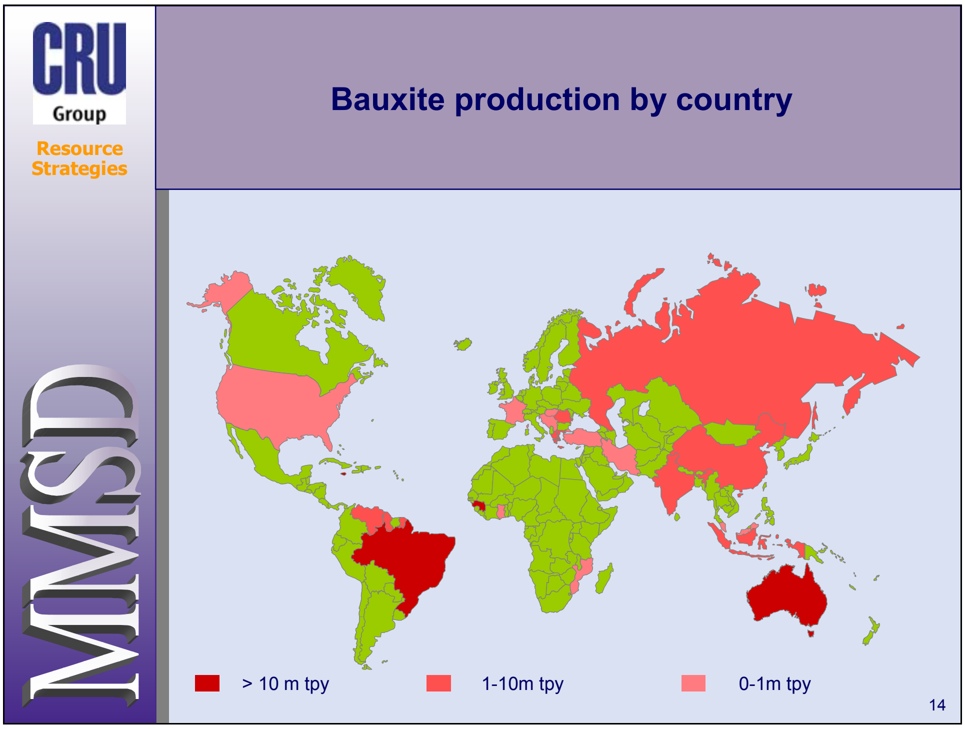
Most countries that produce iron ore also smelt iron ore in blast furnaces or in direct reduction plants. Norway and Mauritania are the only exceptions. Iron ore production and consumption are seldom in balance within any one country. Moreover, many countries that consume iron ore do not produce it. These countries include most of Europe, all of South and East Asia with the exceptions of China and India and several countries in South America and Africa.



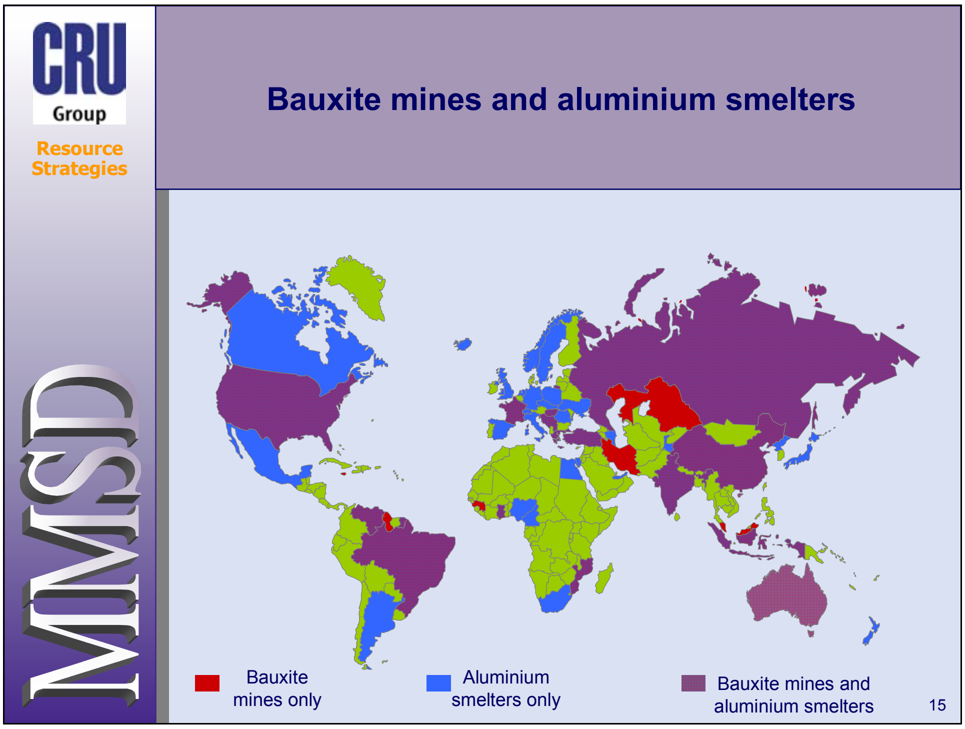
Chile is the biggest producer of copper minerals, and important producing countries also include the USA and Indonesia. Copper also can be found in many other parts of the world, although Europe and much of Africa are relatively poorer than elsewhere in the abundance of copper.



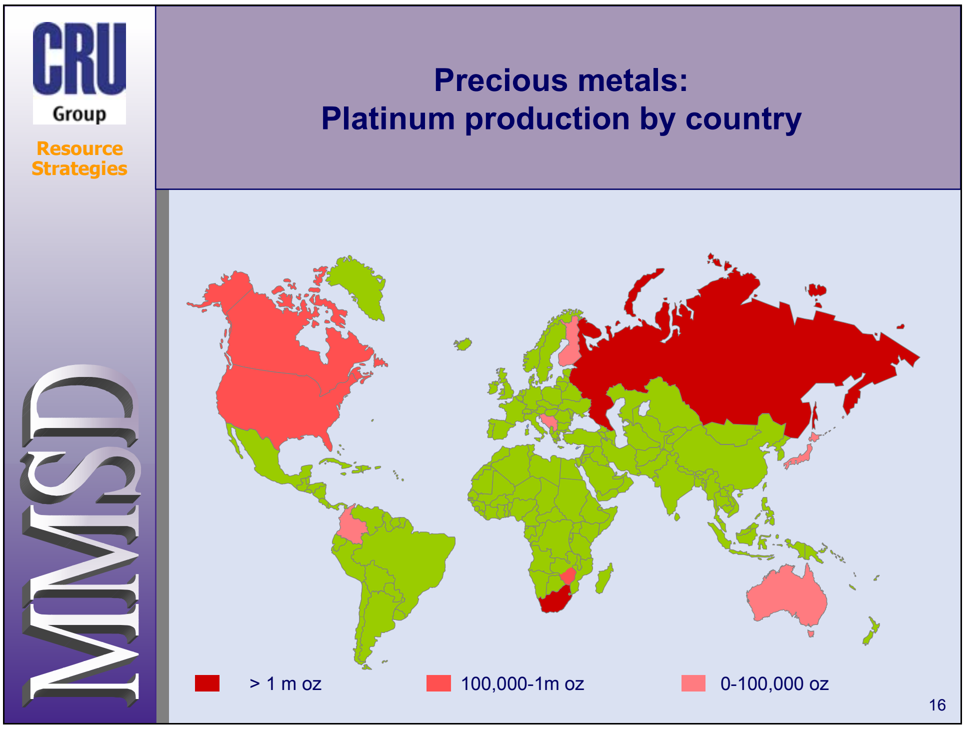
There is a high degree of correspondence between countries where copper is mined and countries where it is refined. Oxide ores tend to be refined *in situ*, but there is significant international trade in copper concentrates from sulphide ores. Only Morocco, Saudi Arabia, Namibia, Botswana and Papua New Guinea have copper mines but not refineries. Important countries with refining but no mining include Germany, Italy, Japan and South Korea.



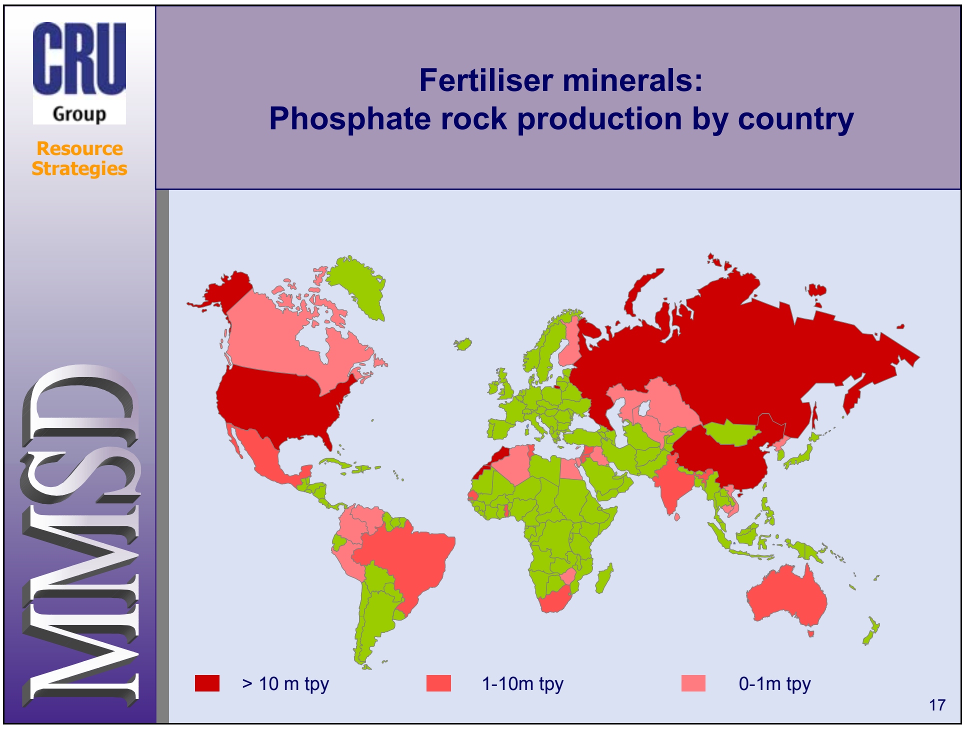
Bauxite, the main raw material for aluminium, is produced not only in big countries such as Brazil and Australia, but also in large volumes in tiny Jamaica and Guinea. There is little production, by contrast, in North America or Europe, or, apart from Guinea, in Africa. Even Asian countries tend to be only middling producers compared with the major ones.



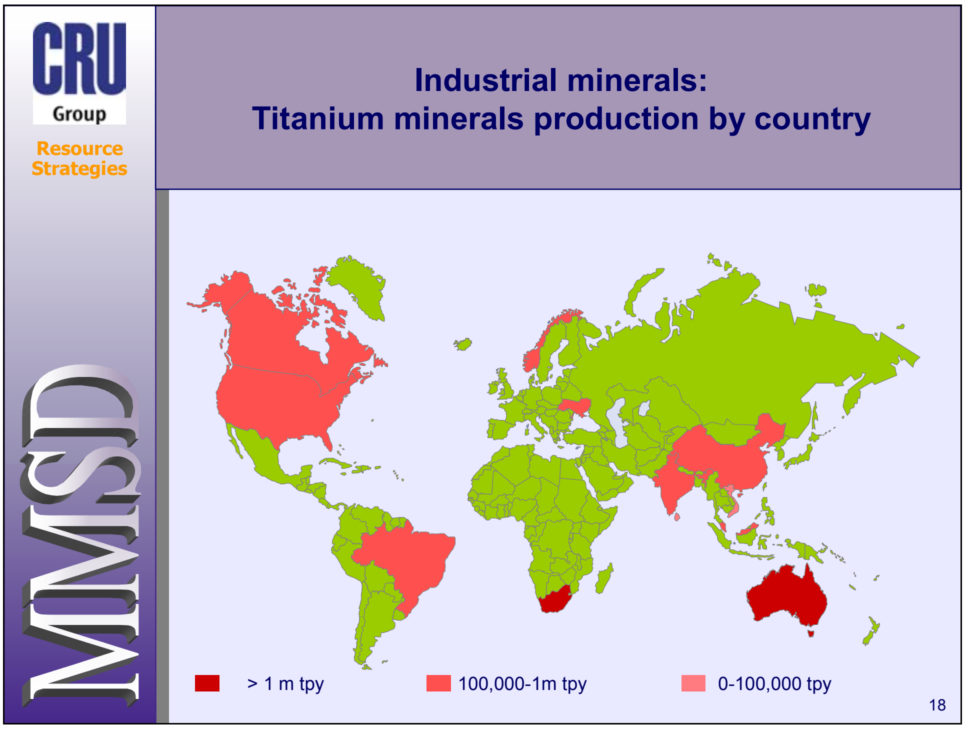
There is no necessary correlation between the location of bauxite mines and aluminium smelters, even though all the large countries have both. Aluminium smelters tend to be located in countries where electric power is generally cheap or in industrial countries where utilities have granted special power rates to aluminium countries.



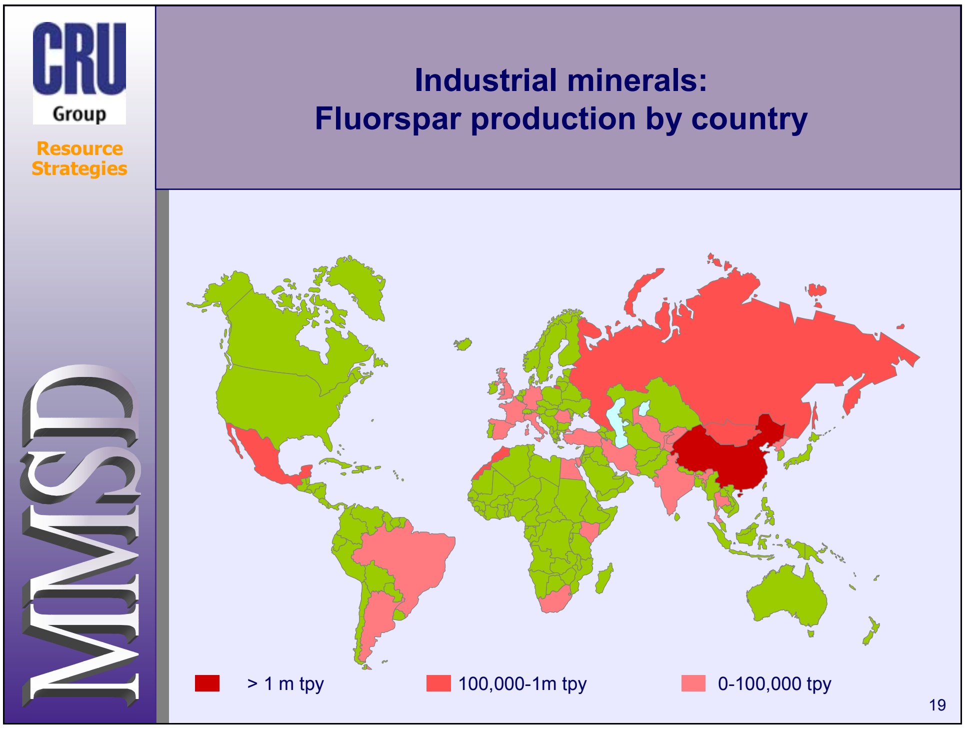
Few countries produce platinum. By far the biggest producers are South Africa and Russia. In South Africa, platinum group metals are primary products of mines, often with nickel as a by-product. In Russia, platinum group metals are a by-product or co-product of nickel production.



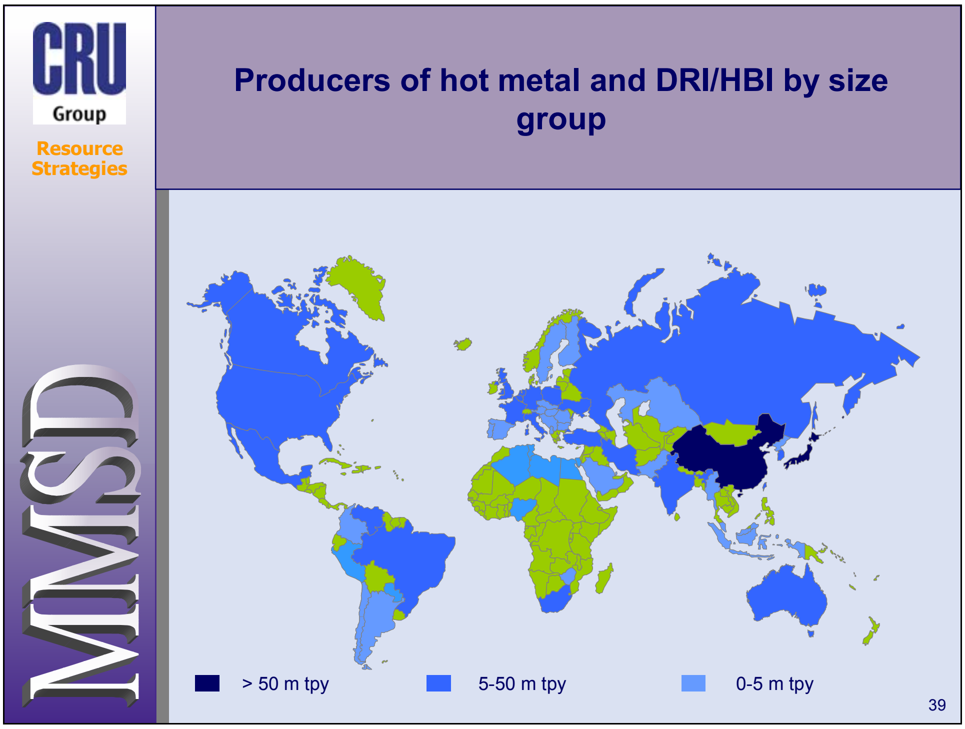
Three big countries - the USA, Russia and China - produce large volumes of phosphate rock, but so does Morocco. In Europe, phosphate rock is mined only in Finland.



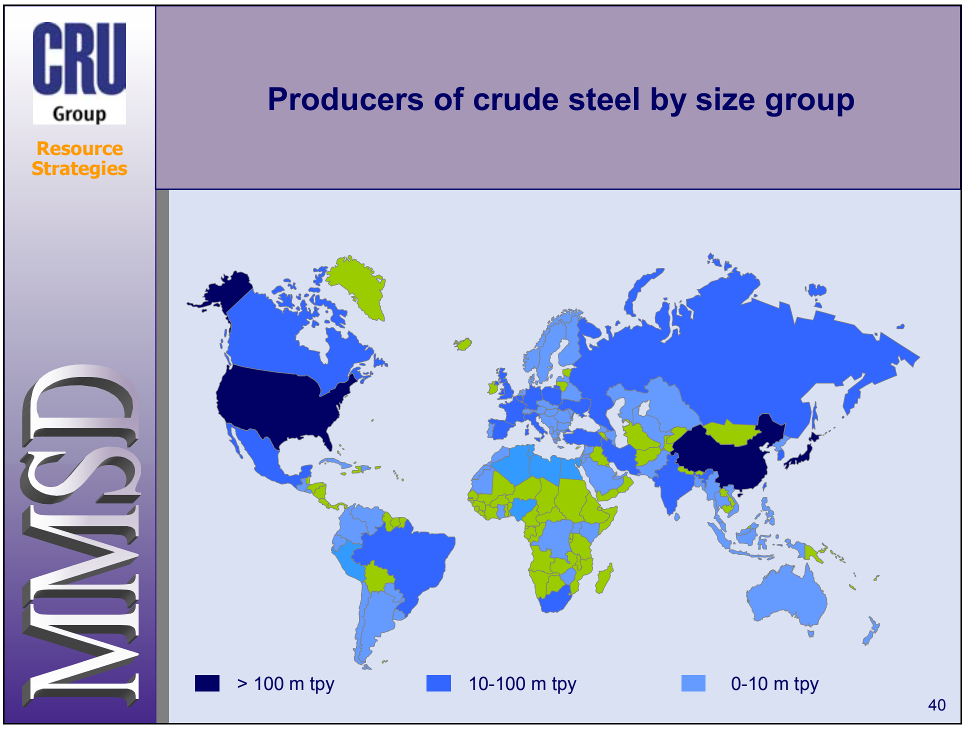
Titanium minerals are found principally in South Africa and Australia. The number of countries where titanium minerals is found is small, compared with coal or minerals of the major ferrous and non-ferrous metals.



China is the biggest producer of fluorspar. Other important producers include Mexico, Russia, Mongolia and Morocco. This mineral is not mined in the USA, Canada or Australia among the big countries. On the other hand, it is found at least in small commercial quantities in much of Europe.

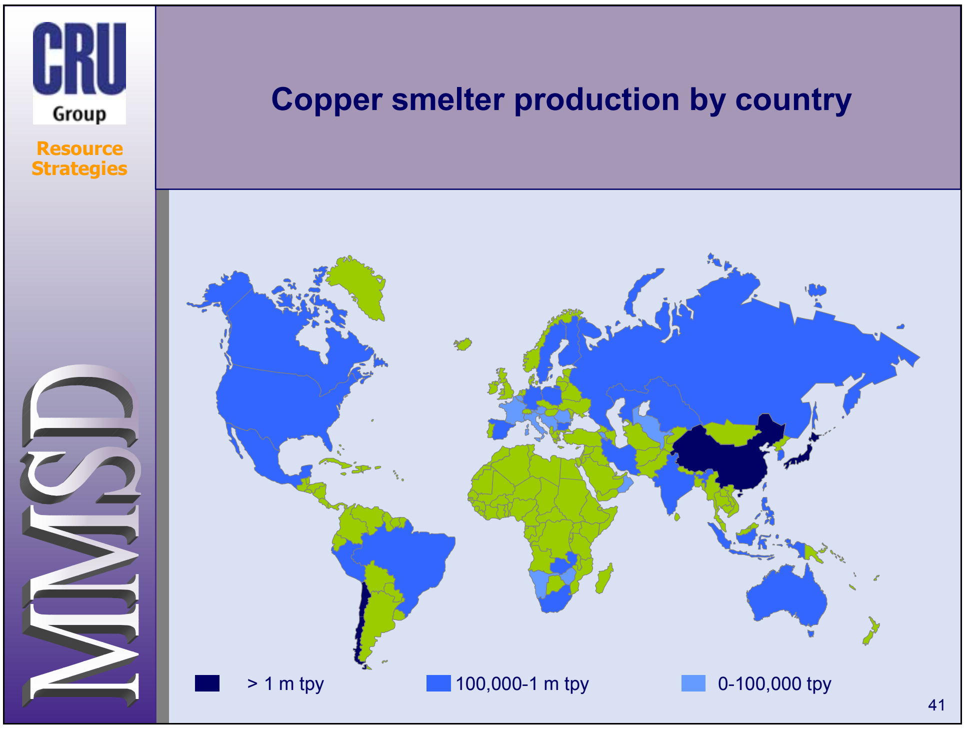


By country, China and Japan are by far the biggest consumers of iron ore. Other large consumers are spread throughout the developed world and also include some of the larger countries in the developing world - Mexico, Brazil, Poland, Ukraine, Russia, Turkey, Iran, South Africa and India. Venezuela is also a large consumer of iron ore, mainly because it is the largest producer of merchant HBI in the world.

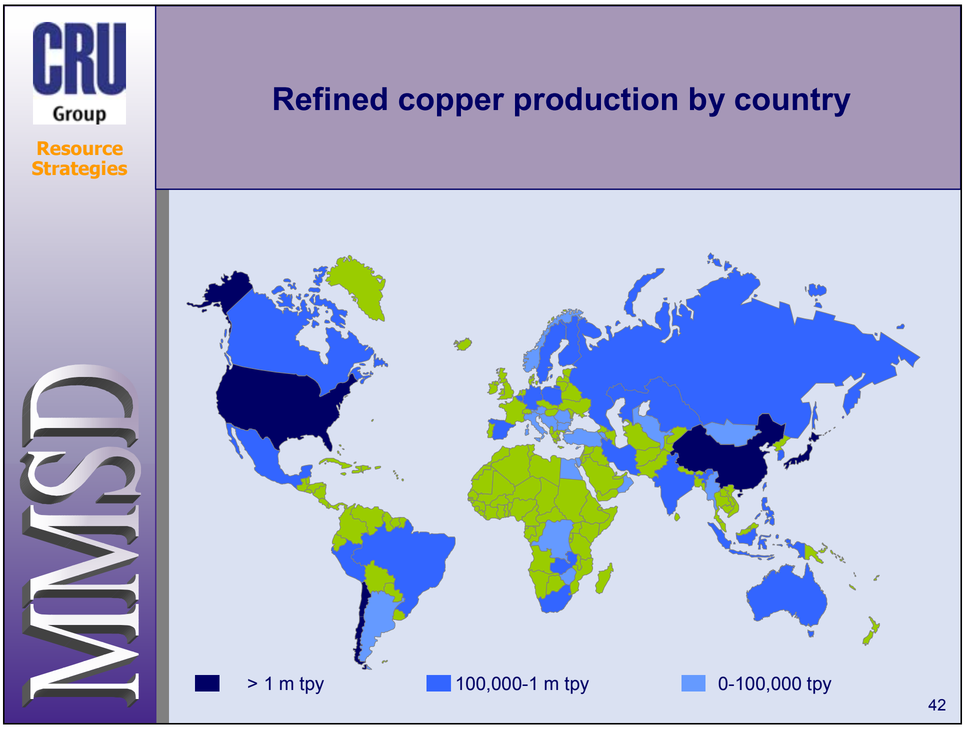


The picture of crude steel producers by country is broadly similar to the picture for iron ore consumers. A major difference is the inclusion of the USA alongside China and Japan as a huge producer. The USA obtains a greater proportion of the iron used in steelmaking from scrap, and hence its need for iron ore is smaller.

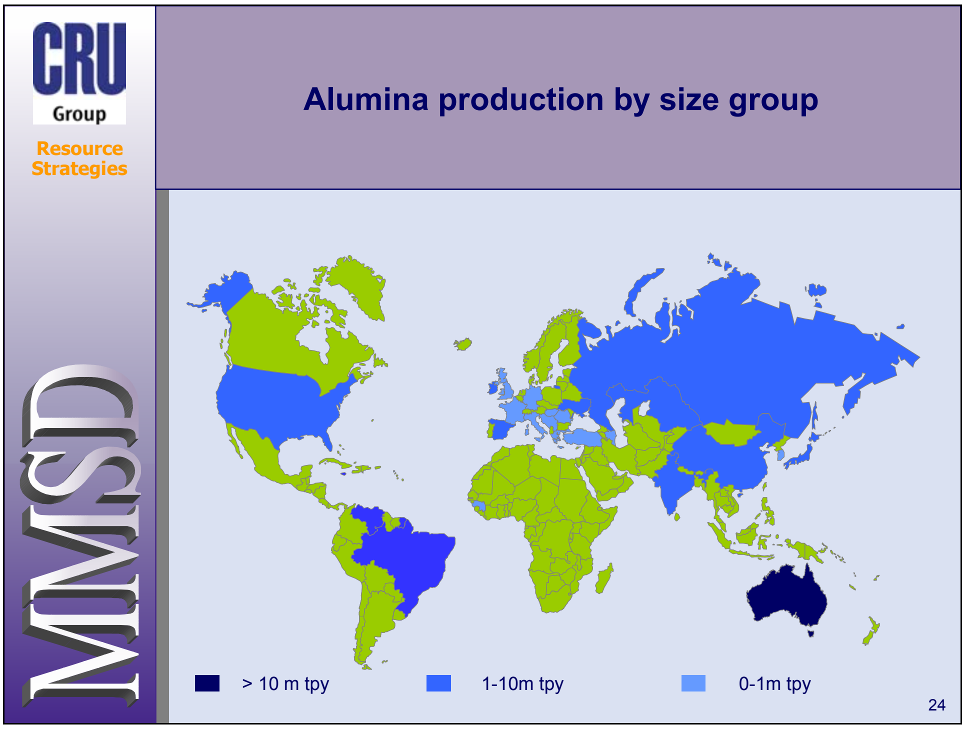
The number of countries that produce crude steel is much larger than the number that consume iron ore. Many smaller countries produce steel by the electric arc furnace method, using scrap as a feed, although they have no blast furnaces or DRI /HBI plants.



The three big producers of blister copper are Chile, China and Japan. Chile is the world's biggest producer of copper ore, while China and Japan are big consumers. Both China and Japan must import copper concentrates. Indeed, Japan has no indigenous copper production. Elsewhere, major smelting facilities are divided among countries that are major producers of copper raw materials (for example, Peru, Zambia, Indonesia), countries that are major consumers (for example, Germany) and companies that are both (for example, the USA).

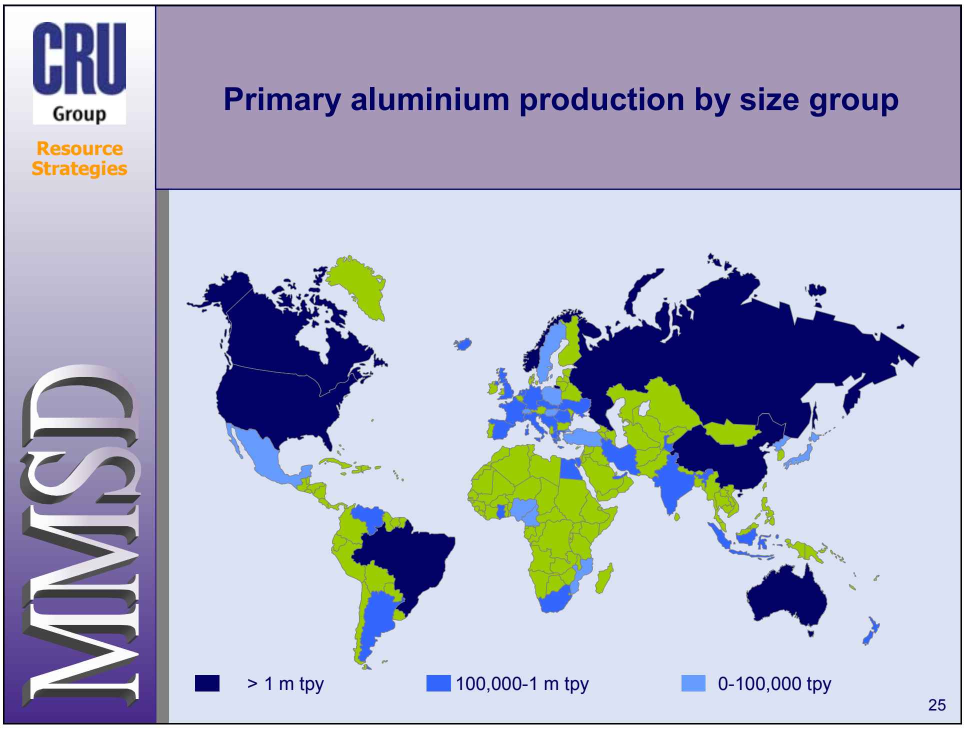


Refined copper production follows a similar geographic pattern to the production of blister, as trade in blister is fairly small relative to production volumes. Refined copper also includes electrowon cathode, which does change the country rankings somewhat. The USA, in particular, produces large volumes of electrowon copper and is in the same size class as Chile, China and Japan by this measure.



Alumina is an intermediate product between bauxite and aluminium. Some alumina is produced near the mines and then shipped to smelters elsewhere. This explains the high volumes of production in Jamaica, Guyana and Guinea. Elsewhere, the bauxite is shipped to regions where there is aluminium smelting capacity, although not necessarily to the final destination. This explains the existence of alumina plants in Europe and North America.

Australia has abundant mines and some major aluminium smelters. It is the largest producer of alumina in the world.



Primary aluminium consumption is concentrated on sites where electric power is cheap, or at least was cheap when the smelters were built. Most developed countries, and some of the larger developing countries, have large aluminium industries. An exception is the Far East, where the most of the Japanese industry closed down long ago and South Korea and Taiwan produce nothing.

There has been a tendency for aluminium smelters to locate in countries that have nothing to offer but cheap power - for example, Norway and Iceland.

4. Mineral producers

The structure of the minerals sector is complicated and diverse. In some sectors, minerals and metals are produced mainly by large mining companies, while small producers dominate in others. Some industries contain a mix of large multinational companies operating huge mines, smelters and refineries and smaller companies operating small mines. Some sectors are highly concentrated while others are not.

A second issue concerns the level of state ownership in the metals and mining industry. Most mining and processing is today in private hands. There has been a trend in the last twenty years towards the privatisation of nationalised industries in general, of which mining has made up just a small part of the world total. However, there remain some significant producers that governments own. Many of these enterprises are likely to be privatised in the next 10-20 years. There is little likelihood of an increase in state ownership.

There is no general rule about how big a mining or metal company should be. Firms range from huge multi-metal multinational companies to small companies operating a single mine or processing plant. The largest companies may be active at more than one stage of the industry and may also have unrelated manufacturing, resource-related or engineering businesses.

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Some large mining and metallurgical groups

Company	Home country	Sales ($bn - most recent year)	Main activities
Alcan	Canada	9	Aluminium
Alcoa	USA	23	Aluminium
Anglo American	UK	21	Non-ferrous and precious metals, coal, steel, forest products, diamonds, ferroalloys
BHP Billiton	UK	19	Non-ferrous and precious metals, coal, iron ore, steel, oil & gas, ferroalloys and their ores
Nippon Steel	Japan	22	Carbon & stainless steel
Posco	Korea (S.)	11	Carbon & stainless steel
Rio Tinto	UK	10	Non-ferrous and precious metals, coal, iron ore, industrial minerals, diamonds

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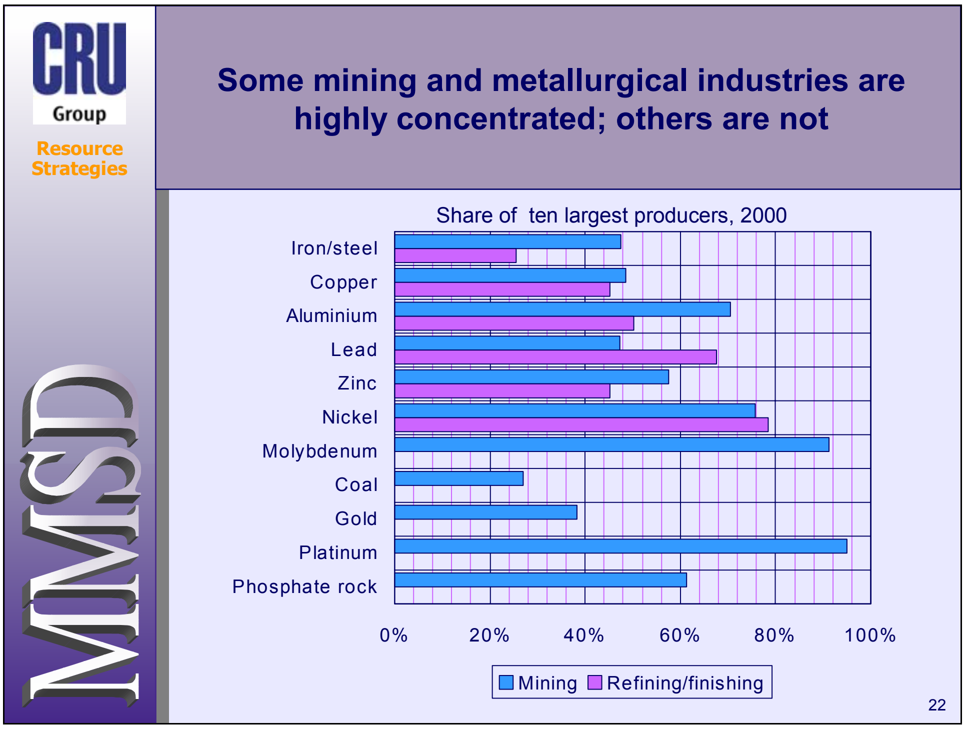
It is not always easy to identify the smallest producers in an industry, but the largest producers can be identified. Some of the big producers in the industry are shown in the accompanying slide. They include two companies that produce aluminium and related finished products, two companies that produce carbon and stainless steel and three diversified mining companies, two of which have significant interests in non-mining-related activities.



The concentration of producers of metals and minerals varies significantly from one to the next. For coal and steel, the ten largest producers manufacture less than 30% of global output. The corresponding ratio is over 90% for molybdenum and platinum.

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Some big producers of iron ore

	Country of head ofice	Main countries of operation
CVRD	Brazil	Brazil
Rio Tinto	UK	Australia, Canada, Brazil
BHP Billiton	UK	Australia, Brazil
Caemi	Brazil	Brazil, Canada
Kumba Resources	S. Africa	S. Africa

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Big producers of iron ore tend to be mining companies, not steel companies. If anything, the trend in the industry is to move away from vertical integration. BHP Billiton is a significant producer of steel but has announced plans to sell its steel division to concentrate on mining. Kumba Resources is a spin-off from Iscor, the South African steel company, which wanted to separate its manufacturing and mining activities. CVRD, the world's largest iron ore producer, recently expanded by acquiring a mine previously owned by the German steel group ThyssenKrupp AG.

Iron ore producers tend to focus mainly on countries with large individual deposits, rather than on a diverse group of countries. Of the main iron ore producers shown above, only Rio Tinto is active in as many as three countries.

Some big producers of steel

	Country of head ofice	Main countries of operation
Nippon Steel	Japan	Japan
Posco	Korea (S.)	Korea (S.)
Arbed	Luxembourg	Germany, Luxembourg, Belgium, Spain, France, Brazil
Usinor	France	France, Belgium, Germany, USA, Brazil
Corus	UK	UK, Netherlands, USA

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Big steel companies tend to operate mainly at the national or regional level. The two biggest steel producers in the world, Posco and Nippon Steel, operate mainly in their home countries, although they do have finishing operations or joint ventures elsewhere. The three big European producers also operate mainly in Europe, although they have smaller subsidiaries or affiliates in the USA and Brazil. They do not produce their own iron ore.

Arbed and Usinor plan to merge. If the European Commission approves the merger, the LNM Group of the UK would move up to fifth place in the table of steelmakers. The LNM Group is unique among steel groups in that it comprises a number of steelmakers from all around the world, including the USA, Canada, Mexico, Trinidad & Tobago, France, Germany, Kazakhstan and Indonesia.

Some big producers of aluminium

	Country of head ofice	Main countries of operation
Alcoa	USA	USA, Canada, Germany, Italy, Norway, Spain, Ghana, Australia, Brazil, Surinam, Venezuela
Alcan	Canada	USA, Canada, Iceland, Norway, Switzerland, UK, India, Brazil
Russian Aluminium	Russia	Russia
BHP Billiton	UK	Mozambique, S. Africa, Brazil
Pechiney	France	Canada, France, Greece, Netherlands, Cameroon, Australia

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Aluminium producers tend to move in a world of their own. Of the largest aluminium companies, only BHP Billiton is a major participant in the mining of other commodity minerals. The big companies, apart from Russian Aluminium, tend to have interests in smelting around the world. They also tend to be integrated back into bauxite mining and alumina refining, and forward into semi-fabrication. The accompanying chart shows only the location of aluminium smelting activities; the geographic spread of the four Western companies would be far greater than shown above if all the other activities were taken into account.

Some big producers of copper ore and concentrates

	Country of head ofice	Main countries of operation
Codelco	Chile	Chile
Phelps Dodge	USA	USA, Chile, Peru
BHP Billiton	UK	Canada, Argentina, Chile, Peru, Papua New Guinea, Australia
Rio Tinto	UK	USA, Argentina, Chile, Indonesia, Portugal, Australia, S. Africa
Grupo Mexico	Mexico	USA, Mexico, Peru

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The biggest copper producers include two big mining groups and three producers that specialise in copper, and to a lesser extent, in molybdenum. Codelco operates only in Chile, but the other companies operate further afield. All five major companies operate in various parts of the Western Hemisphere, and the two big international groups operate in the Pacific Rim as well. Rio Tinto even has mining interests in Portugal.

Some big producers of nickel

	Country of head ofice	Main countries of operation
Norilsk	Russia	Russia
Inco	Canada	Canada, UK, Indonesia, Japan, Korea (S.)
Falconbridge	Canada	Canada, Norway, Dominican R.
Eramet	France	New Caledonia, France
BHP Billiton	UK	Colombia, Indonesia

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Apart once again form BHP Billiton, the big nickel producers tend to produce mostly nickel, although Inco, Norilsk and Falconbridge get a large part of their revenue from by-products including copper, cobalt and precious metals. Falconbridge is somewhat more diversified into other base metals, compared with Inco, Norilsk and Eramet, although Norilsk and Inco are major copper producers in their own right. Norilsk is also a huge producer of platinum group metals, while Eramet is a major producer of manganese ores and alloys and a big producer of high strength steels and nickel-based alloys.

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Some big producers of coal

	Country of head ofice	Main countries of operation
CIL	India	India
Peabody Energy	USA	USA
Rio Tinto	UK	USA, Colombia, Brazil, Indonesia, Australia
BHP Billiton	UK	USA, Colombia, S. Africa, Indonesia, Australia
RAG	Germany	Germany, USA, Australia, Venezuela

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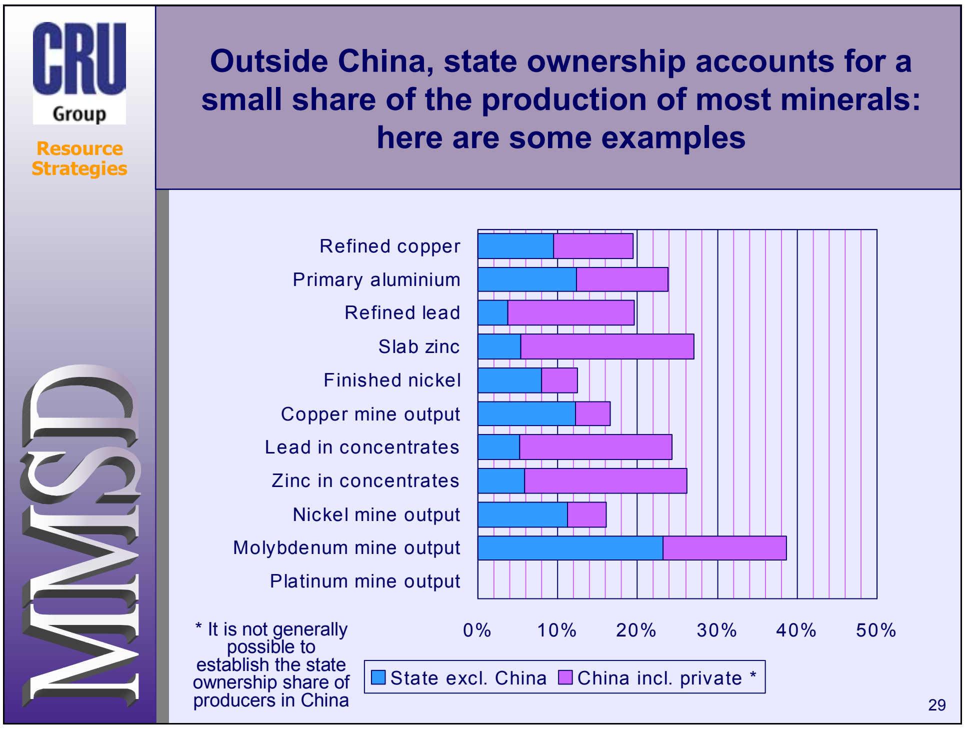
The ubiquitous BHP Billiton and Rio Tinto also figure among the main producers of coal. The largest single producer is the state-owned Coal India Limited. The other two big produces are private and are totally focused on coal and related businesses. Rio Tinto and BHP Billiton are the major producers of coking coal for the world export market.



State ownership no longer accounts for a major share of world mining and metals activity. If Chinese companies are excluded, state-controlled firms account for less than 25% of world production of each of a number of non-ferrous commodities. Chinese firms are shown separately because it is not always possible to disentangle state and private ownership over a large number of enterprises. Even if all Chinese enterprises are counted as state-owned (which is untrue), the share of state-owned enterprises is below 40% for molybdenum, and below 30% for all other commodities shown in the accompanying chart.

Most state ownership is concentrated in a few countries, and for some countries, only on a few products. State ownership is still widespread in China although the government is trying to encourage private ownership. In Chile, the large copper-molybdenum producer Codelco is state-owned but most other mining and metallurgical activities are private. In Eastern Europe and the CIS, states have managed to sell off most of their more attractive nationalised assets but still find themselves running some of the less profitable enterprises in order to maintain employment. Most mining enterprises in Iran are still state-owned. In Turkey, the mining holding company Eti Holdings is a state-owned group although a privatised mining and metallurgical sector flourishes alongside. India is burdened with state-owned giants such as the coal producer CIL, the steel producer Sail, the base metals companies Hindustan Copper and Hindustan Zinc and the aluminium company Nalco. Attempts at privatisation have been few and far between, although a private sector industry has sprung up alongside these companies in many areas. Various governments in the Middle East still operate mining and metallurgical companies. In North Korea, the old-fashioned Communist regime still operates a command economy.

5. Employment

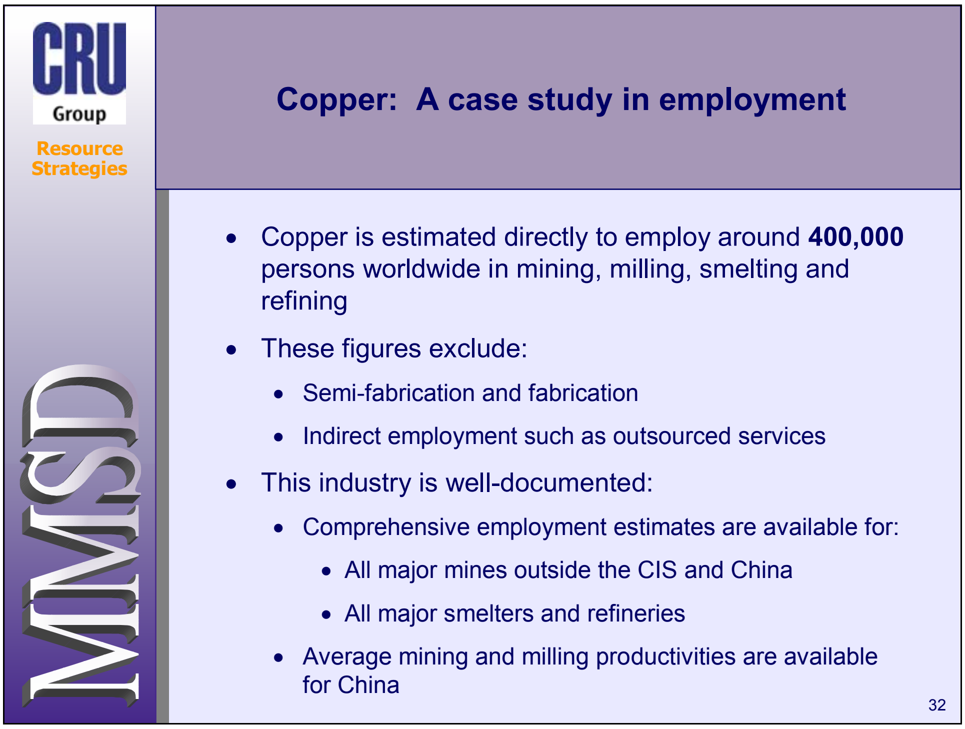
Mining does employ a significant number of people around the world, though information can only be guessed at for many companies. The sheer number of different metals and minerals makes it difficult to give a sensible figure for the whole world. Some countries report total employment in mineral extraction to the International Labour Office (ILO), but the picture is far from complete.

We have done a detailed analysis of employment in the copper industry, because this is the one metal for which detailed employment totals are available on a production unit basis for most of the world. This covers mining, smelting and refining.

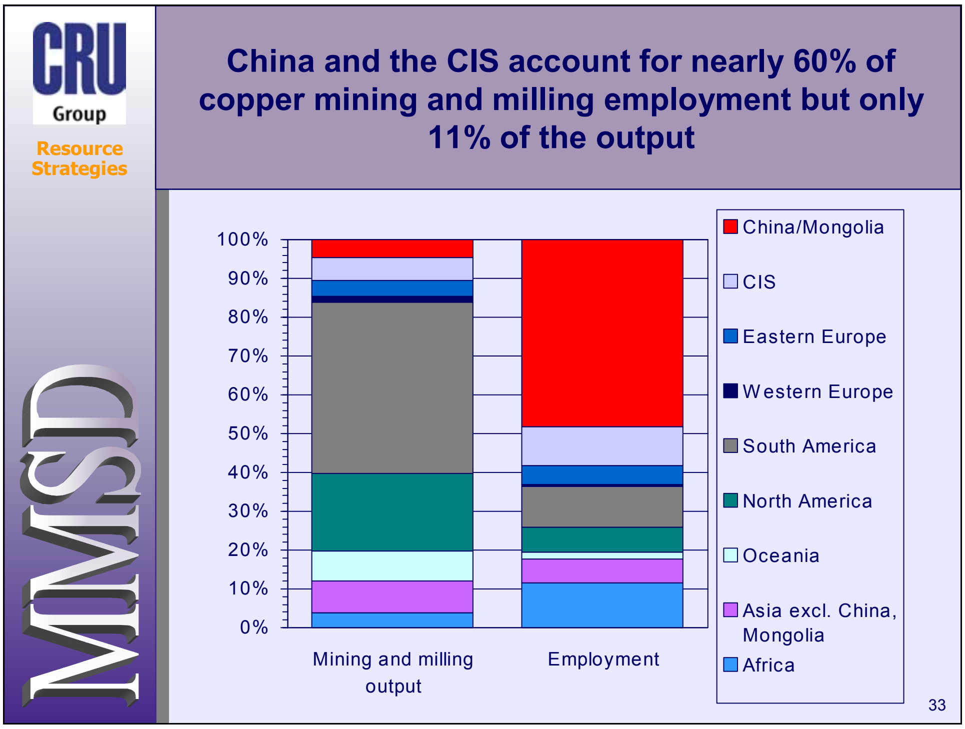
The number of persons directly employed in metals and mining, whatever it is, is far smaller than the number of persons whose livelihoods depend on it. Virtually all manufacturing industry, and the service industries that it supports, rely indirectly on the mining and metals industries, and indeed could not exist without them.

The ILO has estimated that 30m persons were employed in mining around ten years ago not counting over 10m persons engaged in artisanal mining. Since then, rationalisations in mining industries, especially in Eastern Europe, the CIS, China and India, which have traditionally employed huge numbers of workers, has probably resulted in cuts in total employment.

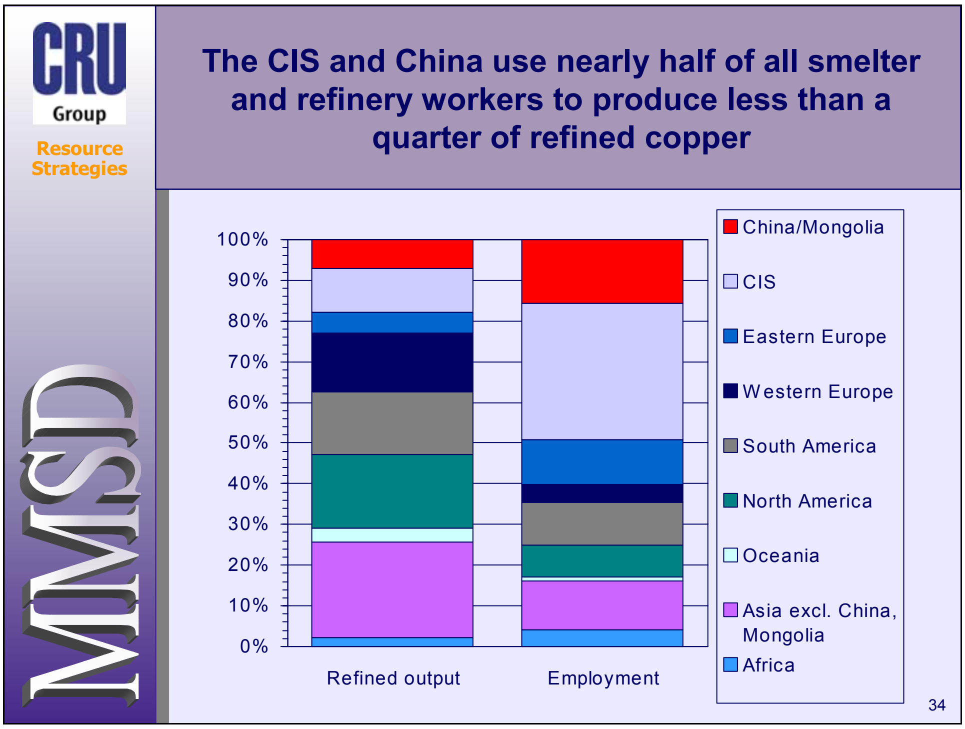
We have looked at recent ILO statistics on 84 countries, some developed and other developing. These suggest that countries with 63% of world population employed 13-14m persons in the late 1990s. If these figures are extrapolated to the world, it would imply 21-22m persons. This figure suggests that the old ILO figures may have been approximately correct, if total mining employment has indeed been falling.



Based on detailed information on mines, smelters and refineries, it is possible to come up with an estimate of around 400,000 persons employed directly in the copper industry, up to the stage of cathode refining. This figure includes actual or estimated data for all major and some minor individual mines outside the CIS and China and all major smelters and refineries including the CIS and China. Employment has been extrapolated from known figures for those countries for which the information is incomplete, mainly on the basis of labour productivity at known facilities in these countries. For China, productivity information on mines can be estimated by using official global estimates of mining productivity in open pit and underground mines.



Nearly 60% of all employment in copper mining and milling takes place in China and the CIS. Indeed, China accounts for nearly 50% of the world total. China and the CIS, however, account for just over 10% of world output. South America, by contrast, employs just 10% of the labour force to mine over 40% of the copper, and productivity is higher still in the developed countries.



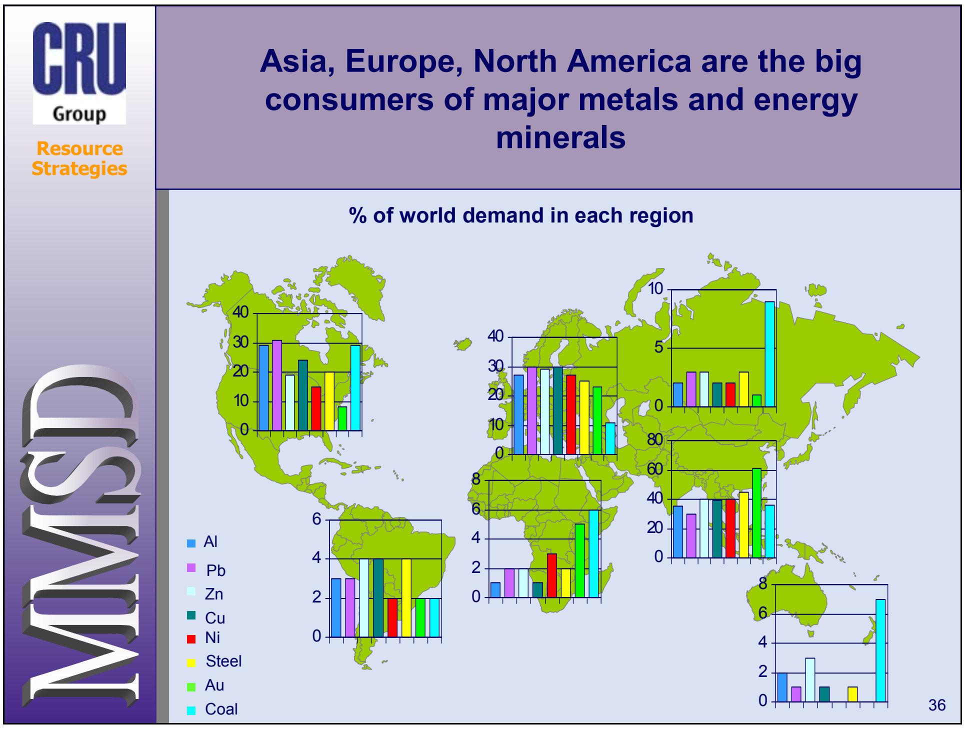
The story is similar for copper smelting and refining, although Chinese productivity seems to be relatively better, and Russian productivity relatively worse, than for mining and milling.

In sum, then, China employs over 160,000 workers in its copper industry, and Russia over 60,000, out of a global workforce of around 400,000.

6. Mineral markets

Metals and minerals tend, on a *per capita* basis, to be used principally in the developed regions of the world. In Asia, moreover, large populations in less developed countries, especially China and India, permit high levels of consumption even when consumption is relatively low per head of population. There are significant differences among products, but the overall pattern is broadly similar.

Metals and minerals tend to be used in virtually every sector of construction and manufacturing. Energy minerals are used to provide electricity and are also used in industrial applications. Fertiliser minerals are used in agriculture.



Europe and Asia are the main two consuming regions for most of the eight metals and minerals - aluminium, lead, zinc, copper, nickel, steel, gold and coal - illustrated in the accompanying chart. North America is also important, especially for aluminium, lead and coal. Europe, in turn, is a proportionately smaller consumer of coal relative to North America and Asia.

Coal is perhaps the most anomalous of the commodities covered. Regional consumption as a share of the world total is much higher for coal than for other commodities in the CIS and Australasia.

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Consumption of main non-ferrous metals by region, 2000

'000 tonnes	N. America	S. America	Europe	CIS	Asia	Africa	Other
Aluminium	7,291	823	6,632	612	8,819	294	421
Lead	2,057	227	1,982	191	1,995	126	50
Zinc	1,714	352	2,572	280	3,563	162	240
Copper	3,649	534	4,551	270	5,868	116	176
Nickel	165	24	416	25	449	31	2

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For all the main non-ferrous metals, North America, Asia and Europe are the main consuming regions. However, the ranking of the three varies by metal. Asian consumption exceeds European consumption for all five commodities, but the place of North America varies. For zinc, copper and nickel, North America is the smallest of the three regions. For aluminium, it ranks second, and for lead, it is the most important single region.

South America is the next most important region for all metals except nickel. The consumption of nickel is highly correlated with the production of stainless steel. In the nickel market, South America ranks below Africa and the CIS.

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Consumption of selected other commodities by region, 2000

	N. America	S. America	Europe	CIS	Asia	Africa	Other
Finished steel (m tonnes)	136	26	165	20	301	14	7
Gold (tonnes)	246	67	727	34	1,945	144	6
Coal (m tonnes oil equivalent)	613	37	241	197	767	123	158

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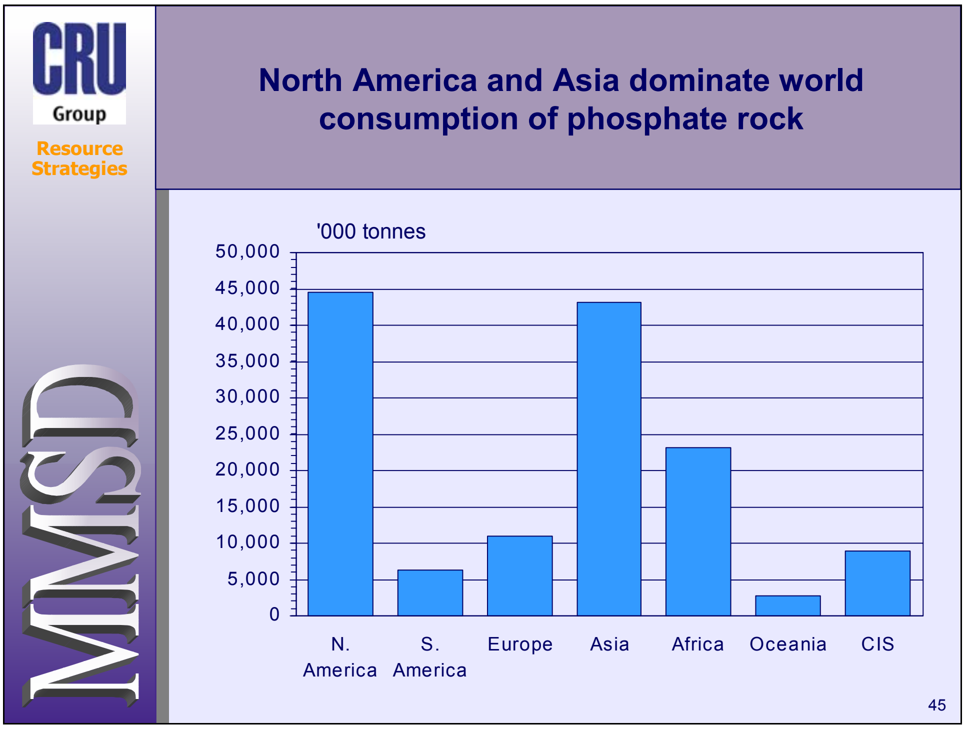
Asia is the largest consuming region for finished steel, gold and coal. As with non-ferrous metals, North America and Europe are the other two main consuming regions. Europe ranks ahead of North America in steel and gold but far behind in coal.



Phosphate rock consumption depends on the proximity of phosphoric acid and phosphate plants as well as on the location of final consumption. North America and Asia are the largest consuming regions. Africa is also an important consumer, largely because Morocco is the largest producer in the world.

By end-use, metals are used in all sectors of manufacturing, although some especially large sectors can be identified. Construction is also important. Some metals have specialised uses that will be discussed later.

Non-metallic minerals may be used in manufacturing, but some minerals also have other distinct uses, including agriculture and power generation.

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Major end-uses of steel: transport, construction, machinery

	USA	Japan
Transport equipment	37%	24%
Construction & materials	34%	21%
Packaging	8%	3%
Domestic & commercial	6%	10%
Oil & gas	5%	0%
Electrical equipment	5%	3%
Machinery	5%	38%

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It is possible roughly to estimate the shares of different end-use sectors for steel in the USA and Japan. The figures are inexact because substantial volumes of reported shipments either go to distributors on their way to the final consumer, or else are not classified by end-use. The end-use classifications used in the USA and Japan, moreover, may be defined differently.

Transport equipment and construction are important sectors for final steel demand in both countries. Machinery appears to be much more important in Japan than in the USA, although it is possible that this results from differences in end-use classification between the two countries.

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Aluminium has similar end-uses but packaging is much more important

	USA	Japan	4 largest European countries
Transport equipment	35%	34%	31%
Construction & materials	14%	21%	18%
Packaging	26%	12%	16%
Domestic & commercial	6%	5%	7%
Electrical equipment	8%	6%	9%
Machinery	7%	6%	12%
Other	3%	16%	7%

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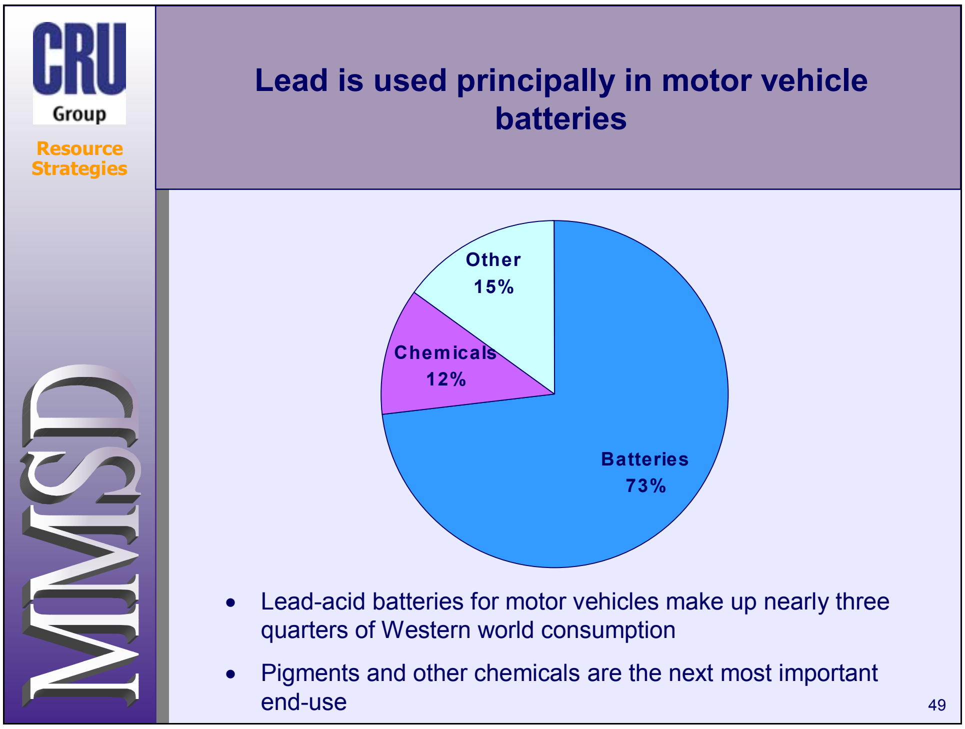
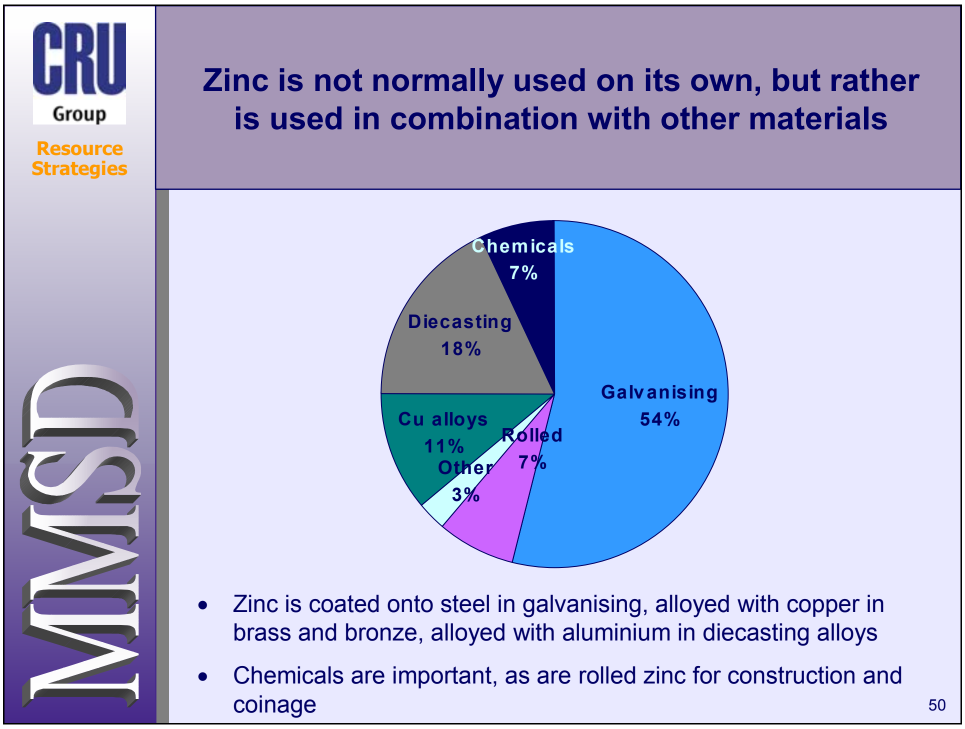
Transport equipment is the largest single sector of end-use for aluminium in those countries for which estimates are available. Construction is the second largest use in Japan and Europe, but it comes third to packaging in the USA, where beverage can production and consumption is disproportionately high.



Lead is an example of a metal where a single use predominates worldwide. It is mainly used in lead-acid storage batteries for cars and trucks. Pigments and other chemicals is the only other major sector of use. The remaining uses are small and diverse.



Zinc is an example of a metal for which most end-uses are in the fabrication of other metals. Over half of consumption is in the galvanising of steel. Another important use is in the copper alloys, brass and bronze. Even zinc diecasting alloys, used primarily in transport equipment, contain aluminium although zinc is the major component. Much of zinc consumption thus depends on the demand for other metals.

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Some metals are produced mainly as alloying agents, especially for steel

- In carbon steel, these include:
  - Manganese
  - Silicon (in the form of ferrosilicon and silico-manganese)
  - Vanadium
  - Niobium
  - Molybdenum (also used in stainless steel in large volume)
- Nickel and chromium are used mainly in stainless steel, but also have applications in carbon steel and non-ferrous alloys
- Other elements (tungsten, titanium, boron) are sometimes used in steel alloys but are used primarily outside the steel industry

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There is a whole series of metals that are used primarily as alloying agents for steel. The final consumption by end-use of manganese, vanadium, niobium and molybdenum therefore depends on the end-use patterns for steel. For nickel and chromium, final consumption is even more specifically tied to stainless steel production, which is only a small subset of the total market for steel. A large proportion of silicon is consumed in ferroalloys for the steel industry, although much silicon is also consumed in aluminium alloys and in chemicals. A few other alloying elements, such as tungsten, titanium and boron, have their principal uses in other areas but are used as well in small quantities in steelmaking.

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Other minor metals have a variety of uses

Antimony	Chemicals, lead alloys	**Rhenium**	Superalloys, catalysts
Beryllium	Electronics	**Selenium**	Glass, electrical, other
Cobalt	Superalloys, chemicals, magnets, cutting tools	**Tantalum**	Electronics
Gallium	Electronics	**Tellurium**	Electronics, steel
Germanium	Electronics	**Titanium**	Pigments, aerospace, chemical plant
Hafnium	Nuclear power	**Tungsten**	Tools, lighting, steel
Indium	Electronics	**Uranium**	Nuclear power
Rare earths	Catalysts, glass, metals, phosphors, ceramics	**Zirconium**	Nuclear power

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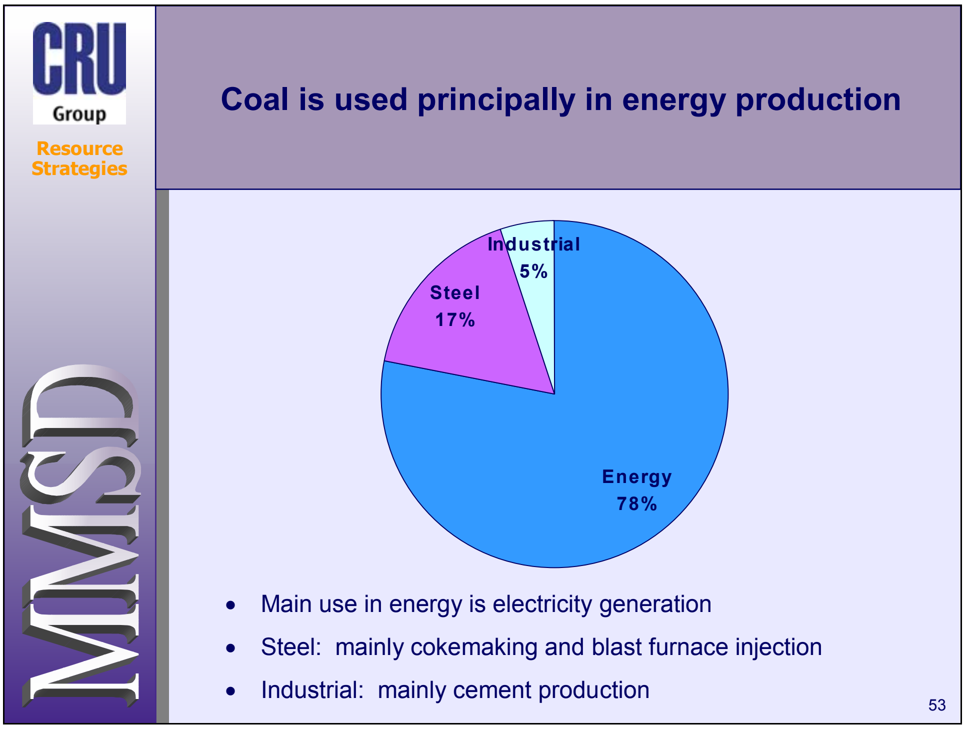
Numerous minor metals, as well, are consumed in specialist applications. Few of these metals have diverse uses. Most are specialised in specific sectors of industry. They are produced in small volume and therefore tend not to be used in heavy structural uses, except perhaps as alloys. The accompanying slide shows some, though by no means all, of the minor metals and their end-uses.



Over three quarters of world coal production is used in the production of energy at power stations. The steel industry is the second biggest user of coal, mainly for the production of iron in blast furnaces. Coal is consumed indirectly in a blast furnace after carbonisation to metallurgical coke, or it is consumed directly in a blast furnace by injection, after pulverisation or granulation. Small volumes of coke have uses outside the steel industry. The main direct non-steel end-use for coal is in cement production.

7. Recycling

A substantial proportion of some metals are recycled. This section of the report explains recycling and looks at the recycling flows for some metals.

Recycling activity depends on the nature of the metal or mineral. The key determinant is that the metal or mineral retains its chemical form in use. Steel, is always steel and can therefore be recycled, even if it requires remelting and refining to become usable once more. Lead, copper and aluminium also keep their basic properties and can be recycled.

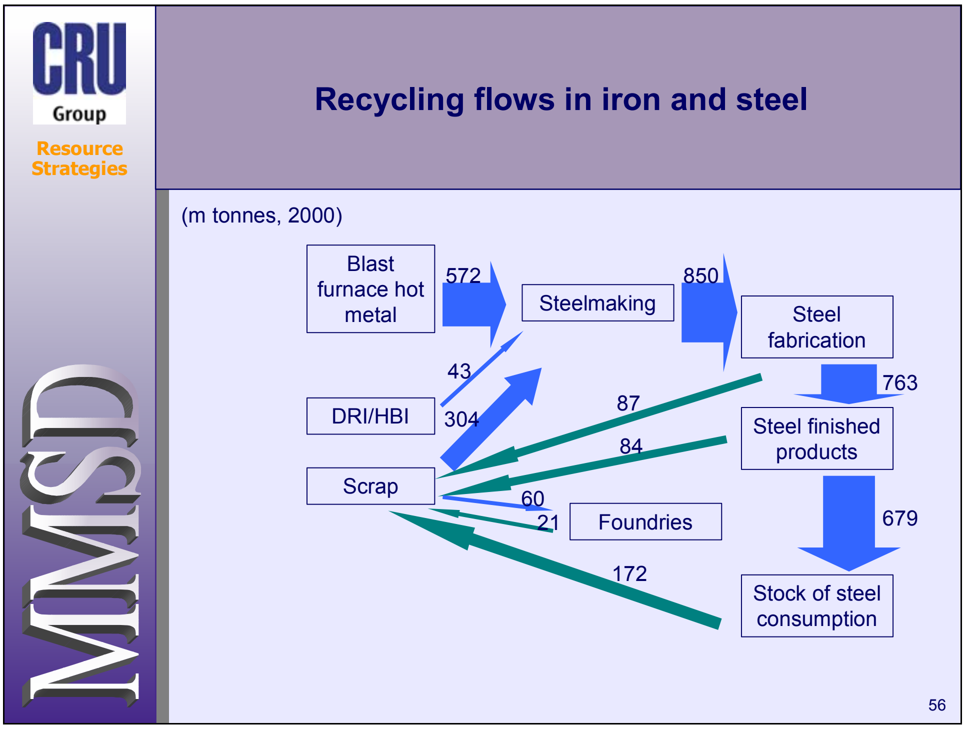
Nickel is more complicated because most is consumed in stainless steel or non-ferrous alloys. However, the stainless steel and the alloys can themselves be recycled. If the non-ferrous alloy scrap is insufficiently pure to be recycled back to new non-ferrous alloys, it can even be blended with stainless steel scrap to produce new stainless steel.

If a metal is converted into a new chemical form, as in the production of chemicals, recycling is impossible. It is also impossible to recover metals that are widely dispersed in use. A key condition for recycling is that it must be economically feasible to recover the metals.

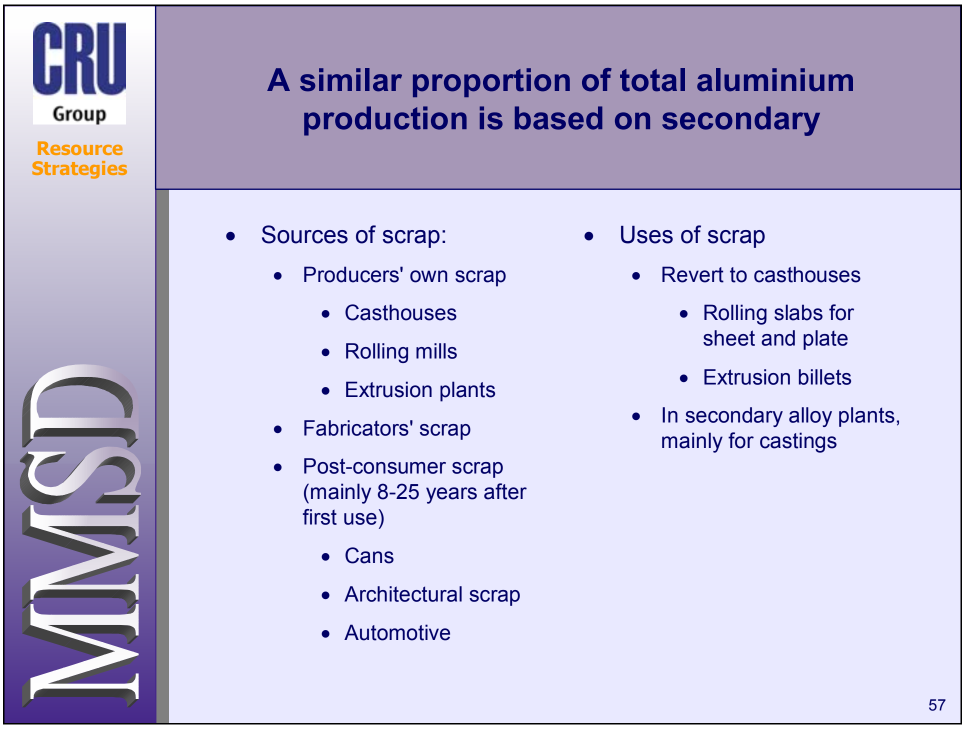
By definition, fertiliser and energy minerals are not recycled. Energy minerals are burnt and lost, while the final products or fertiliser minerals disappear into the soil.

In the iron and steel industry, over one third of production comes from scrap. The scrap itself comes from different sources. Producers generate their own scrap in steelworks and in foundries. The steelmakers' customers, the fabricators of steel, generate scrap in their manufacturing activities, collect it and supply it to traders who send it back to the steel industry. A significant volume of scrap also comes back to the industry after use. Steel food and beverage cans can be returned immediately after use. Other steel products have a longer life but are also eventually returned. Most old motor vehicles are eventually shredded, and the contained scrap returns to the steel industry. Demolition scrap, including obsolete building elements, plant and equipment, rails and so forth, can also be recycled.

The major use of steel scrap is in the steel industry itself. Scrap can be consumed in electric arc furnaces as the major raw material feed, or it can be used as a coolant in basic oxygen steelmaking where the main feed is hot metal (liquid iron) from iron ore.

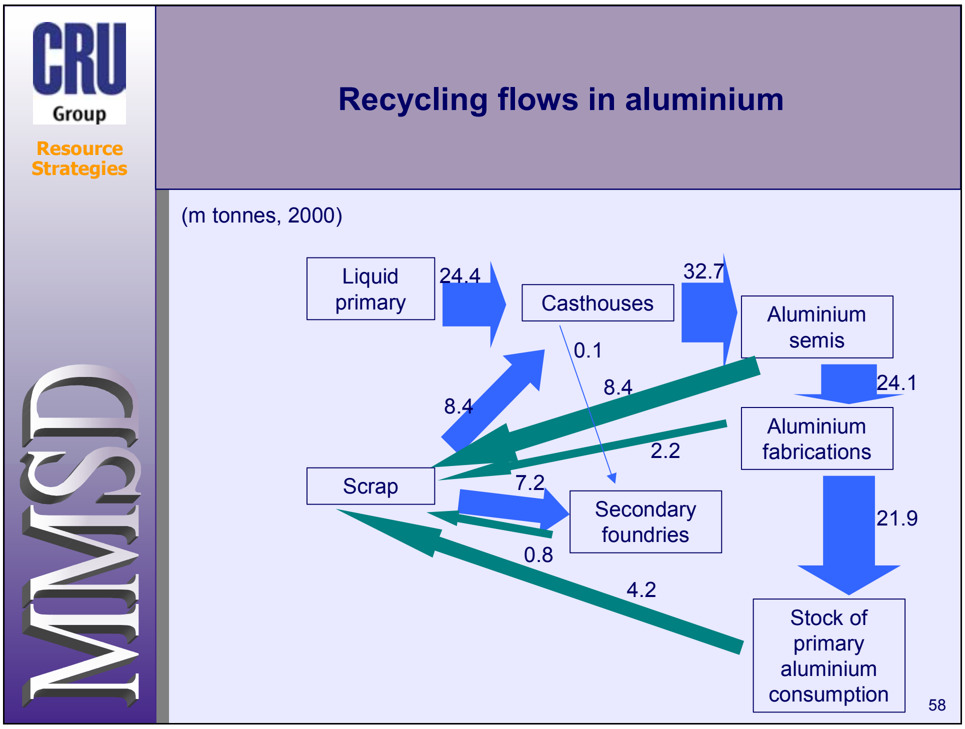


Worldwide, about half of steel scrap comes from the production and fabrication of finished steel products, and half from the return to the industry of post-consumer scrap. Some foundry scrap is also generated and recycled. Over 80% of all iron and steel scrap is used in steelmaking, and the balance in foundries.



Secondary aluminium comes from similar sources as iron and steel scrap. Again, it comes from the producers themselves in casting, rolling and extrusion applications. It comes from the direct consumers of primary and secondary aluminium when they fabricate it into finished products. Beverage cans are a major source of post-consumer scrap, and old post-consumer scrap can also be recovered from buildings, other construction and motor vehicles.

Scrap finds its way back to the industry in both the primary and secondary aluminium industries. In the primary industry, it is blended with primary aluminium in casthouses, whether at some smelters or, more commonly, at rolling mills and extrusion plants. Secondary aluminium plants also exist, to recycle scrap directly into castings.



Primary aluminium production was 24.4m tonnes in 2000, while 15.6m tonnes were recycled. Primary casthouses consumed around 8.4m tonnes of scrap and secondary casthouses the balance.

The sources of the scrap are diverse, but over half was generated in the production of semi-finished aluminium products. Over one quarter was post-consumer scrap, and the rest came from aluminium fabricators and from secondary foundries.

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Lead is a hazardous material and scrap is widely recovered

- Environmental laws usually require the recycling of used batteries and other products containing lead
  - Recycling rates are correspondingly high: over 90% in most of the developed world
  - Recycling regulations and enforcement are weaker in the developing countries, where recycling rates are nonetheless rising
- Some lead is converted into pigments, fuel additives and other chemicals and is lost from the scrap cycle
- Secondary lead production exceeds primary production in most years
- Virtually all recycled lead consists of post-consumer scrap

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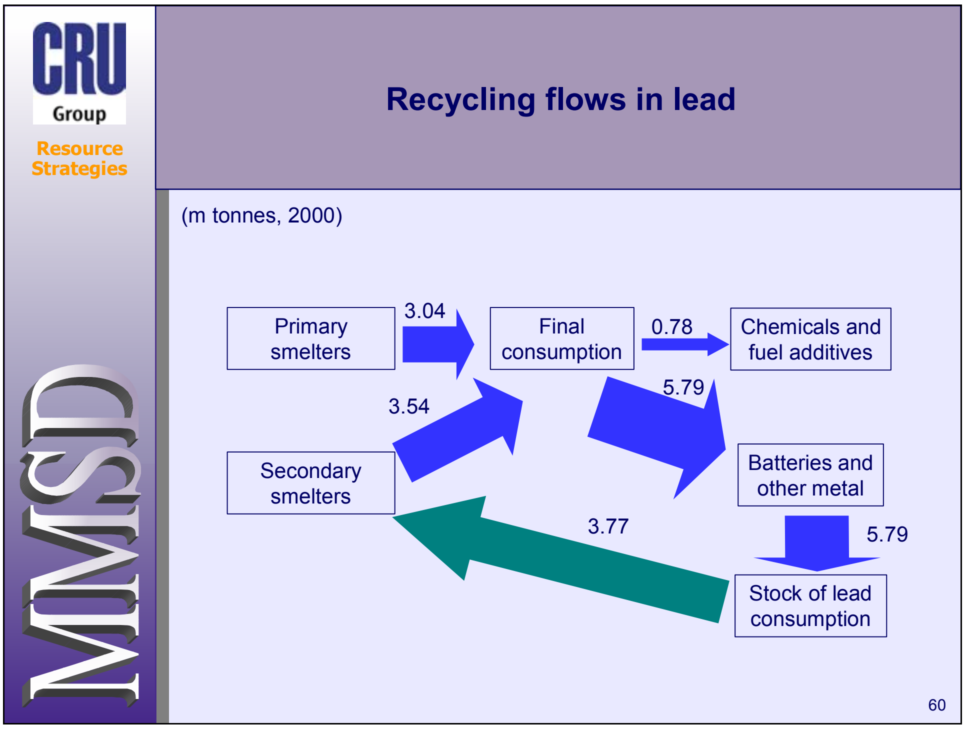
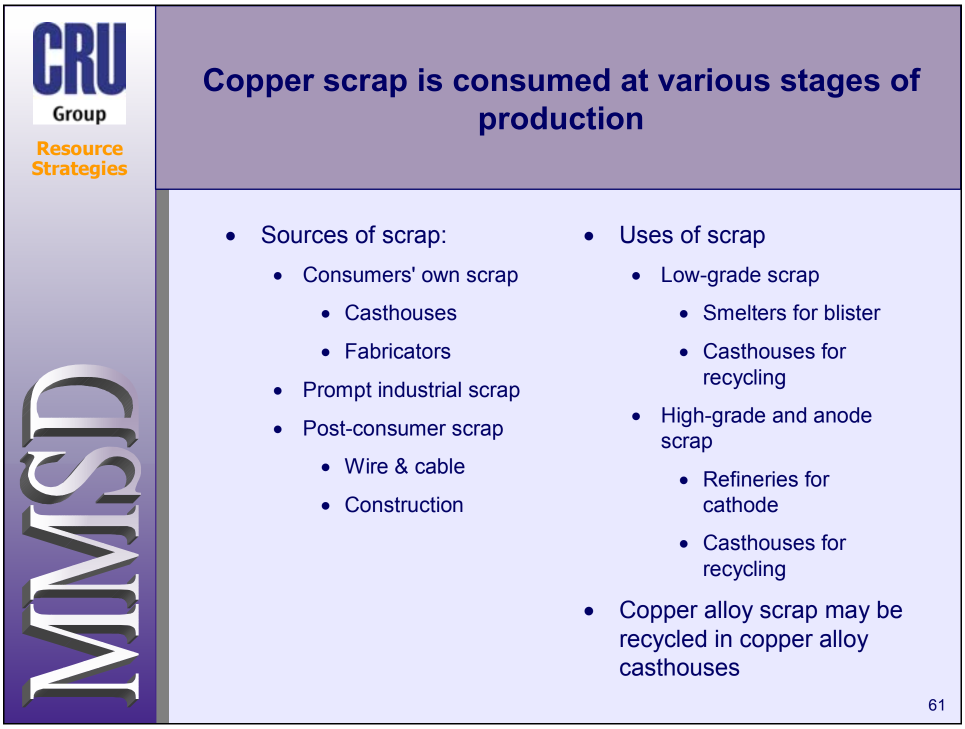
Lead is unique among the major metals in that its dispersal is deemed to constitute a major health and environmental hazard. Most countries therefore have strict environmental laws requiring the recycling of batteries and other products containing lead. Since batteries make up around 73% of world consumption of lead, the dispersal of lead into non-recoverable uses is small. In developed countries, recycling rates for batteries are usually over 90% and sometimes over 95%. Post-consumer scrap makes up most of the secondary lead that is consumed.

Some developing countries also have tough environmental laws, but not all do. Moreover, the environmental laws are not always enforced as strictly as they are in the developed world. Nevertheless, recycling rates are rising even in developing countries.

Some lead is lost into pigments, chemicals and other dispersive uses. Nevertheless, the volume of lead smelted from secondary sources exceeds the volume coming from concentrates.

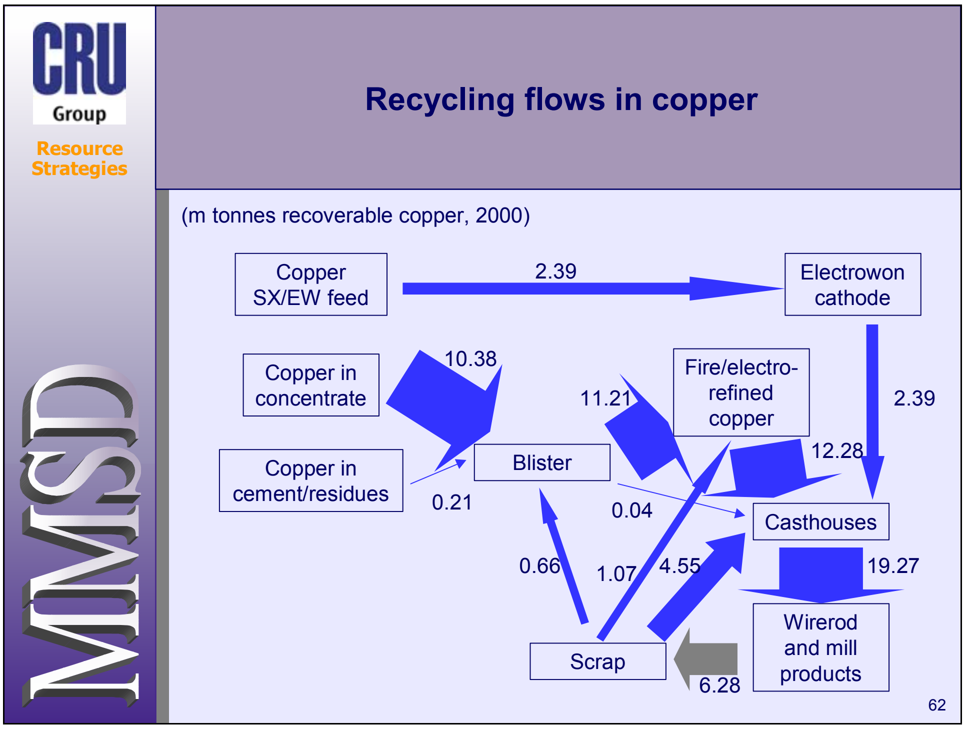


In 2000, primary smelters supplied only 3.0m tonnes of lead, compared with 3.5m tonnes from secondary smelters. About 5.8m tonnes were consumed in non-chemical uses, contributing to the eventual stock of post-consumer scrap. About 3.8m tonnes of lead were consumed in 2000 in secondary smelters. The difference between scrap consumption and secondary production is metal loss at the smelters.



The sources of copper scrap are similar to the sources of aluminium scrap: casthouses, fabricators, direct consumers and final consumers. Because the end-uses are different, the specific sources are different. Wire and cable scrap is more important in copper, but there is no such thing as a copper food or beverage can.

Copper scrap consists of low-grade and high-grade scrap. Low-grade scrap typically consists of copper alloy. It may be used in a smelter in the production of blister, but more often it is returned to a copper alloy casthouse and recycled directly. High-grade scrap and anode scrap from a copper refinery have a higher copper content and may be re-refined directly into cathode or remelted in a casthouse.



Around 6.3 m tonnes of copper scrap were recycled in 2000, compared with total casthouse production of 19.3m tonnes. The 6.3m tonnes include both prompt and post-consumer scrap. The largest volume of scrap, 4.6m tonnes, went straight back into casthouses without further smelting or refining. About 0.7m tonnes were consumed in smelters and 1.1m tonnes in refineries.

8. Trends affecting sustainability

It is possible to identify three main trends in world economic activity that will have a major effect on the minerals cycle in the future. These are:

- Economic growth
- Globalisation
- Privatisation

Economic growth benefits sustainability in two ways. First, it encourages environmental protection directly. Second, it encourages substitution of high-value materials in place of low-value materials.

Economic growth improves the living standards of individuals. Up to a certain stage of economic development, individuals are interested mainly in the goods that will help them to live a materially more comfortable life. Once they have achieved a certain basic minimum level of material comfort, they turn their attention to environmental considerations. This explains why the developed countries tend to have tighter environmental laws and tougher enforcement thereof than do developing countries. These laws include regulations encouraging recycling, reducing harmful emissions at industrial sites. If metals can be used for positive environmental purposes, such as platinum group metals in catalytic converters for motor vehicles, the consumption of these metals will increase. Correspondingly, the consumption of materials that are perceived to damage the environment, such as lead or asbestos, is discouraged.

The use of higher-value added materials is also encouraged because they outperform lower-value added materials. The use of nickel has grown much faster than GDP around the world mainly because stainless steel consumption tends to rise as average incomes increase. Aluminium has similarly replaced steel in some applications where structural strength is less than critical.

The aluminium industry also highlights the positive environmental effects of such substitution. The substitution of aluminium for steel in cars helps to save energy consumption in use because aluminium is much lighter than steel.

The trend towards globalisation of industry benefits the environment by encouraging economic growth. Globalisation does cause short-term problems, some of them serious, especially in local labour markets. Workers in high-cost industry segments do gradually lose their jobs, often through no fault of their own, to workers at lower-cost competitors. In the longer run, however, workers in a free labour market will migrate towards sectors that offer higher returns and contribute more towards economic growth.

Globalisation encourages the reduction of all costs, not just labour costs. Energy must be used more efficiently, and materials consumption is reduced in order to save money. By reducing the waste of energy and raw materials, globalisation is conducive to a better environment.

The opposite of globalisation is protection, where countries tend to protect their home markets, either for reasons of prestige or because governments want the support of local vested interests. There has been a trend towards reduced protection, as the formation of the World Trade Organisation makes clear, but progress is not all one way. The recent profusion of anti-dumping litigation and trade disputes shows that further globalisation of industry is by no means inevitable.

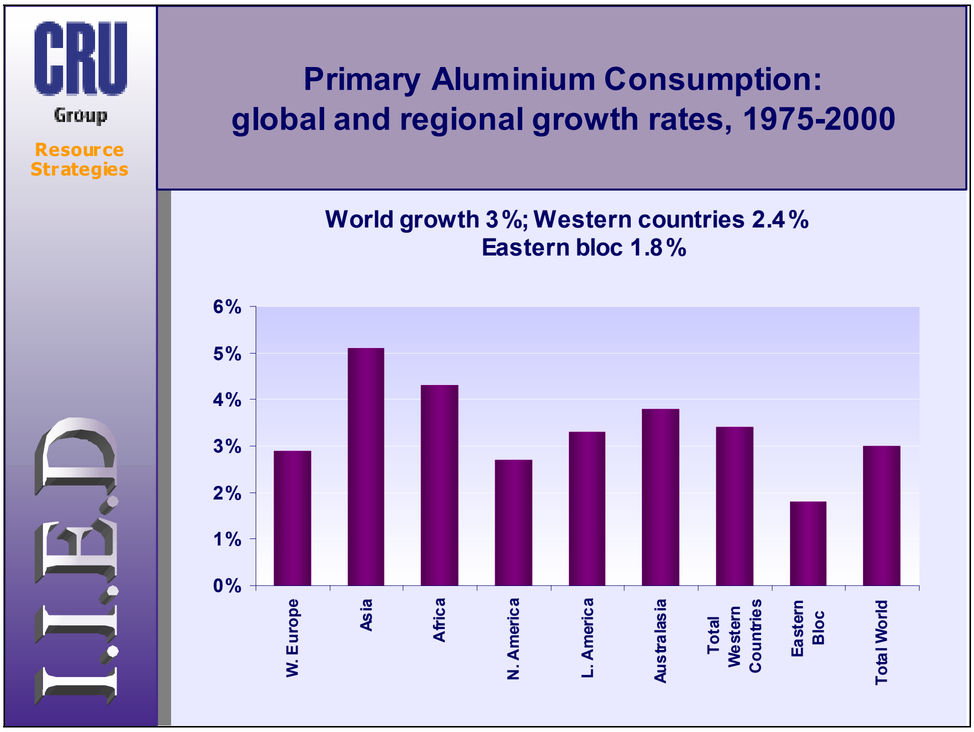
Privatisation has the same effects as globalisation. It exposes companies to market forces, forcing them to become more efficient or to disappear. Resources tend to be reallocated within an economy from less efficient to more efficient uses, thereby promoting economic growth. The short-term effects of privatisation are also similar in that it tends to reduce direct employment at the firms being privatised.

Privatisation also makes it easier for governments to enforce environmental regulations. The forces that motivate privatisation in the first place, namely a desire to protect inefficient home industries in the face of global competition, imply that governments will be less than willing to force upon firms that they own measures that will increase costs without a direct payback. An adversarial relationship with industry is far better for ensuring compliance with environmental laws.

Unlike globalisation in general, the direction in privatisation has all been in one way. In the last fifteen years, there have been almost no nationalisations or re-nationalisations of mining or manufacturing industries. There have been many privatisations, not the least in the CIS and in Eastern Europe. Governments have come to the realisation that they are not as good as their private sector counterparts in running businesses, while at the same time, the revenue from privatisation has benefited state treasuries.

Chapter 2
The need for minerals: Aluminium

1. Global and regional growth in demand



The demand for primary aluminium grew at an average rate of 3% per year in the 25 years from 1975 to 2000. The major regional contrast within this period is between the Western world, where demand grew at an average of 3.4%, and the Communist or former Communist economies of the world, where demand grew at only 1.8%. This is a testimony to the constraints imposed on the use of metals by centrally planned economies, and to the low level of personal incomes generated by Communist systems.

Within the Western world, faster growth was recorded in regions where the majority of the economies were passing through the development phase, a period when substantial investments are commonly made in infrastructure and basic services such as housing, water and electricity supply. Thus demand in Asia as a whole (excluding the CIS) grew at an average of 5.1% per year; demand in Africa grew at 4.3% per year (though from a very low base in 1975); and demand in Latin America grew at 3.3% per year.

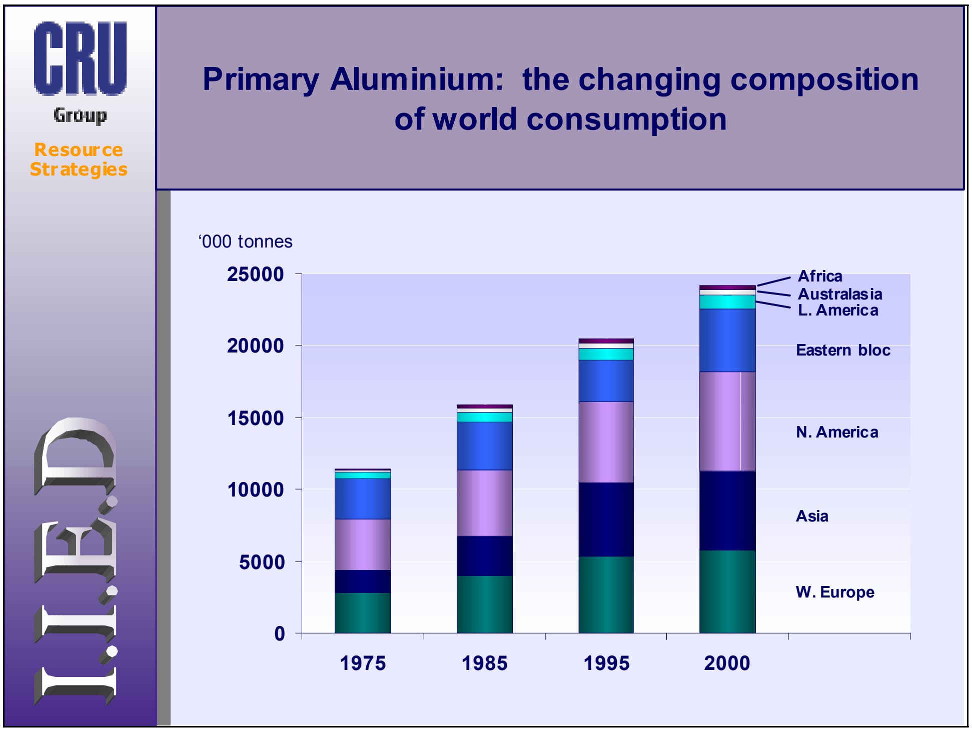
Within the industrialised economies, aluminium demand grew at rates below the world average: 2.9% per year in Western Europe and 2.7% in North America (defined as only the USA and Canada). This reflects the smaller importance of infrastructure spending in these economically more mature regions.

It is most important to note here, and throughout the following discussion of the demand for aluminium and indeed all other non-ferrous metals, that consumption or demand is measured at the point where refined metal is delivered to a semi-fabricating plant, where is converted into a sheet or extrusion or rod or casting. These products are typically further processed and then incorporated into finished products, such as cars, aeroplanes, household goods or machines.

International trade can and does occur at every stage in this manufacturing process; in semi-finished and finished metal products and in the final manufactured goods that incorporate finished metal products. Therefore the location of final consumption may be far removed from the location of the semi-fabricating process.

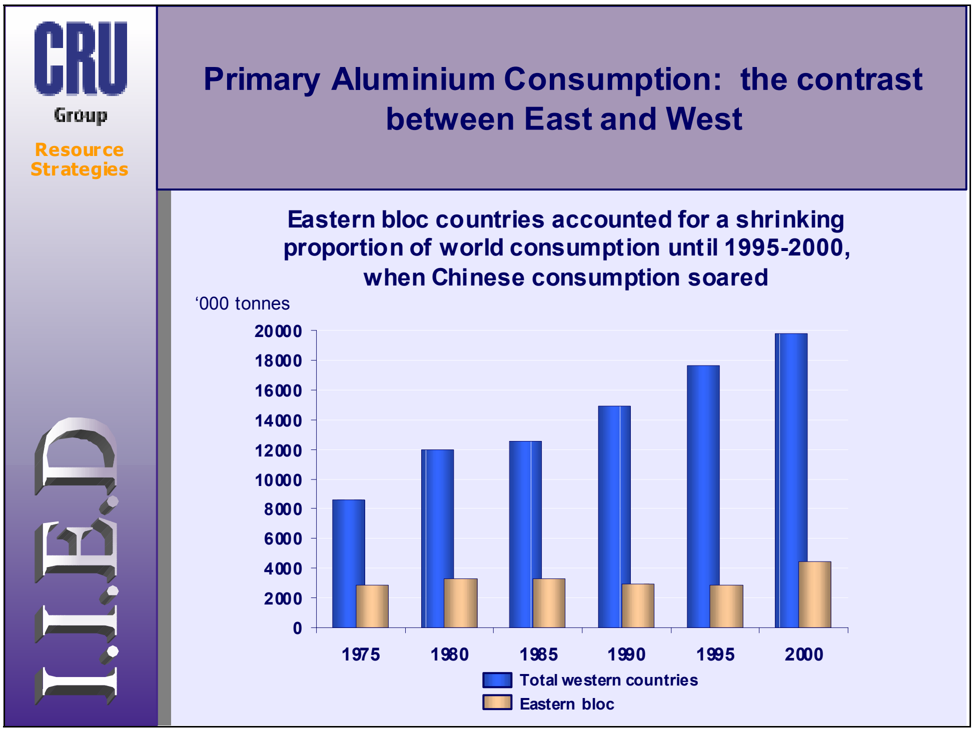
It is impossible to measure the consumption of aluminium at the point of final consumption, when the metal may well be only a small component by volume and by value of the final product.

Any analysis of the consumption of non-ferrous metals is therefore biased towards the industrialised countries, because that is where the majority of the semi-fabricating plants are located. These countries are typically net exporters of semi-processed or finished goods to the industrialising countries. Such products containing aluminium which are exported should ideally be counted as consumption in the countries where the final product is bought and used. However, the available data allows them to be counted only in the countries where the first semi-fabricating process occurs.



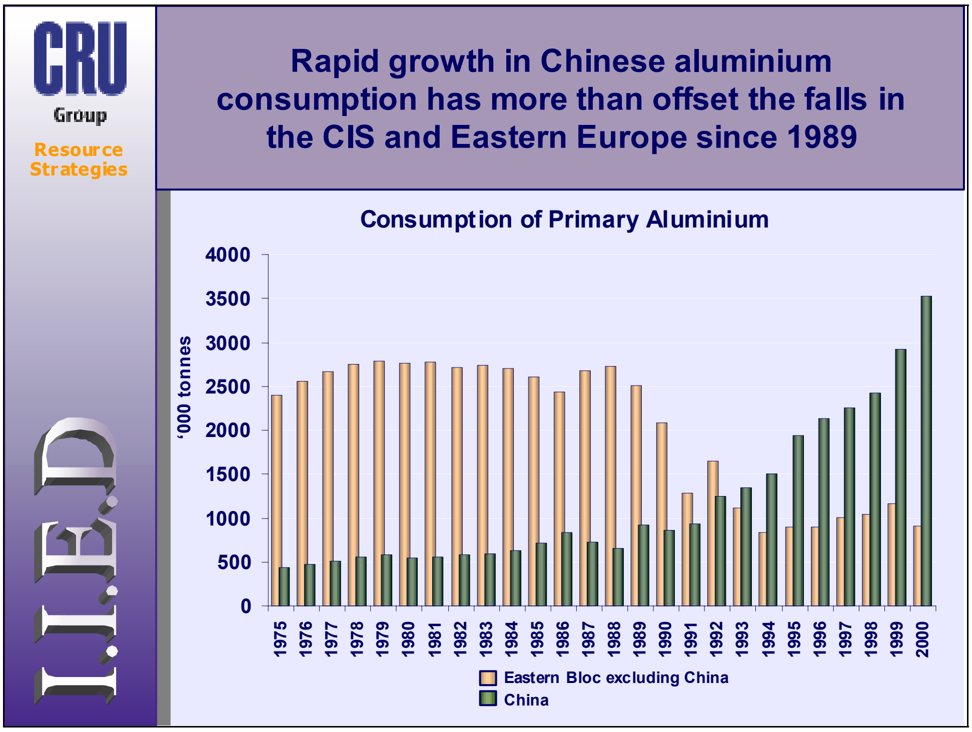
In volume, North America remains the largest single market for primary aluminium, with 6.9m tonnes or 28% of total world consumption. However, its share in 1975 was even higher, at 31%. Western Europe follows with 5.8m tonnes, or 24% of the world total, exactly the same share as it held in 1975. Asia comes third with 5.4m tonnes, or 22% of the world total; this region's share of the total has grown from 14% in 1975.

The former Communist countries of the Eastern Bloc accounted for 4.4m tonnes of consumption in 2000, or 18% of the world total, down from 25% in 1975. However, consumption has followed a very erratic pattern. It rose to a peak in the mid 1980s but then declined as the economy of the former USSR fell into decay. In 1995 the volume of metal consumed in the Eastern bloc was exactly the same as it was in 1975, at 2.8m tonnes. In the five years of 1995-2000 the Eastern bloc was the fastest growing consumer of aluminium in the world, entirely as a result of the extraordinarily high growth in demand in China. We illustrate this development on the following page.



The increasing dominance of the Western world as a consumer of aluminium from 1975 to 1995 is illustrated above. In 1975, some 75% of aluminium consumption occurred in the Western economies; by 1995, which marked approximately the low point in the collapse of the economies of the former USSR and Eastern Europe, this share had risen to 86%.

Since 1995, total consumption in the Eastern bloc countries has grown by 9.4% per year. The driving force has been the Chinese economy, where demand for aluminium has grown by 12.7% per year since 1995, compared to a mere 0.3% in the remainder of the Eastern bloc.



The chart above illustrates the massive growth in Chinese consumption of primary aluminium since the early 1990s and the collapse in Russian and East European demand that started at the same time. China consumed a mere 440,000 tonnes in 1975. By 1989, this had roughly doubled to 920,000 tonnes. Consumption then grew at 13% per year in the subsequent 11 years, to reach 3.55m tonnes in 2000, when China was the second largest national market for primary aluminium after the USA.

The experience of the former USSR and of Eastern Europe has been the mirror image of Chin's growth. In 1975 these centrally planned economies consumed an estimated 2.4m tonnes of aluminium (though it must be admitted that the quality of data on consumption in the former USSR and Eastern Europe in this period was far from perfect). By 1989, consumption was still at a similar level, at 2.5m tonnes. Since then it fell very sharply in the early 1990s and recovered only slightly in the second half of the 1990s, to stand at 908,000 tonnes in 2000.

The lesson is that when the centralised economic planning system was operational in the whole of the Eastern bloc, it delivered no growth in metal consumption, which is closely related to the general standard of living. When this economic model broke down in the USSR and Eastern Europe, the collapse in the standard of living was reflected directly in a collapse in the consumption of aluminium. The lack of purchasing power put aluminium products beyond the reach of domestic consumers; producers of the metal by the same token had every incentive to export metal to Western countries, rather than sell it locally.

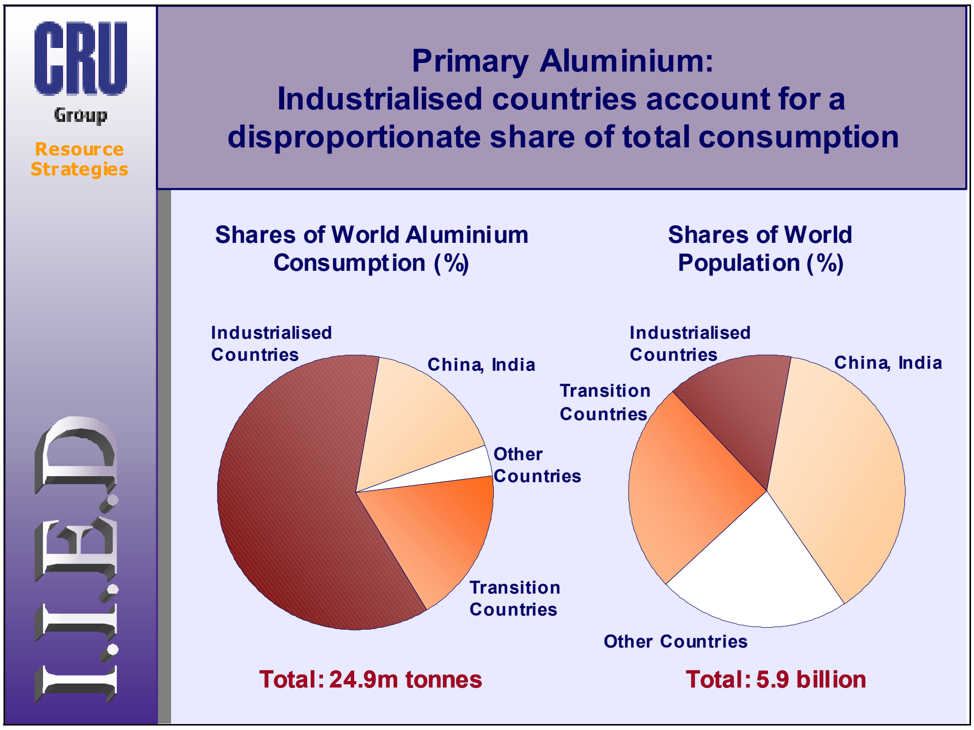
The Chinese economy has developed along different lines. Central planning has been replaced gradually by free market policies; private enterprise has been allowed to grow and foreign investment has been attracted; at the same time, the state has been able to finance large infrastructure projects. When applied to the huge Chinese population, this process has generated very rapid growth in demand for aluminium.

2. Consensus forecasts of demand

The consensus among forecasters of the long term trends in the aluminium market appears to be that consumption will continue to grow at its historical growth rate of 3% at least over the next five years. ABARE (the Australian Bureau of Agricultural and Resource Economics) forecasts a world growth rate of 3% in 2000-06. CRU International forecasts 3% growth in the Western world but 3.5-4.0% for the world as a whole because Chinese consumption is expected to continue growing at double digit rates.

Shorter term forecasts produce lower average growth rates because a downturn is expected in 2001. Thus Credit Suisse First Boston, for example, forecasts no overall growth in consumption 2000-03, but this includes a fall of 5.4% in 2001.

3. The distribution of aluminium demand



Primary aluminium consumption is heavily concentrated in the industrialised countries of the world. We have defined these as the USA, Canada, Western Europe as a whole, Japan, Australia and New Zealand. In 2000, these countries accounted for 61.5% of aluminium consumption but for only 14.6% of the world's population.

The second group, which we have called transition countries comprises Taiwan, South Korea and the emerging East Asian economies, Turkey, Latin America as a whole, Eastern Europe and the CIS. These countries in general have a moderate level of industrialisation and infrastructure, and are at the stage when faster growth in metal consumption can be expected as they enter or move through the metal-intensive phase of economic development. The disparity between population and metal consumption here is not so severe. This group accounts for 18% of total metal consumption and 25% of total population.

China and India have been shown separately. They can also be regarded as transition economies. However their populations are so huge that they would swamp other countries in any collective analysis. In 2000, they accounted for 16.6% of aluminium consumption and 37.8% of total population.

Finally, the remaining countries of the world, which consist principally of all the African countries and the remainder of the Asian continent contain 22.4% of total population but account for only 3.6% of aluminium consumption.

We must repeat the caveat expressed earlier about the definition of metal consumption. This term measures the use of metal at the first processing or semi-fabricating stage, and not at the point of final use. Therefore it is biased towards the countries which have large semi-fabricating industries and which export semi products or finished goods containing aluminium. The data does not exist to calculate the final consumption of metal by country, but if it did, we can be fairly confident that it would reduce the apparent disparity between the richer and the poorer countries shown in this chart. Nevertheless, there can be no doubt that the richer and more industrialised countries do consume proportionately more metal than the poorer countries, simply because their citizens have greater purchasing power.

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Large variations in per capita consumption

	% of World Population	Aluminium kg/head (2000)
Industrialised Countries		
USA	4.6	22.3
Canada	0.5	26.6
Western Europe	6.9	14.2
Japan	2.1	17.7
Australia	0.3	18.3
Average / Total	**14.6**	**17.8**
Transition Countries		
Korea	0.8	17.6
Taiwan	0.4	22.8
Other S.E. Asia	7.8	1.1
CIS	4.8	3.1
Turkey	1.1	3.3
Eastern Europe	1.8	6.5
Latin America	8.6	1.8
Average / Total	**25.2**	**3.1**
China and India	**37.8**	**1.9**
Others	**22.4**	**0.7**

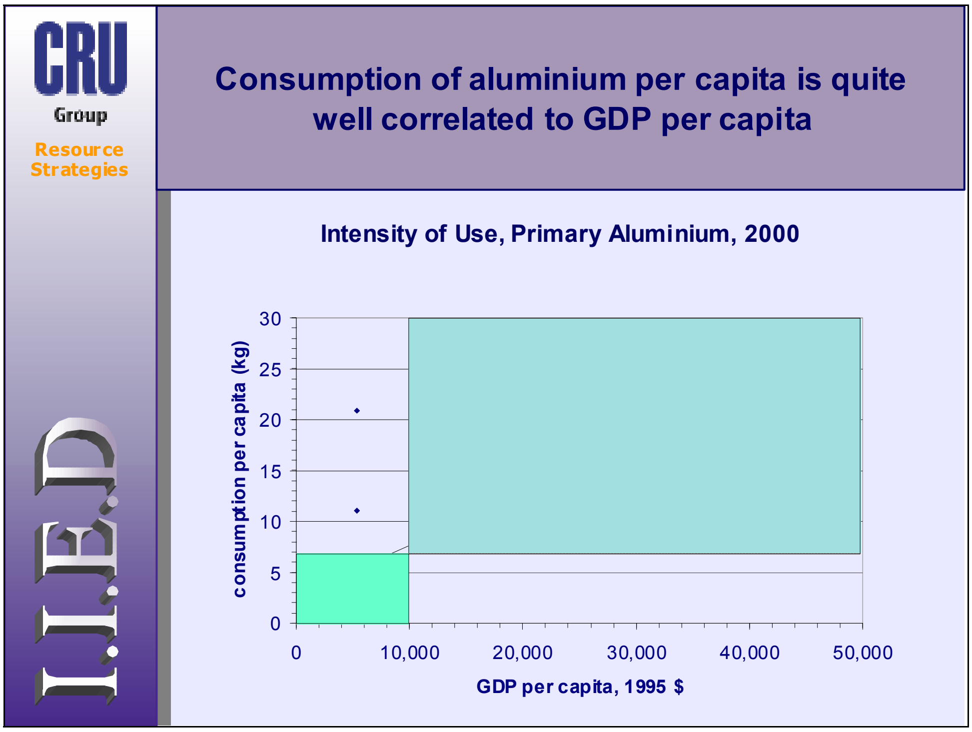
Sources: United Nations, WBMS

I.I.E.D

Calculations of aluminium consumption per capita by country fill out in greater detail the contrast shown in the previous chart. Consumption averages 17.8kg per capita in the industrialised countries, and reached over 20kg per capita in North America.

In the transition countries, the average is only 3.1kg per capita. However, it is instructive to note the very high consumption levels of Taiwan and South Korea. The former has a higher per capita consumption than the USA, and the latter has a level of consumption almost equal to the average of the industrialised group of countries. Both countries have pursued a policy of investment in the metal sector, and particularly in semi-fabrication of non-ferrous metals in order to serve export markets.

In both countries there is no doubt that the real consumption of aluminium per capita in final uses would be much lower, if it could be measured. These countries provide good examples of the weakness of using the only available data on metal consumption as a basis for assessing per capita consumption.



Plotting consumption per capita against GDP per capita reveals a reasonably good relationship between the two measures. Consumption rises as GDP per capita increases. However, a more interesting distinction is also revealed between countries with per capita GDP above and below $10,000. A large number of countries are clustered below this level and all, with two exceptions, consume less than 6 kg of aluminium per capita.

Above this cut-off point, consumption per capita rises quite rapidly because this appears to be the level at which substantial semi-fabricating industries develop, partly to serve domestic demand and partly to serve export markets. Note that Western Europe is shown as a single point on this chart at 14.9 kg per capita.

The outliers among the countries with GDP per capita of less than $10,000 are Hungary and Czech Republic. These two countries happen to have developed substantial semi-fabricating industries in relation to the size of their populations. In Hungary, the aluminium industry was developed under the Communist system, from bauxite mining through to smelting and semi-fabricating. The upstream part of the industry has to a large extent closed down since 1989, because it was uneconomic, but the semi-fabricating sector continues, and is largely export-oriented.

Among the countries with GDP per capita below $10,000, there are a few countries, notably Brazil, Russia and China, which do have considerable semi-fabricating industries, and therefore considerable metal consumption in absolute terms (520,000 tonnes in Brazil, 760,000 tonnes in Russia and 3.5m tonnes in China). And the great majority of this production is consumed domestically. However, the size of their populations is such that per capita consumption is still below 6 kg. One should not conclude therefore that all countries in the lower GDP range are deprived of access to aluminium semi products.

4. Drivers of demand and competition with alternative materials

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I.I.E.D

Aluminium has a wide range of end-uses, with some variation between major areas of consumption

	USA	Japan	4 largest European countries
Transport equipment	35%	34%	31%
Construction & materials	14%	21%	18%
Packaging	26%	12%	16%
Domestic & commercial	6%	5%	7%
Electrical equipment	8%	6%	9%
Machinery	7%	6%	12%
Other	3%	16%	7%

In the industrialised countries, construction, transport and packaging are the most important end-uses for aluminium. In the construction sector the metal is used in the form of extrusions in window and door frames, partitions, hand-rails, parapet railings, light fittings and Venetian blinds. Aluminium sheet is used in some countries to cover the sides of buildings, and also for roofing.

In the transport industries applications include aircraft body panels ands interior fittings, structural components in buses and trucks, wheels, engine blocks and other cast components in cars, and bicycle frames. Considerable efforts are now being made by the major aluminium companies to develop new applications for aluminium in cars, in order to help car manufacturers to produce lighter and therefore more fuel-efficient cars. These applications include body panels, bumpers, roof racks, side impact bars, seat frames and air bag frames. There are also prototype car bodies in which the entire body frame is made from aluminium components.

The major packaging application for aluminium is the beverage can. This is widely used for beer and carbonated drinks, especially in North America where the application was first developed. There is still strong competition from other materials such as tinplate, glass, PET and laminated products for packaging drinks.

Aluminium is also very widely used in the form of foil for packaging food, such as confectionary, dairy products and ready cooked meals. Household foil is used for wrapping food in the home. Foil is also used to package pharmaceutical products and cigarettes. Finally, a wide range of laminated products has been developed for packaging food and drinks. These can combine aluminium foil, plastics and paper.

Aluminium is used as an electrical conductor, almost entirely now in overhead power lines, where its light weight in relation to its conducting capacity makes it the most effective available material. Aluminium wiring is seldom used now.

Other domestic applications include cooking pots, garden furniture, greenhouse and conservatory frames, sports equipment and office furniture.

Industrial applications are very diverse. One easily identified use is tread plate in factories and other industrial buildings. In the form of powder, aluminium is used in paints and in fireworks and other explosives.

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Aluminium: the drivers of demand

- Macro-economic drivers: population growth, GDP growth, income levels
- Micro economic drivers: exploitation of the characteristics of Al:
  - Weight/strength ratio
  - Ease of recycling
  - Versatility
  - Formability: rolling, extrusion, casting, drawing
- Product and market development by large integrated companies and by industry associations
- Price and performance in comparison with alternative materials

Aluminium is the most versatile of all the non-ferrous metals and therefore has the widest variety of applications. Consequently, the macro-economic drivers of demand are the most basic measures of the economic development, namely the size and rate of growth in population, the size and rate of growth in GDP and the purchasing power of the population.

More specific, micro-economic drivers of demand are as follows:

- The high strength to weight ratio (which can be improved by alloying) accounts for the use of the metal in aircraft and in other transport applications.
- Aluminium can be easily recycled, and the relatively high value of the metal provides a strong incentive for recycling. This has enabled aluminium to penetrate some applications previously dominated by steel or other materials. The beverage can is the prime example. Aluminium displaced tinplate (steel coated with tin) in North America, even though aluminium is much more expensive. The key to success was the creation of recycling networks which enable used beverage cans to be returned for processing back into canbody sheet. The ease of recycling is also an attraction to the automobile industry and others which face the requirement to take back products at the end of their useful lives.
- Aluminium is an effective conductor of electricity.
- Aluminium can be formed by rolling down to sheet or foil with thicknesses of as little as 7 microns, it can be extruded, cast or drawn into a huge range of shapes.

The structure of the industry has helped to promote and develop applications and markets for aluminium. In the early year after World War II, there were a small number of integrated companies in North America and Europe which had concentrated on producing aluminium mainly for military aircraft. They had to find new markets when the war ended, and therefore invested heavily and successfully in market development. The aluminium beverage can was the most successful product of this effort.

In more recent years, the industry has become more diffuse and less heavily integrated. The enthusiasm for product and market development among the larger players was reduced because they could not retain the benefit of such investments for themselves. Some work was done on a collective basis by industry associations to protect and develop markets, but on a smaller scale and with less effect. In the last five years there has been a move towards consolidation in the structure of the industry, which should provide a new incentive for product and market development. We can see this at work in the efforts to develop new automotive applications.

Whatever the level of investment made in promotion and development, the use of this metal (and of all others) is ultimately determined by the price of the metal and its performance in comparison to alternative materials. There are very few applications where aluminium is the only material which can provide the required properties. In the vast majority of cases, the designer of the final product assesses the properties, performance and price of the metal in comparison with the alternative materials, and selects what he judges to be the best solution for his market.

Aluminium has won and lost markets through substitution, ever since the metal began to be produced on an industrial scale. Aluminium won its first mass market, in aircraft frames, when it substituted for balsa wood and canvas.

In the transmission of electricity, aluminium competes with copper. Aluminium has won the market for overhead conductors but lost the market for house wiring and power cables that are laid under ground. The difficulty in making connections makes aluminium house wiring dangerous; copper is the better material for this purpose. The greater density of copper makes it more effective as a conductor where space is restricted.

In beverage packaging, convenience and recyclability have favoured aluminium, but tinplate has recovered some market share, particularly in Europe, on both counts. PET has made gains on the grounds of convenience for large containers, but still faces opposition because it cannot be conveniently recycled. Glass bottles can be re-used, and have some traditional appeal in some countries. Paper, plastic and laminates compete with aluminium foil in its packaging applications.

The whole packaging sector demonstrates the constant competition between materials at its most intense. Producers of final products are constantly searching for some competitive advantage, either in cost or in the performance of their products. Suppliers of materials are constantly striving to retain or enlarge their markets by improving their products. The ultimate beneficiary is the final consumer, who gets a greater choice of products, and better or more cost-effective products, often without appreciating the investment and competition that has gone into the selection of the materials used.

The same competitive forces are at work in the transport sector, and particularly in the design and manufacture of automobiles. Here, aluminium offers the same or better strength with lighter weight compared to steel. However, the cost of aluminium per tonne can be four or five times as high as steel. Other materials such as magnesium and engineering plastics are also competing for use in automotive components. The car manufacturers are able to exert very great pressure on their material suppliers to invest in product development and also to reduce product prices. The final consumer gains from this competitive process again by obtaining better choice and higher quality and more cost-effective cars.

In the construction sector, aluminium displaced steel and wood in window frames and door frames, but has more recently lost some market share to plastic window frames. The deciding factors here are product design and the performance of the product when exposed to variations in temperature and climate.

Substitution is a continuing process of competition between suppliers of many materials, not all of them metals. The process involves comparison of material specifications, material prices, manufacturing costs, marketing, and consumer preferences. It is a fluid and dynamic process which works to the benefit of the consumer who makes the ultimate choice in what he buys.

The continuing competition between alternative materials also contributes to the most efficient and economical use of each one. In order to retain end-uses, producers and manufacturers of aluminium products seek to use the metal in its thinnest or lightest form. Aluminium cansheet, for example, used in manufacturing beverage can bodies, has been reduced in thickness from 0.30mm in 1994 to 0.28mm in 1999. It is expected to reach 0.27mm in 2004 and material of 0.245mm has been used. The same trend repeated in other end-uses results in a continuing improvement in the efficiency of use of natural resources.

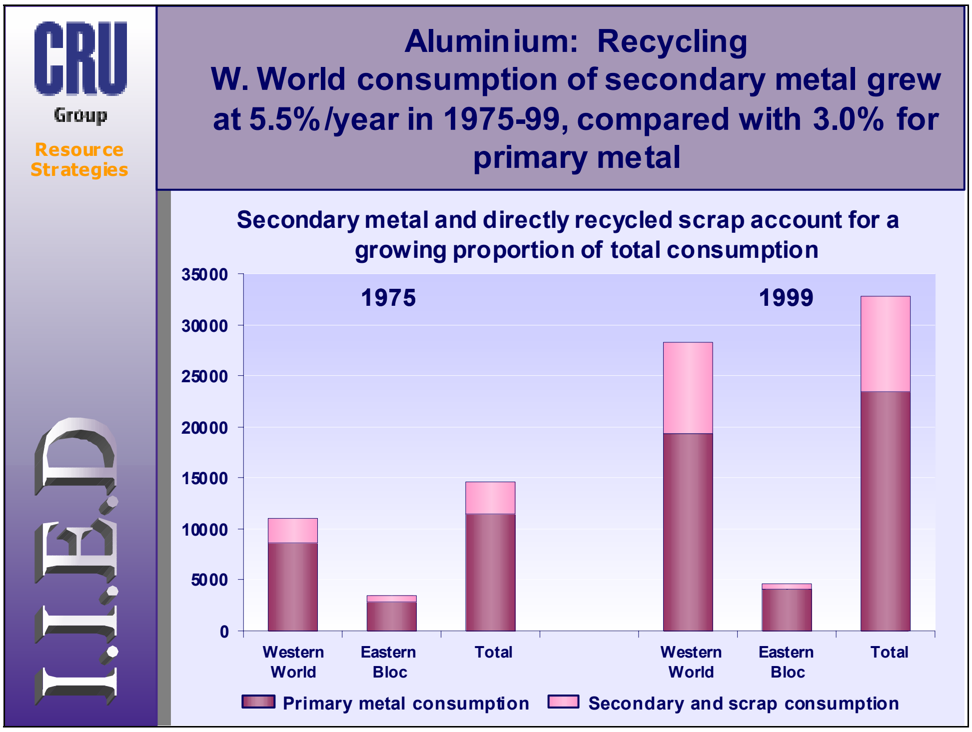
5. The recycling of aluminium

In essence, the recycling of aluminium consists of collecting scrap, separating it from other materials such as plastics or other metals, melting it and casting it into a form in which it can be supplied again to a semi-fabricating process. Aluminium scrap arises in two ways: new scrap is generated in the form of off-cuts, turnings, saw chips and the like in manufacturing processes. New scrap is normally returned to the supplier of the metal for reprocessing very quickly; in many cases it is re-processed by the company that generates the scrap. Its value is recognised and captured immediately.

Old scrap, or post-consumer scrap arises when a product containing aluminium comes to the end of its life and is discarded or dismantled. This may take a few weeks in the case of a beverage can, 10 to 15 years in the case of a car and 30 to 50 years in the case of a building. Some products, notably foil and powder, are used in dispersive applications which prevent the metal from being recovered after use.

The rate at which aluminium is recycled is therefore determined by the rate at which it is fabricated (in the case of new scrap), and the rate at which used products are discarded (in the case of old scrap). Because the use of the metal is growing, the pool of metal in use is constantly growing. Most of this metal can potentially be recycled at some point.

However, a collection system is also required, and re-processing facilities are required to convert scrap into a usable form. These tend to be set up only when there is a sufficient concentration of metal in use to generate scrap in large enough quantities to justify investment in scrap collection and processing.



The volume of aluminium recycled has increase steadily, as the volume of metal in use has grown and the facilities for collecting and re-processing scrap have developed. The chart above shows that the recorded volume of secondary aluminium consumption plus the direct use of scrap has risen from 3.1m tonnes worldwide in 1975 to 9.4m tonnes in 1999 (the last year for which this data is fully available). The rate of growth has been 4.7% per year, compared with 3% per year for primary aluminium consumption alone. In the Western world, where recycling has received more investment and attention, consumption of secondary aluminium and the direct use of scrap has grown at 5.5% per year compared with 4% per year for primary aluminium alone.

The proportion of total aluminium consumption accounted for by secondary metal has therefore increased from 21% in 1975 to 29% in 1999 worldwide, and from 22% to 31% in the Western world. There are major regional differences in the rate of recycling. In North America as much as 35% of total aluminium consumption comes from secondary sources; the recycling of aluminium cans contributes heavily to this figure. In Western Europe, the figure is 31%, but in Asia it is only 25%.

In general, secondary consumption is lower in regions where aluminium consumption has grown rapidly in recent years. Here, metal is still being added to the pool in the form of power lines and building products for example, which may not return as scrap for many years. Metal is also consumed in scattered locations in, for example, South East Asia or China, so scrap collection can be inefficient or even nonexistent.

In areas where metal consumption has been relatively high for many years, such as Western Europe or North America, and where centres of consumption are more concentrated, the collection system is better developed and so proportion of old scrap returning to the market is higher. In the USA as much as 80% of the raw material used to produce can body stock is scrap. In Western Europe the corresponding figure is 50%.

It should be noted that the data for secondary recovery of aluminium is much less complete that that for primary consumption, in several ways. The major form of secondary production is the remelting of scrap to produce alloy ingots. This is reasonably well recorded, but there are undoubtedly some small secondary smelters which do not report production. There are also producers of billet from scrap (with some primary additions). Production from these plants is much less well recorded in Europe.

Then there is scrap that is directly re-used in semi-fabricating plants that have their own casting facilities. This scrap can arise within the plant or be bought in from scrap merchants. This recycled material is not fully recorded and in some countries is not recorded at all.

Finally some pure aluminium scrap is melted in the casthouses of primary smelters and cast into products that are sold as primary aluminium. How this metal is recorded, if at all, is uncertain.

All that can be said with confidence is that the volume of aluminium recycled is greater than the volume recorded and shown in the chart above. This should be borne in mind when considering any calculations about the amount of aluminium scrap that is lost in landfills and could in theory have been recycled.

There are conceptual difficulties in comparing the cost of producing primary aluminium and secondary aluminium, mainly in the way in which raw materials are priced. The best basis for comparison is to ignore or separate out the cost of raw materials (alumina for primary and scrap for secondary metal). The production processes are entirely different. The primary process is an electrolytic process that converts alumina into liquid metal, and requires approximately 13,000-14,000 kWh of electric power per tonne of aluminium. The secondary process involves melting scrap and adding a small proportion of primary metal and/or master alloys, in order to produce a specific alloy

If raw material costs are ignored, the cost of converting alumina to primary metal in a typical modern smelter at 2000 prices was about $700/tonne. The alumina required to produce a tonne of metal cost on average $474/tonne of metal in 2000, which gives a total operating cost of $1174/tonne of primary metal. At the average cash LME metal price in 2000, there was a margin of $375/tonne to cover marketing, delivery and finance costs and provide for a return on capital. In practice, the margin would have been higher because producers also receive a premium over the LME price.

At a secondary smelter, a typical cost in Europe for converting scrap to alloy ingot in 2000 was $307/tonne. The difference between that figure and the average price for the standard LM24 alloy was $1093/tonne. This amount was therefore available to cover the cost of marketing, delivery, freight and finance, provide a return on capital and pay for the acquisition of scrap. The actual division of this margin between the secondary smelter and the seller of scrap varies according to market conditions. Scrap is priced normally on the basis of the LME aluminium price or (less commonly) the LME aluminium alloy price. Typically the scrap seller is able to claim the great majority of this margin. The value of scrap varies overtime, in line with the value of primary metal or aluminium alloys, but it is clearly considerable.

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Factors that promote or hinder recycling of aluminium

- The value of scrap is the main incentive to collect and recycle; for new scrap this is a sufficient incentive
- For post-consumer scrap, price is an adequate incentive when scrap arises in reasonable volume (e.g. building demolition)
- For more dispersive uses (e.g. beverage cans), investment in collection systems is required, plus a cash incentive to the consumers (e.g. cash deposits or payments)
- Some governments require certain rates of recycling to be achieved
- Deterrents include environmental costs of operating recycling plants and controls on shipment of scrap

I.I.E.D

The analysis of the economics of recycling indicates that there is a substantial (though variable) margin available to remunerate the scrap collecting chain that brings scrap to the secondary smelters or the direct user of scrap. For companies that generate new aluminium scrap, the economic incentive to obtain cash for what would otherwise be a waste product is irresistible, especially since their own scrap collection costs will be small.

For old scrap, the economics of collection may not be quite so compelling. There may be a chain composed of four or five parties between the point where old scrap is generated and the point where it is sold to a secondary smelter. Each one has collection, storage, transport and finance costs. The value of the scrap therefore diminishes as one goes back to the beginning of the chain.

Nevertheless, the value of the scrap even at the start of the chain will be enough to ensure that it is recycled rather than thrown away as waste in a landfill site, provided the scrap arises in sufficient volume or close enough to a scrap merchanting operation.

The scrap that is wasted tends to arise in very small units (for example, individual beverage cans or pieces of foil); alternatively, it arises in places where there is no scrap collecting industry because the total volume of metal consumption in that location does not yet justify investment in a yard to collect and sort scrap.

Any government intervention designed to improve and encourage the recycling of aluminium should therefore focus on those types of scrap which do not have sufficient value to ensure that the existing system gathers them in. One option is to add a deposit to the price of an aluminium can, which is returnable when the can is recycled. However, the costs of operating this system may easily outweigh its value. In the USA some aluminium companies have installed at supermarkets and similar locations machines which return a small amount of money for every used can deposited. Another option is for municipal authorities to provide recycling centres for the general public where they may return used cans from their household waste.

Many countries have legislation controlling packaging materials and recycling. Several US states have legislation requiring certain recycling rates to be achieved for all drinks containers. Some also require packaging materials to contain minimum proportions of recycled raw materials.

Japan has a target of 70% for recycling aluminium cans by 2000 and 80% by 2002. The proportion of old cans used in the production of new cans must be 80% by 2002. The European Union Directive on Packaging and Waste requires that by 2001 member countries should recover 50-60% of their used packaging; that material recycling rates should be 24-25%; and that no material should be recycled at less than 15%. In practice, the aluminium can industry far exceeds these targets. Aluminium foil, on the other hand, is recycled at generally very low rates.

Government intervention can also hinder the collection and recycling of scrap. Environmental controls are rightly imposed on the secondary smelting industry, which can cause serious pollution. Compliance involves additional capital and operating costs. However, if these regulations are not fully and uniformly imposed, they enable non-compliant recyclers to remain in business and compete on an unfair basis with those smelters that have incurred the costs of compliance. This can threaten to drive the compliant smelters out of business.

One inter-governmental initiative that could hinder the recycling of scrap is the Basel Convention, which is designed to prevent the movement of hazardous waste materials across national borders and ensure that they are processed close to the point where they arise. The precise definition of hazardous wastes is still not finalised. Aluminium scrap is traded internationally, and any restriction on this trade could result in scrap being thrown away, rather than recycled.

Scrap Sorting Techniques

A persistent obstacle to the efficient recycling of aluminium is the fact that the metal is used in many different alloys. Ideally scrap should be sorted into alloys so that it can be recycled as that specific alloy. With new scrap that arises in an industrial process, it is not difficult to keep scrap of the various alloys separate. With old scrap, and particularly with scrap that arises from the shredding of cars or household goods, there is currently no commercial process for separating the scrap by alloy; separating the different metals that are contained in a car (steel, zinc, copper, aluminium, for example) is all that can be achieved.

If aluminium scrap contains several different alloys, it is feasible to recycle it only as the lowest grade of foundry alloy with the least demanding specifications regarding impurities and alloying elements. Thus unsorted scrap feeds only the lowest value category of alloy production.

A recent development by Alcan Aluminium promises to make it possible to segregate shredded scrap by alloy. The process uses laser induced optical spectroscopy. Each piece of scrap is sampled by means of a laser, identified and then separated by alloy. If commercially proven, the process would enable much more of the value of aluminium scrap from shredded automobiles to be retained. The process is being tested by the Huron Valley Steel Corporation, and is being promoted by the Auto Aluminum Alliance.

(sources: Aluminum Association; Mechanical Engineering, 1999)

6. The pricing and trading of aluminium

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The Pricing of Primary Aluminium: smelter products

- Primary metal is traded between smelters and semi-fabricators in the form of ingots, T-bars, sows, billets, rolling slab, wirerod and molten metal
- Pricing is commonly the LME cash or forward price plus a premium to reflect casting costs, delivery, credit terms and security of supply. Contracts may be annual, quarterly or spot.
- In North America, producers publish monthly list prices for ingots and standard billets, which are related to the LME price. Transaction prices are negotiated on the basis of list prices.
- A maximum of 5% of LME transactions relate to physical sales or purchases of metal; all other transactions are for hedging or speculative purposes.
- However, as the world's market of last resort for buyers and sellers, the LME generates the world market price, which is used as a basis price for the great majority of metal sales

I.I.E.D

Primary aluminium emerges from smelters in the form of pure liquid metal which must be cast into a usable shape before it can be sold or transferred to a semi-fabricating operation. Smelters can cast and sell metal in the form of standard ingots, T-bars, sows, rolling slabs, billets and, wirerod. Occasionally, the metal is transferred in liquid form. The most commonly used basis price for the sale of aluminium is the London Metal Exchange price.

The London Metal Exchange (LME) trades primary aluminium and aluminium alloy. Transactions can be undertaken for immediate delivery (i.e. on a cash basis), or for delivery up to 27 months in the future. A seller of metal on the LME can elect to deliver metal into a registered LME warehouse, and a buyer can elect to take metal from a registered warehouse. The LME can therefore be a market for physical delivery, but only a very small proportion (5% at the maximum) of LME transactions result in a physical transaction. The vast majority of transactions are made for future delivery and are cancelled out by another transaction before delivery becomes due. These transactions are undertaken normally for hedging purposes (i.e. to fix a price and thus eliminate risk), or sometimes for speculative purposes (i.e. to take on a risk).

The LME price that emerges on every working day from these futures transactions is accepted as the best reflection of the worldwide balance between supply and demand, and is therefore used as a reference price for most sales of metal between producers and consumers worldwide. However, there is a common misapprehension that all aluminium traded is bought and sold through the LME. This is not the case. Most metal is sold by smelters to semi-fabricators and never passes through the LME. The buyer and seller simply agree to use the LME price as the basis for their transaction. The LME is used for physical transactions only as a market of last resort. A seller of metal with no customers may choose to deliver to an LME warehouse. A buyer with no supplier may similarly choose to buy on the LME and take delivery from a registered LME warehouse.

In the vast majority of cases, metal is sold direct by smelters to semi-fabricators on the basis of the LME price. A premium is added to the LME basis price, to reflect the cost of casting metal into ingot, slab or billet (or any other shape); the premium also reflects the value of delivery from the smelter to its customer; the value of credit given; and the value of any additional services that the smelter may provide.

Smelters may sell on a spot basis or on annual or quarterly contracts. Commitments are often made to sell metal at a future, and therefore unknown LME price. This introduces a risk for both parties, which they may accept; alternatively they can offset this risk by entering into an LME futures transaction. This is the hedging process which is the origin of the great majority of LME transactions.

Even when metal is transferred between a smelter and a semi-fabricating plant within an integrated aluminium company, the internal transfer price will generally be based on the LME price.

These comments about the role and use of the LME apply equally to the other metals traded on the LME, i.e. copper, lead, nickel, tin and zinc. (There is also a silver contract on the LME but it is little used.)

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The Pricing of Aluminium: semi-fabricated products and raw materials

- There is a high degree of integration between smelting and semi-fabrication in the aluminium industry
- Many producers therefore transfer primary metal internally from smelter to rolling mill or extrusion plant, and sell semi-fabricated products to third parties
- In some cases, semi products are priced on a formula basis, consisting of the LME price plus conversion cost
- In other cases, semi products are sold at negotiated prices, which reflect LME price movements but are not precisely based on the LME price
- The LME price is also commonly used as the basis for pricing alumina and electric power used in the smelting process

The LME aluminium price also has some influence on the pricing of products upstream and downstream of the production of metal. Alumina (which is the intermediate products between bauxite and aluminium metal) is often priced at a percentage of the LME aluminium price. It can also be priced at a fixed US dollar price, but even that price will tend to reflect the current LME metal price.

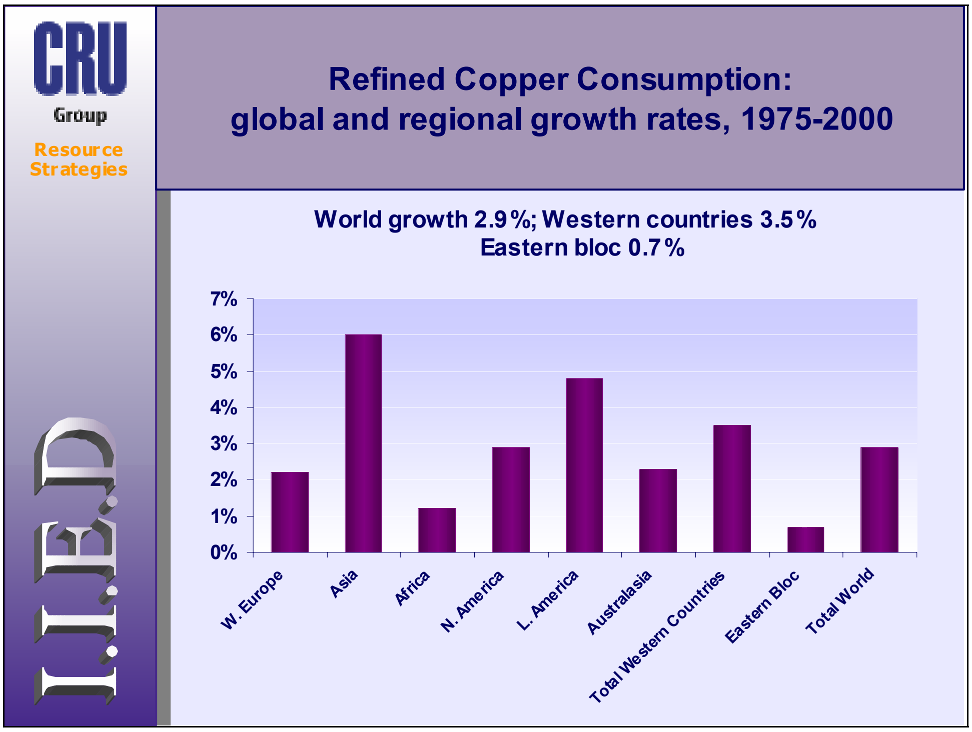
Electric power sold to smelters can also be priced through a formula which relates the price of power to the price of metal on the LME. The effect is to enable the smelter to share some of the risk of future fluctuations in the metal price with its power supplier.

Downstream products such as aluminium sheet and extrusions may be priced on the basis of the LME price and a conversion margin. Alternatively the price may simply be negotiated in local currency per tonne of product, but even in these cases, the price will be strongly influenced by the LME price of metal, since this will be a large component of the price of producing the semi product.

The LME therefore plays a central role in the trading of aluminium in many forms, and also in the price of raw materials for aluminium production, even though only a very small proportion of the metal produced annually passes physically through LME registered warehouses.

Chapter 3
The need for minerals: Copper

1. Global and regional growth in demand

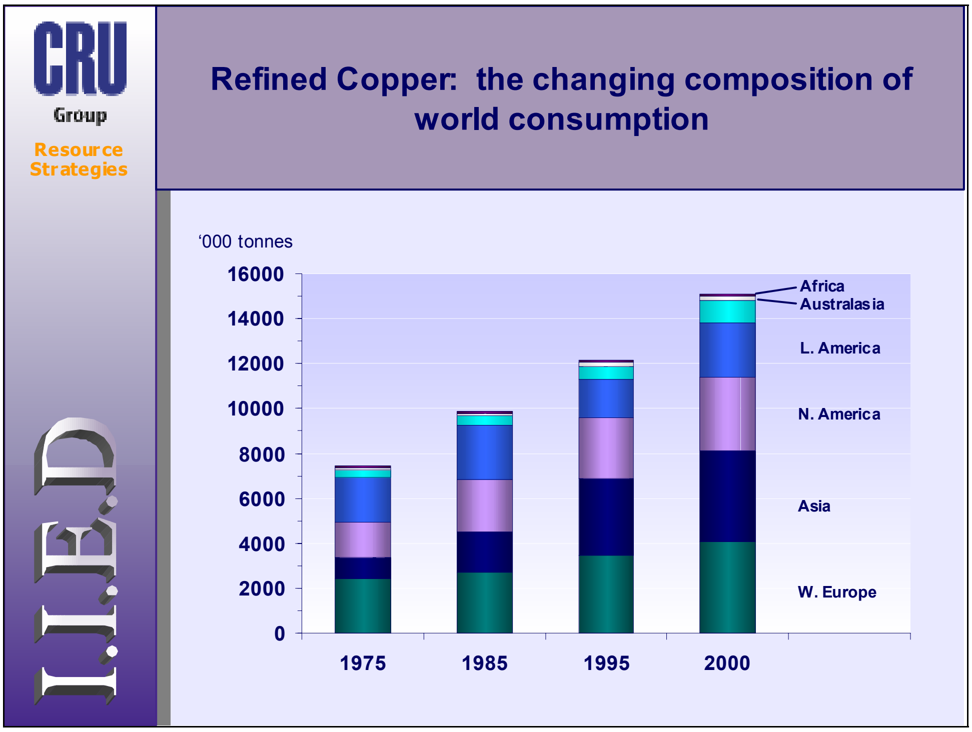


The consumption of refined copper grew at average rate of 2.9% per year worldwide in the 25 years from 1975 to 2000. Growth was fastest in the regions with a high concentration of developing economies. In Asia, excluding the former USSR/CIS, growth in consumption averaged 6.0% per year; in Latin America, the rate of growth was 4.8% per year. In contrast, in Western Europe, North America and Australasia, consumption grew at between 2.0 and 3.0% per year.

There was also a sharp distinction between the 3.5 % rate of growth achieved in the Western World and the rate of 0.7% achieved in the Eastern bloc, which is defined as the former USSR/CIS, Eastern Europe, China and North Korea. Under the central planning systems adopted in the former Communist regimes, copper was regarded as a strategic material which was not made available for domestic and household applications such as house wiring, water pipes, brass fittings and decorative items.

We must note here that the consumption of refined copper, like the consumption of primary aluminium, is measured at the point where copper is delivered to a semi-fabricating plant (such as a wirerod plant, a tube plant or a plant producing rolled copper sheet). The products of these plants may then be shipped elsewhere for manufacture in to final products, and those products in turn may not be consumed in the countries where they are produced.

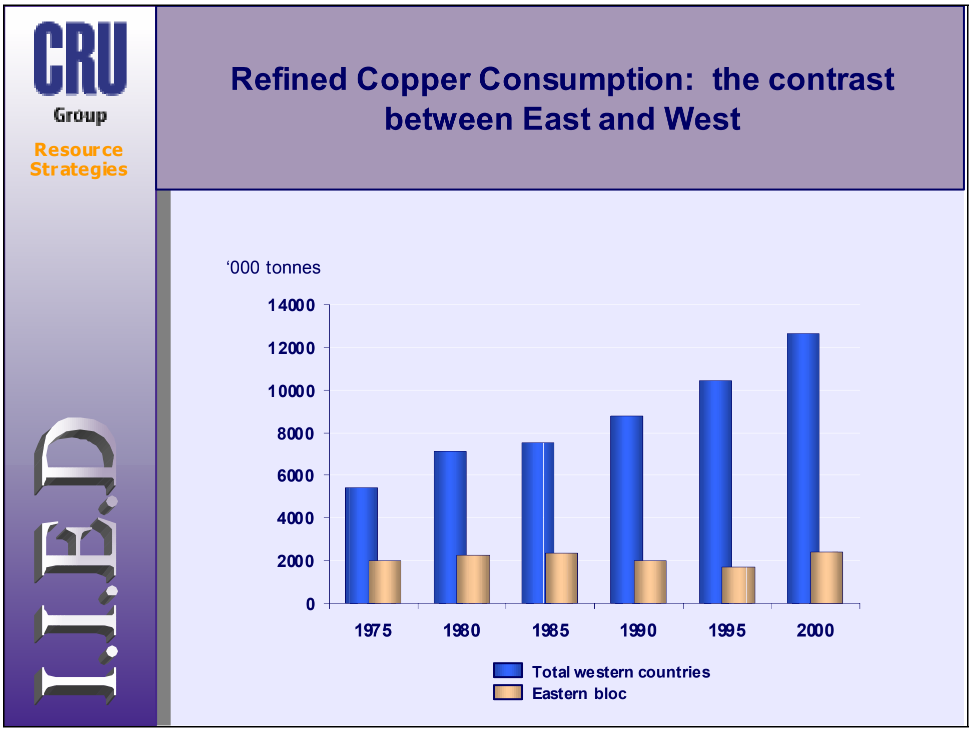
The copper industry's consumption figures therefore measure the growth in the semi-fabrication of copper, and not the growth in final consumption after adjustment in trade in copper products or finished goods containing copper. The figures therefore under-estimate the consumption of copper in countries that are net importers of goods containing copper, and exaggerate the share of consumption accounted for by countries which export semi-fabricated copper products.



As a result of varying growth rates, the composition of world consumption of copper has changed considerably since 1975. Western Europe has been the largest consuming region throughout that period, but its share of world consumption has fallen from 32% in 1975 to 27% in 2000. In absolute terms, the Western European market, at 4.1m tonnes in 2000 was only very slightly larger than the Asian market at 4.0m tonnes. The Asian share of the world market has grown from 13% in 1975 to 27% in 2000.

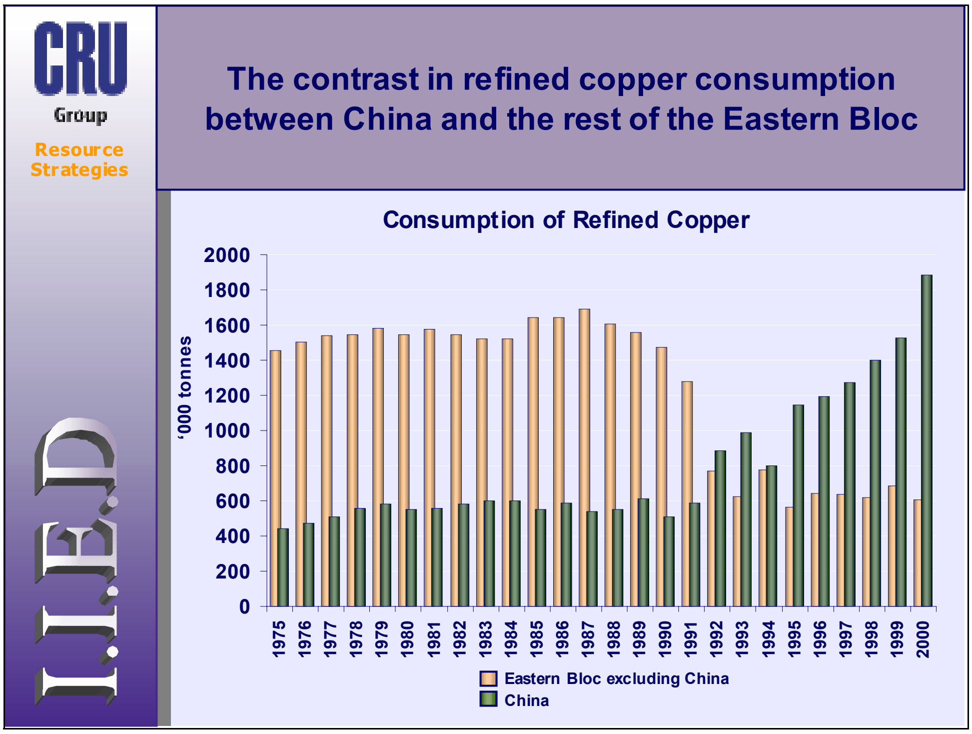
The North American market has doubled in size from 1.58m tonnes in 1975 to 3.25m tonnes in 2000, but its share of the world total has barely changed, and was 21.5% in 2000.

The Eastern bloc consumption grew in absolute terms from 2.0m tonnes in 1975 to 2.4m tonnes in 2000 but its share fell from 27% to 16% during that period. And the absolute size of this market fell by 660,000 tonnes between 1985 and 1995, when the Communist regimes in the former USSR and Eastern Europe collapsed. It was only in the second half of the 1990s that a sharp recovery occurred, thanks almost entirely to the rapid growth of the Chinese market.



The contrast between the Western world's consumption of copper and that of the Eastern bloc is illustrated above. The Western world dominated the world market even at the start of this period, with 73% of total consumption. By 1995 this share had grown to 86%. The growth in Chinese consumption brought the Western world's share down to 84% by 2000.

It should be noted that data on copper production and consumption for the Eastern bloc in the period before 1991 is much less reliable than that for the past decade. The former USSR classified all data on non-ferrous metals as a state secret, so the figures published in the West were only estimates compiled by analysts. Official data was never made available. In China, a similar restriction applied, and even since the early 1990s there have been doubts about the efficiency of data collection within the large and diffuse Chinese metals industry.



We can see in copper exactly the same contract between the experiences of China and the rest of the former Communist bloc as we saw in the previous chapter in aluminium. Demand in the Former USSR is estimated to have ranged from 1.4m to 1.7m tonnes per year from 1975 to 1990, while growth in Chinese demand was negligible.

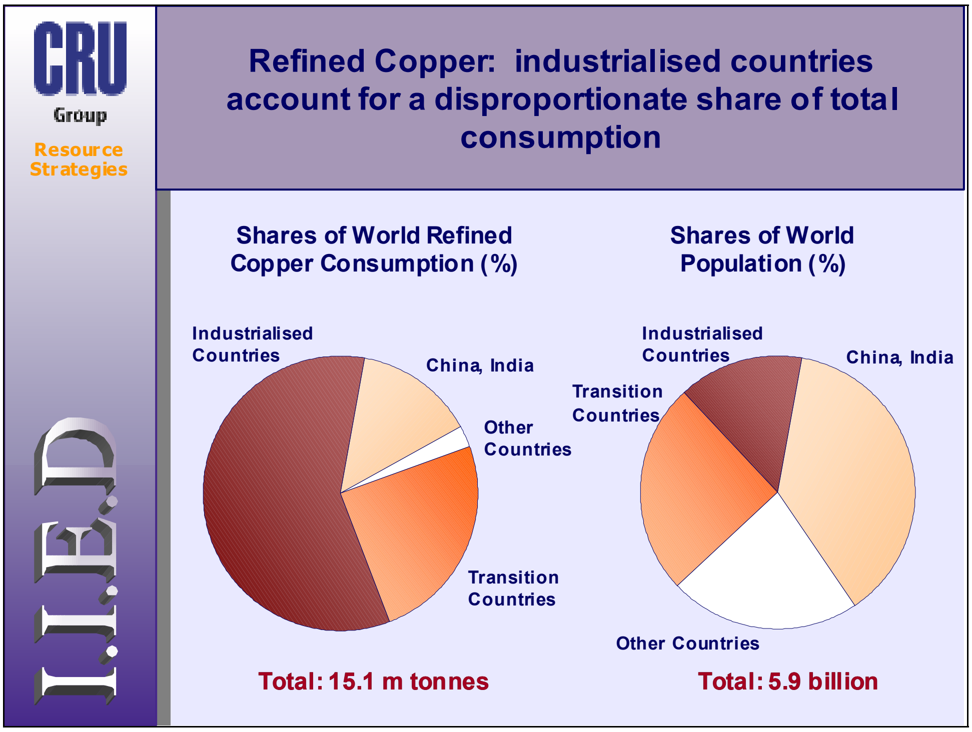
Consumption in the CIS and Eastern Europe collapsed in the 1990s to less than half of its level in the previous 15 years, and has not recovered significantly. Meanwhile consumption in China has soared to almost 1.9m tonnes, as a result of the liberalisation of the economy and the huge infrastructure investment programme undertaken in the past decade. The focus on the generation and distribution of power, and to a lesser extent the investment in telecommunications, has particularly helped the consumption of copper.

2. Consensus forecasts of demand

The consensus among analysts is that the consumption of copper will continue to grow in the next five years at a rate very similar to that of the last 25 years, which was 2.9% worldwide and 3.5% in the Western world. In 2000, ABARE, in Australia, forecast a growth rate of 3.0% worldwide for 2000-2005. CRU International forecasts a growth rate of 2.7% in 2000-2005, influenced by the prospect of a recession in late 2001 and 2002.

These forecast growth rates are clearly lower than the growth rate recorded in 1995-2000; this was 4.4% for the world as a whole and 4.0% for the Western world. Unusually, East bloc consumption grew at an extremely rapid 7.7%, as a result of the spectacular growth of the Chinese market.

3. The distribution of copper demand



There is an imbalance between the population and copper consumption in the groupings of countries shown in this chart. The industrialised countries (defined as the USA, Canada, Western Europe, Japan, Australia and New Zealand) contain 14.6% of the world's population but account for almost 59% of refined copper consumption.

The transition countries are very closely in balance, with 25.2% of the world's population and 24.6% of copper consumption. These countries consist of Taiwan, South Korea and the emerging economies of South East Asia, Turkey, Latin Africa as a whole, Eastern Europe and the CIS. However, the figures for this group are distorted by the data for Taiwan and South Korea. These two small countries consumed 1.49m tonnes of copper in 2000, which was 40% of the total consumption of the transition countries (and 10% of the whole world's consumption). Taiwan and South Korea have chosen to invest very heavily in the production of copper wirerod and other copper semi products, and are major exporters of these products. If Taiwan and South Korea are excluded from the transition countries, the remainder would account for 24% of world population and 15% of copper consumption.

China and India, with vast populations and, in the case of China, large copper consumption (1.88m tonnes in 2000) account for 37.8% of population and 14% of copper consumption. The remaining countries of the world contain 22.4% of population and 2.6% of copper consumption.

The imbalance is exaggerated to some unquantifiable degree by the definition of copper consumption as deliveries to semi-fabricating plants, as is shown by the cases of Taiwan and South Korea. However, this element of distortion certainly does not account for the overall imbalance between the industrialised and the non-industrialised countries.

The typical evolution is that countries at the early stages of development do not consume enough of any final product to justify local manufacture. Countries must reach a moderate stage of industrialisation before they can justify producing finished goods, and a higher degree of industrialisation before they can justify investment in intermediate copper products such as copper tubes, sheet and rod. There is a trend for these processes to migrate towards the developing and industrialising countries of the world, but the process lags the development of final markets for copper products in such countries.

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Large variations in per capita consumption

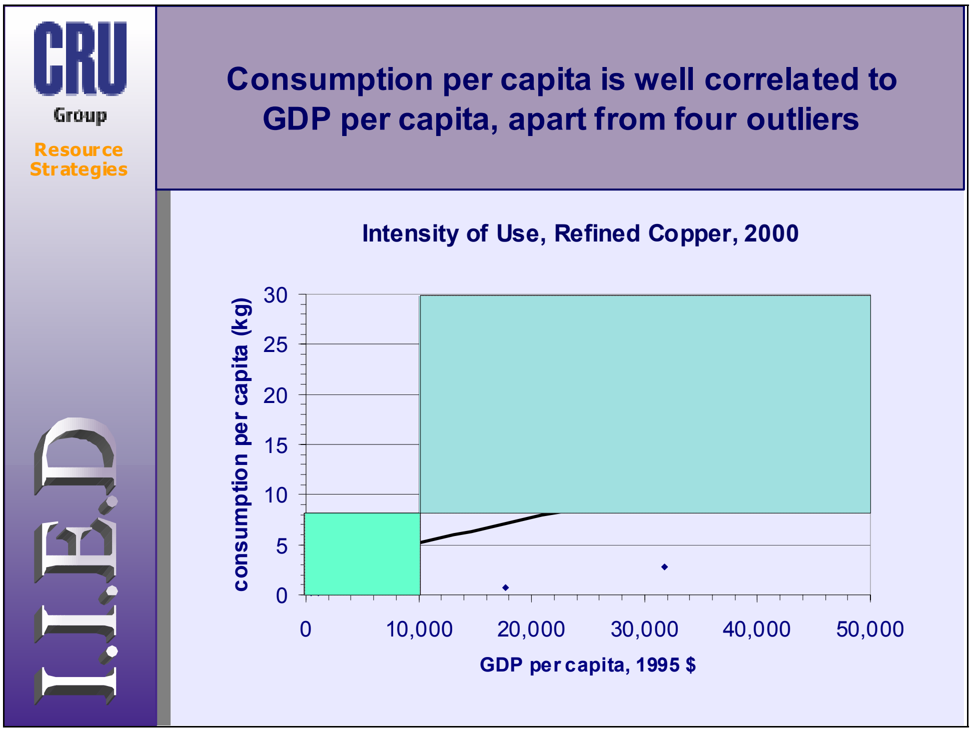
	% of World Population	Copper kg/head (2000)
Industrialised Countries		
USA	4.6	10.9
Canada	0.5	8.9
Western Europe	6.9	10.0
Japan	2.1	10.8
Australia	0.3	8.9
Average / Total	**14.6**	**10.3**
Transition Countries		
Korea	0.8	18.4
Taiwan	0.4	28.6
Other S.E. Asia	7.8	0.9
CIS	4.8	0.8
Turkey	1.1	3.7
Eastern Europe	1.8	3.0
Latin America	8.6	2.0
Average / Total	**25.2**	**2.5**
China and India	37.8	1.0
Others	22.4	0.3

Sources: United Nations, WBMS

The more detailed picture of copper consumption per capita emphasises the distinction between the industrialised countries, the transition countries and the others. Consumption per capita in the industrialised countries averaged 10.3 kg, with a narrow range of 8.9 to 10.9 kg, apart from New Zealand which has almost no copper fabricating activities.

The anomalous position of Taiwan and South Korea is even more evident in this table. Taiwan's consumption per capita is almost three times that of Western Europe or the USA, and South Korea's is nearly twice as high as that of Western Europe or the USA. This reflects the highly metal-intensive path of industrial development selected by both countries.

With these two exceptions, the transition countries consume 3 kg per capita or less. China and India average 1 kg per capita and the rest of the world averages 0.3 kg per capita.



The relationship between consumption of copper per capita and GDP per capita shown above is consistent with the comments made above about the stage in development at which copper semi-fabricating operations tend to come into existence. The broad distinction is between countries with GDP per capita below and above $10,000. Below that level, we find that most countries have consumption below 5 kg per capita. Above that level there is a moderate upward trend, if we ignore the outliers of Taiwan and South Korea on the high side, and Singapore and New Zealand on the low side. The latter two are small countries with no copper semi-fabricating industries. Western Europe is shown as a single point on this chart.

4. Drivers of demand and competition with alternative materials

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The Major End-Uses of Copper and Copper Alloys

Electrical conductors:

power cables, house wiring, appliance cables, winding wires, transformers, telecommunication cables

Sheet products:

roofing sheet, connectors, light fittings, circuit boards, lead frames, locks, hinges

Tube products:

water and gas tubes, air-conditioning tube, desalination tube, sprinkler systems

Rod and bar products:

busbars, flanges, bearings, screws, plugs

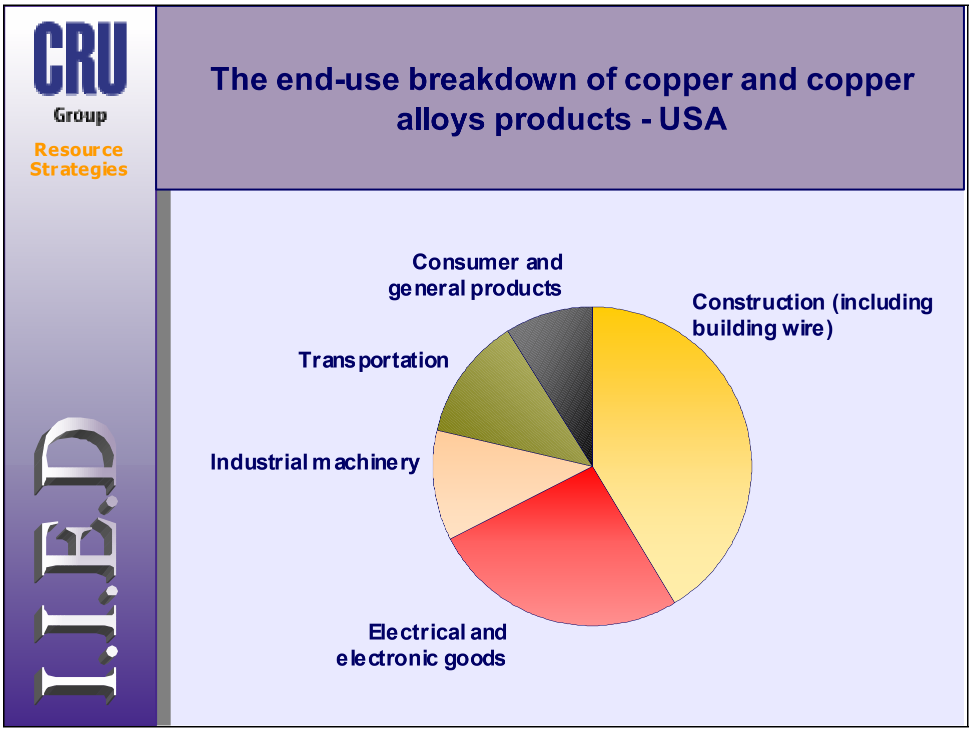
Copper and its alloys (principally brass and copper-nickel alloys) are fabricated into four categories of semi-product: wire, sheet, tube and rod or bar. Its applications are very diverse. The major applications for each category of semi product are listed above.

The majority of the markets for copper exploit its excellent properties as a conductor of electricity and heat. Copper is the preferred material for electrical wiring and cables in all applications except overhead power lines, where aluminium's lighter weight in relation to volume gives it an advantage over copper. Copper wire is also the traditional material for telecommunication cables, although it has been replaced by optic fibre cable in many countries in the trunk line sections of telecommunication networks; copper remains the preferred material for the link from the trunk system to the individual subscribers.

Copper in sheet form is used for its heat transfer properties (as in car radiators and cooking pots), or for its durability and appearance (as in roofing sheet), or for its electrical properties (as in lead frames and connectors). Brass (which is an alloy typically composed of c. 60% copper and 40% zinc) is used in rolled or extruded form for its appearance, machining properties and durability (as in locks, hinges and door fittings) or purely for its appearance (in architectural fittings and decorative items). Nickel-copper alloys are widely used for producing coins.

Copper tubes are used for conducting water and gas in plumbing and central heating systems, and in air-conditioning equipment. Copper alloy tubes are used in numerous corrosive environments such as seawater desalination plants where corrosion resistance is vital. Brass tubes are used for decorative purposes in many public buildings.

Copper or brass extruded into rods and bars is used for its electrical conductivity in busbars and plugs and sockets. Brass is machined into a wide variety of flanges, bearings and screws.



The USA is one of the few countries where firm data is available on the breakdown of copper consumption by final end-uses. The broad breakdown is summarised above. The definitions used include building wire among the construction applications, although this could also be regarded as an electrical application. Therefore the breakdown does not make the dominance of electrical end-uses fully apparent. Other construction applications are plumbing, heating air-conditioning and refrigeration tubes, builders' hardware and architectural applications.

Use in electrical and electronic goods includes power cables, telecommunication cables, computer and other business appliance cables, and all lighting and wiring devices (apart from building wire).

Industrial machinery applications include industrial valves and fittings and all types of uses in industrial plants, non-electrical instruments and heat exchangers.

Consumer and general products include all uses in appliances (which include cabling and winding wires in motors), consumer electronics, fasteners and closures, coinage, military ordnance, and cutlery and utensils.

The breakdown in other major regions will differ according to local conditions and preferences. For example in some part of Europe, roofing sheet is a major application. In several South-East Asian countries air-conditioning tube has become a very important application. In countries at an earlier stage of industrial development, electrical wiring is much the most important application.

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Copper and Copper Alloys: the drivers of demand

- Macro-economic drivers: population size and growth, GDP growth, income levels, investment in power and telephone networks
- Micro-economic drivers: copper is a mature metal, so end-uses have been refined to those where it is the best material for the task, based on:
  - Electrical conductivity
  - Heat transfer properties
  - Durability and corrosion resistance
  - Machining properties
  - Appearance
- Product and market development is mainly in the hands of industry associations

I.I.E.D

As with most metals, the most fundamental drivers of demand are the size and rate of growth of population, and the degree of economic development, as measured by GDP and individual purchasing power. Given the dominance of electrical applications, the amount of public investment in power generation and distribution and in telephone systems is also important.

At a micro-economic level, the use of copper and its alloys is driven principally by the exploitation of the characteristics of the metal which differentiate it from other metals and materials. The metal has been is wide use for hundreds of years, so its applications have over time come to be refined down to those where it is the best available material. This explains the dominance of electrical applications in the use of copper.

The copper industry is much less integrated than, for example, the aluminium industry. There are many non-integrated producers of copper concentrates, and many smelters and refiners that do not mine copper. There are almost no copper producers that are also engaged in semi-fabrication, other than the production of wirerod. This fragmented structure has proved to be an obstacle to the promotion of copper markets and the development of new products using copper, since no one company is large enough within the industry to see an advantage in investing in these activities on its own. This is typical of a mature commodity industry.

Therefore the industry has come to rely on collective promotional activities, organised through industry associations, to promote and defend markets for copper. There is a heavy emphasis on instruction and education in these activities, rather than on research or technical development. Some semi-fabricating and manufacturing companies (such as Olin Corporation in the USA) still conduct research and development into applications where they can develop proprietary products.

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Substitution in Markets for Copper and Copper Alloys

- Competing materials:
  - **Electrical transmission:** aluminium
  - **Telecommunication cables:** optic fibres, radio transmission
  - **Roofing sheet:** lead, zinc, stone, tiles, artificial materials
  - **Heat transfer:** aluminium
  - **Plumbing tube:** plastics
  - **Coinage:** aluminium, paper, cards

IIED

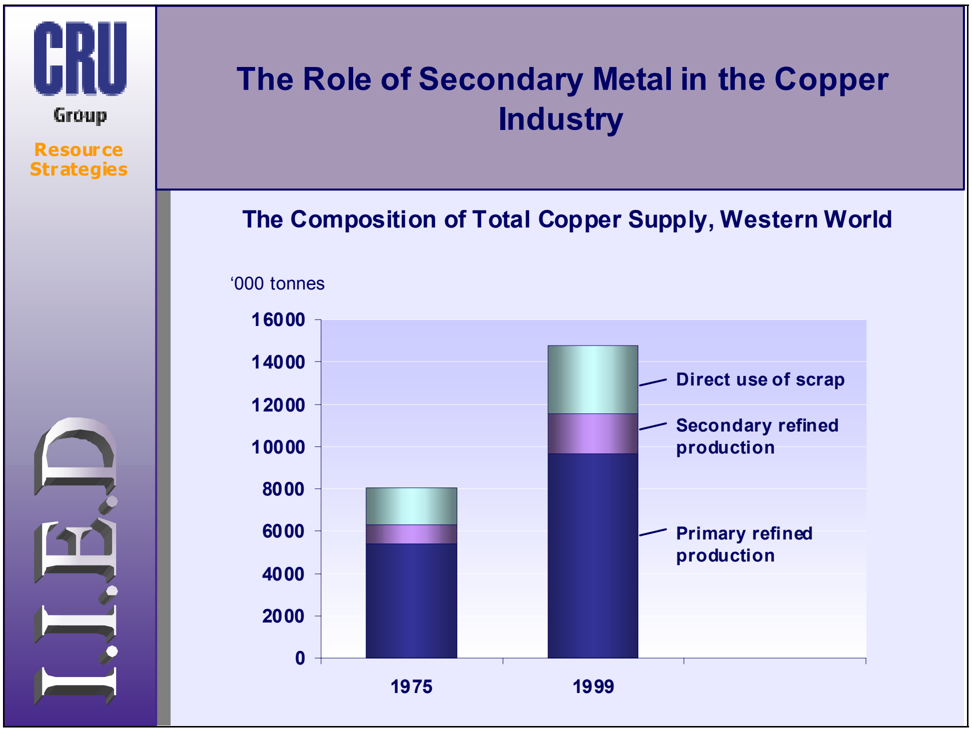
Copper is virtually unchallenged its markets for electrical transmission. The overhead cable market was lost to aluminium some years ago, and aluminium has been ousted from the building wire market. The most recent switch was in Eastern Europe where aluminium building wire had been used under the Communist regimes. However, there continues to be competition with other materials in other end-uses.

Part of the telecommunication cable market has been lost to optic fibres, which are now used for new installations in the trunk lines between major centres. Optic fibres are being used progressively in the branch connections but copper is still the favoured material in the final connection to the telephone user. A newer threat is the mobile telephone, which obviously does not need any cabling at all.

The roofing market is heavily influenced by climate, tradition and the skills of the local building trade. Copper is widely used in Germany and central Europe where snowfall is heavy. Zinc is traditionally favoured in France and Belgium, while lead is widely used in the UK. Alternatives include slate, tiles and roofing felt. The selection of material will depend on the willingness of the consumer to pay a higher price for a longer lasting material. It will also depend very much on the familiarity of the local building trade with each material. Much of the competition between rival materials therefore takes the form of information to specifiers of materials and training for builders.

Aluminium competes with copper in heat transfer applications and particularly in car radiators, where aluminium has been successfully promoted. Plastic plumbing tube has also taken some market share from copper and brass, chiefly on the basis of price.

Copper alloy coinage is threatened in some countries by aluminium and zinc, and more widely by the use or notes rather than coins. The use of credit cards in place of cash is also a form of substitution away from copper.



There are two principal routes by which copper is recycled. Copper scrap free of alloying materials (together with dirty or contaminated alloy scrap) is refined in secondary smelters to produce pure refined copper which is effectively equivalent to refined copper produced from ores and concentrates. Clean alloy scrap (of which brass scrap is a large component) is recycled by semi-fabricators into the same alloy.

Historical statistics for the production of secondary copper and the direct use of scrap exist only for the Western word, and even here it is very likely that the direct use of scrap is not fully recorded in all countries. Secondary production more than doubled between 1975 and 1999 to 1.9m tonnes. The recorded direct use of scrap rose by 80% to 3.2m tonnes.

However the composition of total copper supply changed very little over that period. Secondary refined production rose from 11 to 13% of the total, direct use of scrap fell from 22.2% to 21.8% and refined copper from primary sources fell slightly to 65%.

The supply of secondary copper is sensitive to the price of copper in the short term. Low metal prices cause old scrap to be hoarded in the collection chain, and high prices cause stocks to be released. New scrap is recycled regardless of the price. The Eastern bloc has also had a major influence on scrap supply into Western Europe in the past decade. After the collapse of the former USSR, very large volumes of scrap were exported from Russia to Germany and other West European countries. In 2000 the Russian government took steps to restrict and finally stop the export of scrap, in order to retain this valuable raw material for Russian industry.

On a global basis, this move makes no difference, because it simply changes the location in which recycling takes place. In reality, it makes the situation more obscure because the direct use of scrap in Russia is not recorded or published, so the industry will not know how much is being recycled in Russia. The move was also partly designed to prevent the theft of copper and other metals that are still in use, but which could be removed and sold for hard currency. This source of illicit scrap will now presumably disappear.

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The Economics of Recycling Copper

Average World Direct Operating Costs, 1998 (US c/lb)

	Smelting costs	Refining costs	Total costs
Primary	11.9	4.6	16.5
Secondary	6.7	5.4	12.1

- Secondary smelting varies in cost considerably, depending on the complexity of the raw materials. Refining is exactly comparable to primary refining
- Profitability depends on the cost of scrap and the recovery of all metals (not only copper)
- Higher cost smelters can be the most profitable because they buy dirty and therefore cheap scrap and recover all by-products
- Scrap is priced on the basis of the LME price; high prices encourage scrap collection and help to balance the market
- Directly recycled scrap is priced to compete with primary refined metals

I.I.E.D

Secondary smelting uses a process that is similar in principal to primary smelting. The difference is that it may not be necessary to submit scrap to the full primary process. High grade and pure scrap can be refined in an anode furnace and then refined, whereas low grade complex scrap must be smelted to produce blister copper first. Therefore there is a wide range of smelting costs among secondary smelters, which reflects the type of feed that they buy. Refining costs are less variable and directly comparable to the cost of refining primary copper.

The profitability of a secondary smelter depends very largely on its ability to acquire scrap at attractive prices. In many cases, the higher cost smelters can be the most profitable because they buy low grade and complex scrap at cheap prices and are able to extract not only copper but other metals also (e.g. tin, zinc or precious metals).

Scrap prices vary daily in line with the LME price of copper. High metal prices increase the value of scrap and provide an extra incentive to the scrap merchanting industry to collect scrap and to release any stocks that they hold. Low metal prices cause the scrap merchants to hoard scrap. The secondary industry thus provides a natural balancing influence by increasing the supply of copper when prices are high and reducing supply when prices are low.

Scrap that is recycled directly without refining is priced also on an LME basis, to compete with the primary metals (e.g. copper, zinc or nickel) which provide the alternative method of producing copper alloys.

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Factors that promote or hinder the recycling of copper

- The intrinsically high value of copper and its alloys provides a natural incentive to maximise the recovery of scrap
- Dispersive uses are few, but much wire may be used in quantities too small to be recovered economically
- EU end-of-life directives on cars and consumer goods may ensure more thorough recycling of copper components
- Basel Convention restrictions on the movement of hazardous waste ay restrict the trade in scrap

I.I.E.D

The high intrinsic value of copper always ensures that old scrap has some value, unless it arises in very small quantities or in locations far from any recycling facilities. New scrap is recycled promptly because it represents a ready source of cash for the plants in which it arises.

In general, copper and its alloys are easily recognised and therefore unlikely to be wasted when they become available for recycling. Very little copper is used in the form of powder or sulphate which is dispersed and can never be recovered. A greater threat of loss arises from copper used in small quantities in wire, for example, coated in insulating material. This may be too small in volume to justify recycling.

Legislation directing producers to take responsibility for recycling their products at the end of their lives could perhaps increase the rate of recycling, if such legislation can ever be enforced in practice.

Some low grade or complex copper scrap could be prevented from reaching a suitable smelter by the Basel Convention regulations which seek to prevent hazardous waste from crossing national boundaries.

5. The pricing and trading of copper

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The Pricing of Refined Copper

- Refined copper is traded mainly in the form of cathode
- The almost universal pricing basis is the LME Grade A copper cathode price; the Comex high grade copper price is the only alternative basis price
- Cathode is sold by producers to consumers worldwide on annual and spot contracts at the LME price plus a premium to reflect delivery, credit terms, service and security of supply
- Less than 5% of LME transactions result in physical delivery; most are for hedging purposes and some for speculation
- Because it can be used as a physical market, the LME reflects marginal excess demand or supply, and its price therefore reflects the balance in the world market

I.J.E.D

Cathode is the form in which the great majority of refined copper is sold; smaller quantities are sold in the form of billet (for extrusion) or cake (for rolling). The LME High Grade copper contract provides the basis price that is universally recognised throughout the world as the price of copper. The only rival is the high grade copper contract on the Comex/Nymex exchange in New York which has a following in North America. However, the Comex price does not deviate significantly from the LME price.

However, this does mean that all refined copper is sold through the LME. Copper is sold by producers direct to their customers, generally under annual contracts and sometimes also on a spot basis. The producer contracts direct with his customer and delivers direct to his customer. The LME price (often a future price which is therefore unknown at the time when the sale is negotiated) is written into the contract as the pricing basis. The producer adds a premium to this price which reflects the cost of delivery to the customer, and the value of credit terms given, any other services provided and the security of supply guaranteed by a producer contract.

Because most sales of copper are made for settlement at an unknown future price, both the buyer and the seller have a price risk. They can offset this by entering into hedging transaction on the LME, which are closed before delivery becomes due. This is the source of the vast majority of LME transactions. Thus only a small proportion of LME transactions (5% at the maximum) results in a physical delivery of metal into or out of an LME registered warehouse.

However, the LME is used as a physical market, typically when a seller has no other customer, or a buyer has no other source. Thus it is the physical market of last resort and therefore movements in LME stocks reflect changes in the overall balance between supply and demand worldwide. For the same reason, prices on the LME reflect the balance between supply and demand and are therefore accepted as a fair basis for trading in copper worldwide.

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I.I.E.D

The Pricing of Copper Upstream and Downstream Products

- The LME copper price is used as the basis for trading copper raw materials such as concentrates, blister and scrap
- Hedging transactions also take place on the LME to offset price risk in these materials
- The LME price is also used for pricing downstream products in which the metal constitutes a large proportion of the value (e.g wirerod, tubes, sheet)
- The LME can be use by consumers of copper products to secure fixed prices for three years in advance or even more

The LME copper price is also used as the basis for pricing raw materials used in the production of copper. Copper concentrates (an intermediate materials produced by mines and containing 25-40% copper) are sold at the LME price for the contained metal, minus a charge for converting the concentrates into refined copper. A similar principle is used in pricing blister copper and scrap on the basis of the LME price. In all cases, the sale is negotiated between the producer and his customer, and the LME provides only the reference price.

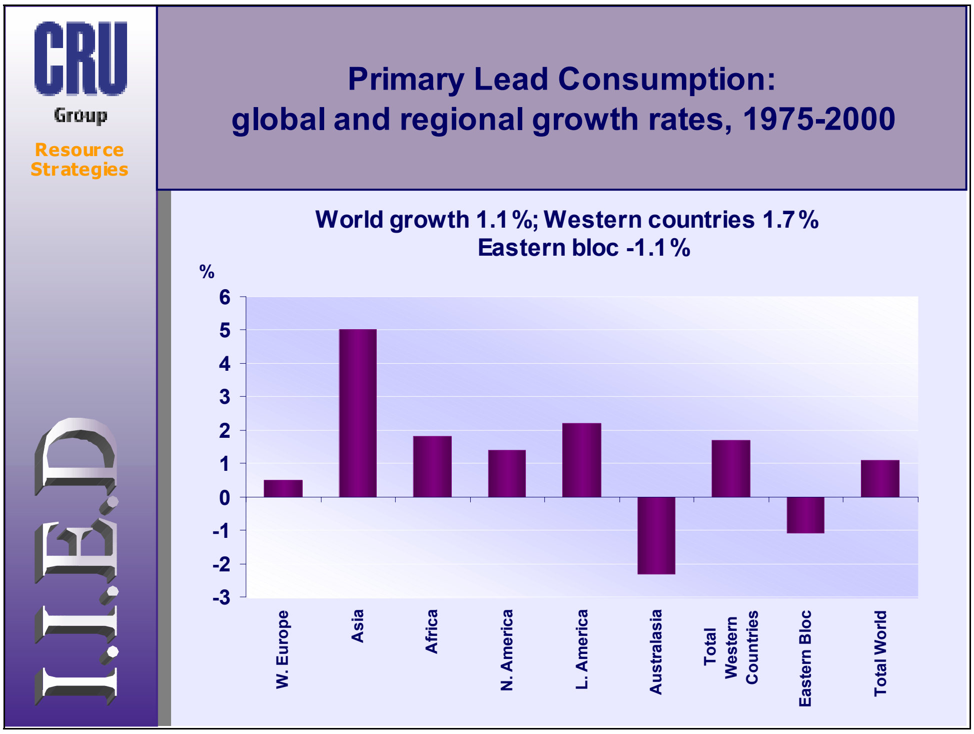
As in the sale of copper cathode, the sale of intermediate materials on the basis of a future, unknown LME price creates a price risk. This can be hedged through the use of forward contracts on the LME, which is a further source of hedging business. Because the underlying material is not in the form of cathode, physical delivery is not an option. Therefore all such hedging transactions are closed out before delivery becomes due and physical delivery never takes place.

Downstream products such as copper wirerod, tubes or sheet can also be priced on the basis of the LME price plus conversion costs. Again, hedging transactions on the LME can result. Consumers who require a fixed price for a copper product (for example, a large volume of cable for a major contract) can enter into forward contracts on the LME to secure this fixed price, even though the supplier of the cable will quote a price based on the unknown future price of copper.

The prime functions of the LME in the copper industry are therefore to provide an accepted reference price and to provide a mechanism for hedging the risk of adverse price movements in the future.

Chapter 4 The need for minerals: Lead

1. Global and regional growth in demand

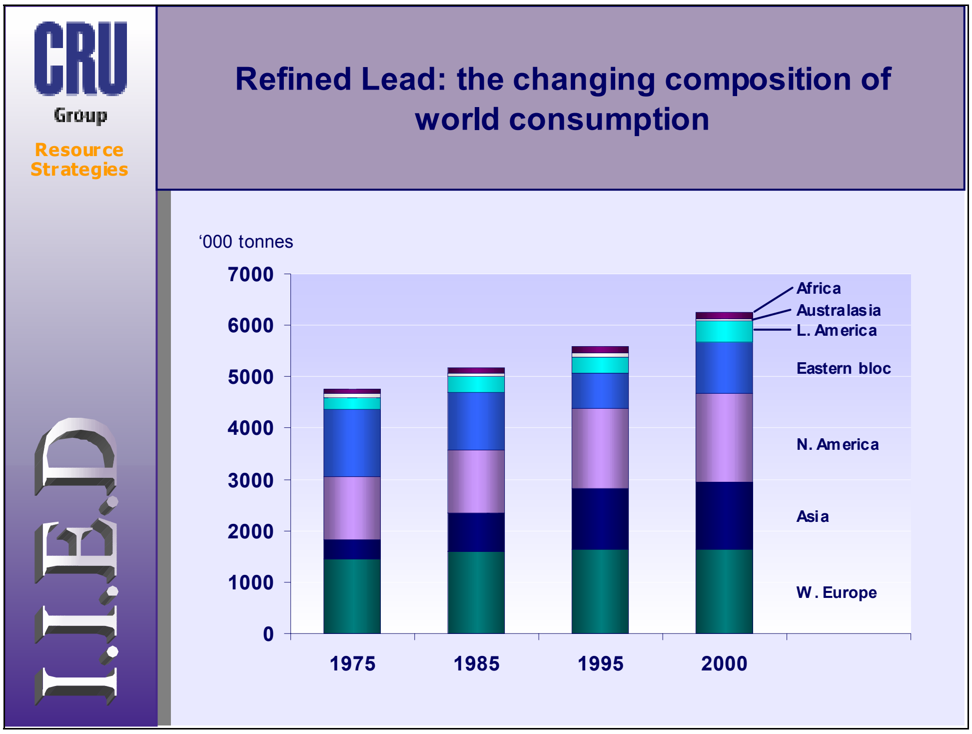


Demand for refined lead worldwide grew by an average of 1.1% per year in the period 1975-2000. This is the slowest rate of growth among all the major non-ferrous metals, caused principally by the fact that lead has been losing end-uses steadily over the years as a result of its toxicity. There was a very distinct contrast between the Western world, where lead consumption grew at 1.7% per year, and the Eastern bloc, where consumption declined by 1.1% per year in the same period. The contrast over the period 1975-95 was even sharper. Consumption in the Eastern bloc fell by 3.1% per year over this period, compared to growth of 1.75% per year in the Western world.

Within the Western world, the only region to record consistently rapid growth was Asia, where demand grew at 5.0% per year, reflecting the growing car population of this region, and also the demand for lead batteries for storage power purposes. Demand in Latin America grew at an above average rate of 2.2%. Elsewhere, growth rates were close to the world average. In Western Europe it was only 0.5% per year.

As with other non-ferrous metals, the consumption of lead is measured at the point where the metal is delivered to consumers. However the lead industry does not have the long chain of semi-fabricating and manufacturing that is typical of the copper and aluminium industries. The majority of lead is used in the production of lead-acid batteries. Manufacturers of batteries buy refined lead and fabricate it directly into batteries, for sale to car manufacturers (in the case of original equipment batteries) or to the retail trade (in the case of replacement batteries).

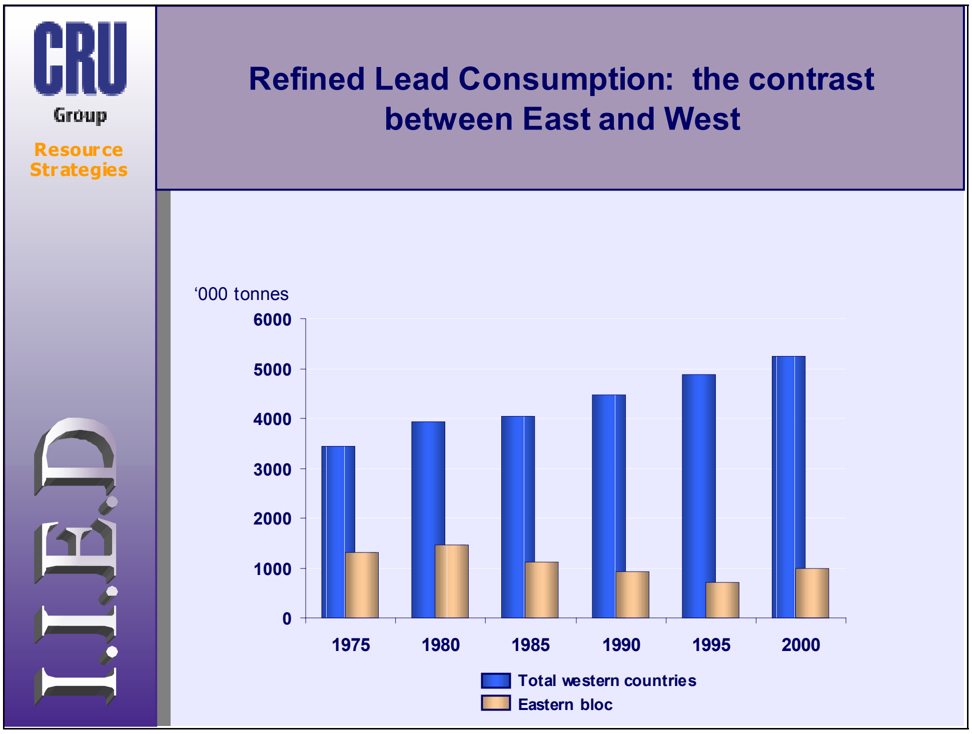
There is some international trade in batteries, and also in new cars containing batteries, but there is less discrepancy between the location of reported consumption of lead and the location of final consumption of the products containing lead than is the case with the other non-ferrous metals.



North America is the largest consuming region for refined lead, accounting for 1.7m tonnes or 27.6% of the world total in 2000. This compares with 25.5% of the world total in 1975. Western Europe was the largest consuming region for most of the period under review but was exceeded by North America in the late 1990s. Consumption in Western Europe totalled 1.65m tonnes in 2000, or 26.4% of the world total, down from 30.5% in 1975.

Asia has been the major growth region. Consumption increased from 382,000 tonnes in 1975 to 1.3m in 2000, and now accounts for 20.9% of world consumption.

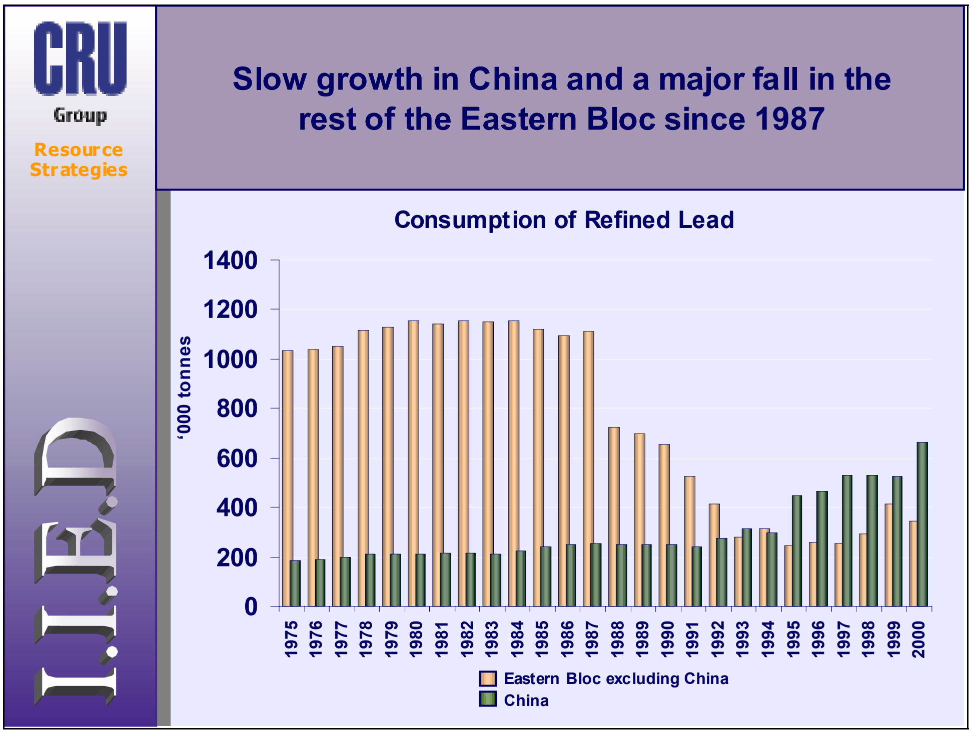
The share accounted for by the Eastern bloc has slumped from 27.5% of world consumption in 1975 to 16% in 2000. In volume, consumption in this region has fallen from 1.3m to 1.0m tonnes.



The familiar contrast between the pattern of consumption in the Western world and Eastern bloc is more pronounced than ever in the case of lead. The Western world's share rose from 72.5% in 1975 to 84% in 2000.

Consumption in the Eastern bloc fell overall during the period 1980 to 1995. However, the quality of data on Eastern bloc consumption in the early part of the period is suspect, and the estimates published by the major statistical sources (World Bureau of Metal Statistics and Metallstatistik) for the former USSR were heavily revised downwards in the early 1990s.

In 1995-2000 there was a sharp recovery in lead consumption in the Eastern bloc, as in the other non-ferrous metals, as a result of growth in the Chinese market.

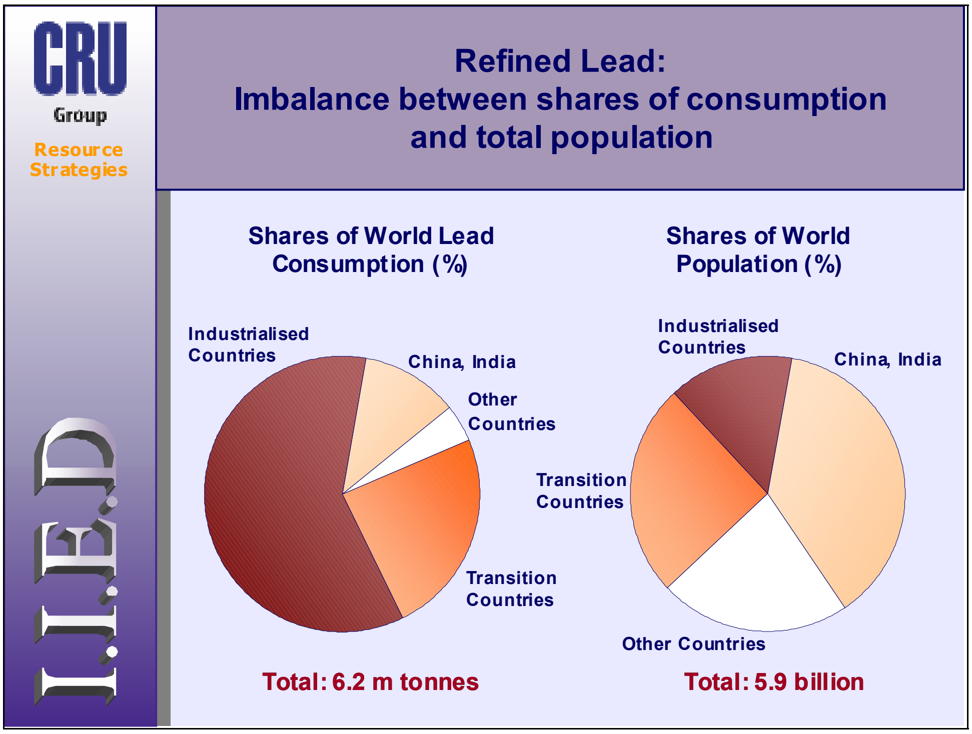


Lead consumption in the former USSR and in Eastern Europe dropped very sharply at the end of the 1980s and has made little progress since then. It is currently approximately one third of the estimated level of 1975. Chinese demand has more than doubled since 1994, but has still not grown to the level where it offsets the consumption lost in the rest of the Eastern bloc.

2. Consensus forecasts of demand

The consensus among analysts is that the demand for lead will proceed at the same trend in the coming five years as has been observed in the past 25. CRU International regards the trend of growth in Western world demand as 1.5-2.0% per year. In the period 2000-2005, the company forecasts a growth rate of 1.5% because a fall in demand is expected in 2001. ABARE forecasts a growth rate of 1.7% in total world demand in 2000-2006.

3. The distribution of lead demand



We find the same imbalance between metal consumption and population distribution in the case of lead as in the other major non-ferrous metals. The industrialised countries account for 60% of lead consumption and only 14.6% of the world's population. Transition countries account for 24% of lead consumption and 25% % of total population, though the level of consumption is heavily influenced by Taiwan and South Korea, which account for 30% of lead consumption in this group of countries.

China and India account for 11.5% of lead consumption but 37.8% of total population. The rest of the world contains 22.4% of the total population but accounts for only 4.2% of lead consumption.

These disparities simply reflect the uneven distribution of wealth across the world, which is directly reflected in the number of cars and other road vehicles in use, and therefore the number of lead-acid batteries required.

CRU Group
Resource Strategies

Large variations in per capita consumption

	% of World Population	Refined Lead kg/head (2000)
Industrialised Countries		
USA	4.6	6.1
Canada	0.5	2.1
Western Europe	6.9	4.0
Japan	2.1	2.7
Australia	0.3	2.4
Average / Total	**14.6**	**4.4**
Transition Countries		
Korea	0.8	6.6
Taiwan	0.4	6.7
Other S.E. Asia	7.8	0.6
CIS	4.8	0.5
Turkey	1.1	0.9
Eastern Europe	1.8	1.8
Latin America	8.6	0.8
Average / Total	**25.2**	**1.0**
China and India	37.8	0.3
Others	22.4	0.2

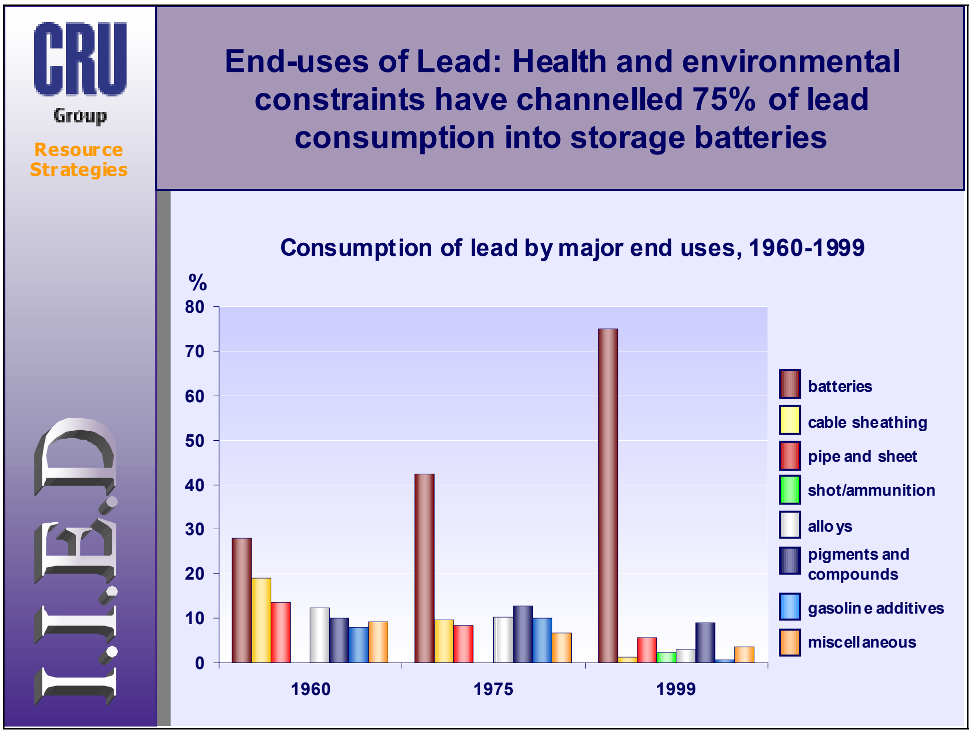
Sources: United Nations, WBMS

Per capita consumption of lead is predictably much higher in the industrialised countries of the world, where the average is 4.4 kg per head, than in the rest of the world. In the USA it is as high as 6.1 kg per head.

In the transition countries the average is 1.0 kg per head, though again Taiwan and South Korea stand out with levels of consumption that are even higher than those in the USA. The two countries are major exporters of lead-acid batteries to the whole South-East Asian region. In effect, much of the metal fabricating capacity required by the whole region has been concentrated in these two countries.

China and India together use 0.3 kg per head and the rest of the world consumes only 0.2 kg per head.

4. Drivers of demand and competition with alternative materials



The well known toxicity of lead has dominated the development of end-uses for the metal in the past 40 years at least. Strenuous efforts have been made to reduce or stop the use of lead in end-uses where the metal is dispersed and in end-uses where it can be substituted by non-toxic materials. In some cases, the use of lead has been prohibited by legislation. The result is that lead-acid batteries, the one end-use where lead cannot be substituted, have become by far the most important end-use for the metal, and now account for about 75% of the consumption of lead, at least in the countries where this is measured and recorded.

In the 1960s and 1970s there was a market for lead in covering electric cables for insulation and general protective purposes. This use of lead has largely disappeared, to be replaced by plastic insulating materials. Lead water pipes have been in use since Roman times, but are no longer used because of the danger of lead leaching into the water supply. The consumption shown under the heading of pipe and sheet is accounted for very largely by roofing sheet and flashings, which are widely used in the UK especially, and to a lesser extent in other parts of Western Europe. Lead is also used in sheet form to provide protection against radiation and X-rays.

Lead shot used for sporting purposes is now under attack because it can accumulate on marsh lands and seashores, and poison wildfowl and other birds that live alongside water. Lead alloys include solder, which has lost a market in the manufacture of food cans, again because of the danger of contaminating the contents of cans.

Lead was widely used in paints, but this application has virtually ceased, at least in Europe and North America, where it is specifically banned for use in indoor applications. Some chemical applications remain, including the use of lead oxide in glass manufacture.

The addition of tetraethyl lead to gasoline was standard in the 1960s and 1970s, to improve the operation of car engines. This end-use has also been lost, for environmental reasons. First, the dispersal of lead particles in exhaust fumes is considered undesirable. Secondly, exhaust fumes are now cleaned to prevent other harmful emissions, through the use of catalysts containing platinum or palladium. Lead in petrol poisons such catalysts, and therefore was eliminated to enable them to work.

The result of these trends has been to limit the use of lead to applications where is does no harm and where it cannot be reasonably substituted. In effect, this means that the use of lead is coming to be confined more and more to the manufacture of batteries. The lead-acid battery, used for providing starting, lighting and ignition power to motor vehicles, is indispensable, and is now the overwhelmingly most important application for lead. Batteries also have the advantage of being easily recycled, and provide a major source of raw materials for the lead smelting and refining industry.

Demand for lead is very closely linked to the demand for motor vehicles, which continues to grow worldwide, in line with overall growth in GDP and more particularly GDP per capita. A motorcar is still a symbol of economic advancement and success in developing economies. In developed countries, where the environmental damage done by motor vehicles and all the infrastructure that they require is more widely appreciated, there is still not enough investment in public transport to persuade many people to abandon car ownership in favour of reliance on alternative means of travel.

The use of lead in new and replacement batteries therefore continues to grow, and accounts for almost all the growth in the use of lead. It was offset in the 1960s and 1970s by a gradual reduction in the size and weight of a battery required to provide starting, lighting and ignition power for automobiles. However, in the last two decades the average weight of an SLI car battery has stabilised at about 10.5 kg.

Environmental and health issues, as mentioned previously, have resulted in the use of lead being severely reduced or even eliminated in some countries, in cable sheathing, petrol additives, solder, shot and pigments.

The development of applications for lead is concentrated very largely on the lead-acid battery. The search for an emission-free vehicle has been under way for many years, to reduce pollution caused by exhaust fumes, and to reduce the use of oil products to power cars. Lead-acid batteries are used for vehicles that need to travel only slowly or within a restricted area, such as golf carts, push-out vehicles for aircraft and delivery vehicles used in restricted localities. They have not been used more widely yet because of the limit on their range, the weight of the batteries required and the need for a widespread network of re-charging stations.

Progress has been made and development work continues, but alternative battery systems are also being examined and developed. It is not yet clear which, if any, will succeed in gaining acceptance as an alternative to the internal combustion engine.

CRU Group
Resource Strategies

Substitution in Markets for Lead

- The process of substitution is largely complete in many applications
- Competing materials
  - Batteries: none for traditional SLI batteries; many alternatives for batteries to power vehicles
  - Roofing sheet: copper, zinc, tiles, slates, roofing felt
  - Pipes: Brass, copper, galvanised steel, plastics
  - Alloys: lead-free solders
  - Shot: tin-based shot
  - Gasoline additives: lead-free gasoline

LEAD

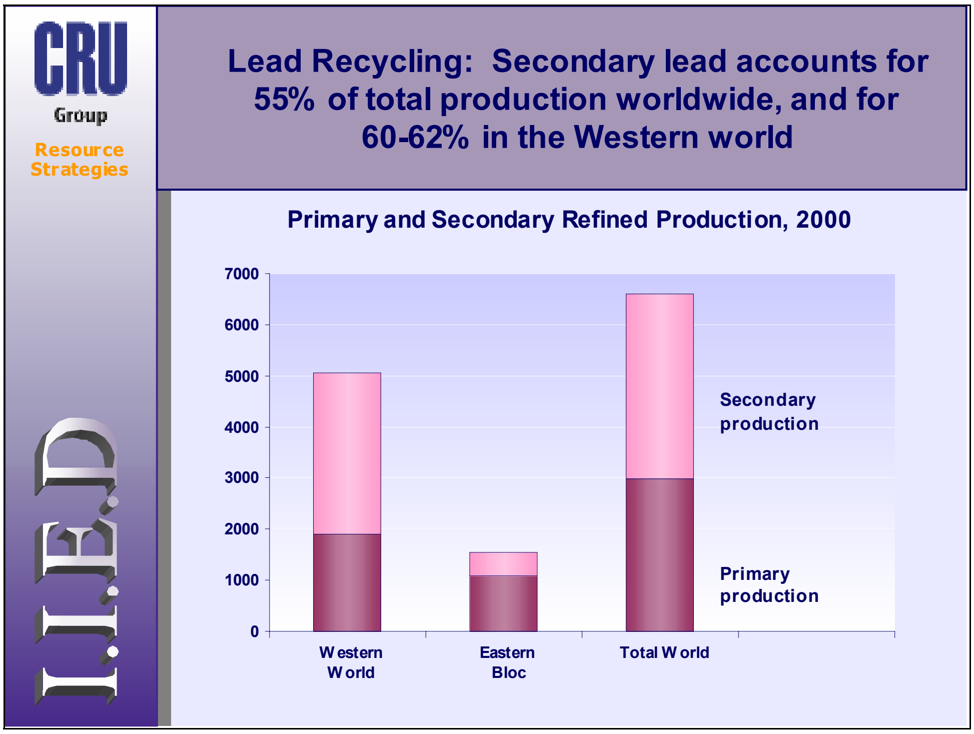
Because it is toxic, lead has already been substituted to a very large extent in all applications where alternative materials are available. The major area where lead competes with other materials is in the development of batteries to power automobiles. Many alternative battery technologies for the motive force in electric cars are being worked on, including:

- solid oxide fuels cells
- hybrid fuel cell-battery combinations
- metal hydride batteries
- zinc-air batteries
- lithium ion/polymer batteries

Fuel cells probably offer the most promising prospects, but none has yet achieved commercial acceptance on any wide scale, and all systems have their proponents. The lead-acid battery has the disadvantages that it is bulky, has a limited capacity and therefore range, and requires time to be re-charged. It may therefore be restricted to applications where these limitations are acceptable.

In the market for roofing, lead is widely used in countries (notably the UK) where its use has been long established. In these countries, the building trade is familiar with the material and its workforce is well equipped to install lead flashing and roof covering. Alternative metal roofing materials are copper and zinc sheet. These are equally good. The choice of material is largely dictated by the training and skill of the construction trade in each country. This is largely a matter of tradition, although industry associations in Western Europe are active in providing training in the use of all three metals (lead, copper and zinc). Other competing materials are tiles, slate and artificial roofing materials such as roofing felt.

5. The recycling of lead



Lead recycling has become a very efficient but not highly profitable operation in most developed countries. Batteries account for a high proportion of total lead use, and constitute an easily identifiable source of scrap. However, they arise not in large volumes through an industrial process but one by one, in the hands of individual motorists. In many countries there is now legislation or some form of local regulation that requires or encourages spent batteries to be collected and re-processed. For example, in the USA, a buyer of a replacement battery either receives a discount if he returns the spent battery, or pays an extra deposit if he does not return a spent battery.

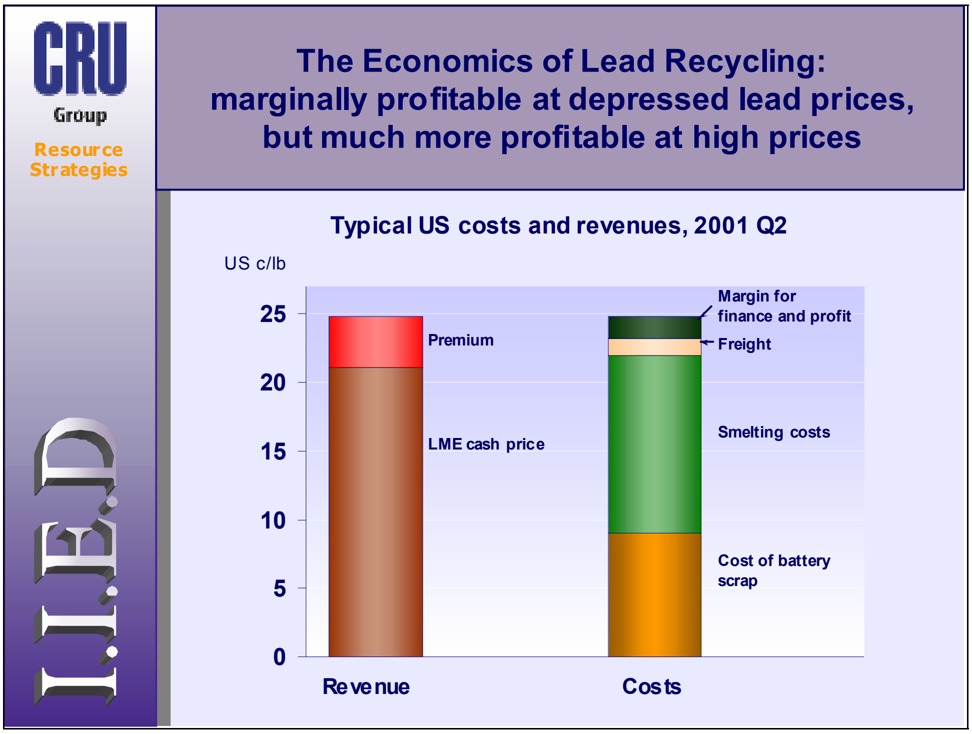
Many battery producers organise their own collection systems for spent batteries through garages and other retail outlets. They then have the batteries toll smelted back into lead by a secondary smelter. The recycling process therefore does not rely totally on the scrap collecting industry seeking to recover the value of lead contained in used batteries, although some batteries are collected by scrap merchants.

Consequently, a high proportion of spent batteries is collected and re-processed, despite the low intrinsic value of a spent battery (typically about $2.00). In the developed countries, the re-cycling rate for batteries is over 90%. Secondary smelting and refining now accounts for 70% of total lead output in the USA, 60-62% in the Western world as a whole and 55% in the Western world excluding the USA.

There is some scope to improve the recycling rates in industrialising and less developed countries, but the majority of any future growth in secondary lead production will arise from greater consumption of batteries and better recycling rates in developing countries.

Secondary smelting is carried out principally in dedicated secondary smelters, but there are also smelters, mainly in Europe, which take a mixture of primary and secondary feed. The figures shown above are adjusted to take account of secondary materials processed in smelters which are classified as primary smelters. There is no shortage of secondary smelting capacity, and none in expected to arise in the medium term.

Some lead products, such as old lead sheet, are recycled without being smelted. They can be remelted and re-used directly. This form of recycling is not captured in the figures shown in the chart above.



The economics of secondary smelting are determined by the price of refined lead and the cost of obtaining and processing scrap. Revenue for a secondary smelter is determined by the LME cash price and the premium which producers obtain in addition to this price. In the second quarter of 2001 in the USA, for example, a secondary smelter would have received on average an LME cash price of 21.07c/lb plus a premium of 3.75c/lb, giving a total revenue of 24.82c/lb.

Scrap batteries would have cost about 5.5c/lb. Lead accounts for about 60% of the weight of a battery, so the price of lead in battery scrap was about 9c/lb. Secondary smelting costs were typically 13c/lb. Freight costs add another 1.2c/lb, so total operating costs were about 23.2c/lb. The margin available to the secondary smelter to cover financing costs and a return on capital was only 1.62c/lb. Margins would expand at higher lead prices, since battery scrap prices do not move exactly in line with the LME price.

The implication is that the inherent value of lead in battery scrap is not great, and in the absence of other incentives may not always be sufficient to ensure that spent batteries are recycled and not thrown away. However, to the battery manufacturer, battery scrap is a valuable resource, since it arises locally, and can be converted into refined metal easily. Indeed some battery companies operate their own secondary smelting plants for this purpose. Their alternative is to buy refined metal at the LME price plus premium.

There is good case for creating or strengthening incentives for the individual motorist to return spent batteries, both to avoid land-filling a potentially hazardous material and to reduce the need for primary lead production.

The Basel Convention constitutes a major potential obstacle to the recycling of lead. Its objective is to prevent the movement of hazardous waste across national borders, in order to prevent the dumping of such waste in countries where environmental controls are weak or poorly enforced. However, it can also prevent the movement of scrap, such as used batteries, which is potentially hazardous but is also a valuable resource for the recycling industry.

6. The pricing and trading of lead

CRU Group
Resource Strategies

The Pricing of Lead: primary and secondary refined lead

- Primary and secondary lead is sold by smelters directly to battery manufacturers and other consumers in the form of ingots, mainly under annual contracts
- Lead is priced almost universally at the LME price plus a premium which varies according to location and grade of metal
- A very small proportion of LME lead transactions result in physical delivery of lead. The majority are undertaken for hedging or speculative reasons
- Only marginal volumes of physical sales pass through the LME. However, this is enough to enable the LME price to reflect the balance of world supply and demand

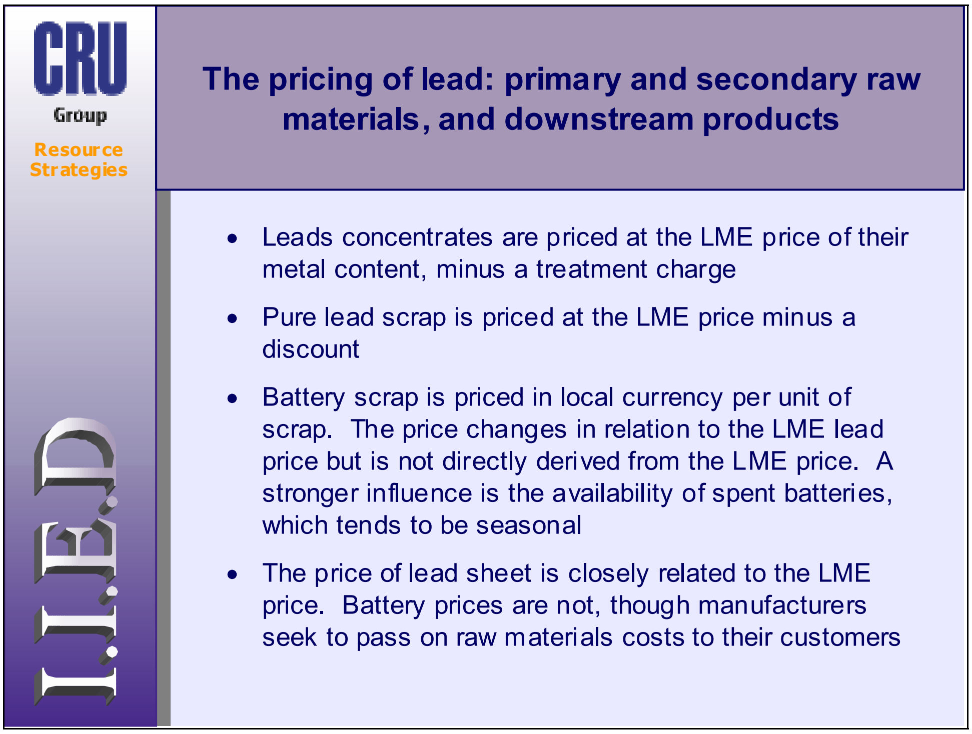
LEAD

Primary and secondary lead smelters produce and sell lead in the form of ingots (or "pigs") of various sizes. The grade of metal is normally 99.97% or 99.99% lead. They sell direct to users of lead, mainly battery manufacturers. Primary smelters sell most of their output on annual contracts. Secondary smelters also sell on annual contracts but they tend to sell a higher proportion on a spot basis.

Lead sold by smelters to consumers is priced at the LME price plus a premium. This premium reflects the delivery costs, security of supply that comes from a contract with a producer and the credit terms and other services that a producer may supply. The premium varies by location. It will be higher in areas where there are fewer producers and therefore less competition; it will also be higher in locations that are far removed from centres of production. The premium for higher grade metal is also greater than the premium for standard grade (99.97% Pb) metal.

Despite the use of the LME price, transactions between smelters and their customers are carried out directly and do not involve the metal passing through the LME. Metal is often priced at a future and therefore unknown metal price. This creates price risk for the buyer and seller, which can be hedged by using the LME contract. These hedging transactions, which are closed out before they become due for delivery, are the origin of the vast majority of LME lead transactions.

The LME is used as a physical market when producers have no customers to whom to sell, or when consumers cannot obtain metal from a producer. The LME is therefore the marginal market, which is why its price is accepted and respected as a fair reflection of the balance between supply and demand worldwide.



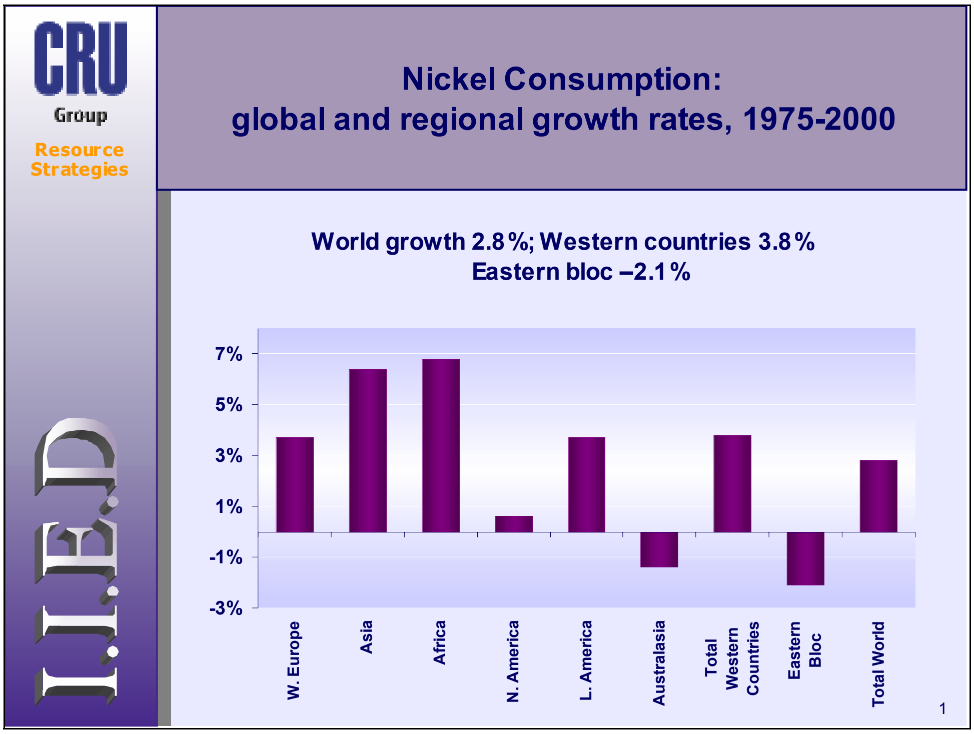
The LME lead price is also used as the pricing basis for lead sold in the form of concentrates by mines to smelters. In principle the lead content of a shipment of concentrates is priced at the LME price, minus a treatment charge which reflects the cost of converting concentrates into metal and the smelter's profit margin in doing so. Sales of concentrates are normally made at unknown future prices, which create price risks that are hedged through LME transactions.

Pure lead scrap is priced at the LME price minus a discount to reflect the cost of re-cycling the material. The price of battery scrap, on the other hand, is only loosely related to the LME price. It is more strongly influenced by the supply of scrap batteries, which varies from year to year, according to past peaks and troughs in new car sales; it also varies seasonally, because batteries tend to fail more frequently in time of extreme heat or extreme cold.

The LME lead price also dictates the price of some downstream lead products, notably lead sheet, which is generally sold at the LME price plus a premium. The price of batteries, on the other hand, is not directly determined by the LME lead price, though battery producers will adjust their prices to pass on raw material costs, of which lead is the major one.

Chapter 5
The need for minerals: Nickel

1. Global and regional growth in demand



The consumption of refined nickel grew by 2.8% worldwide in the period 1975-2000. There was a major contrast between the Western world, where consumption grew at 3.8%, and the Eastern bloc, where it declined at 2.1% per year over this period.

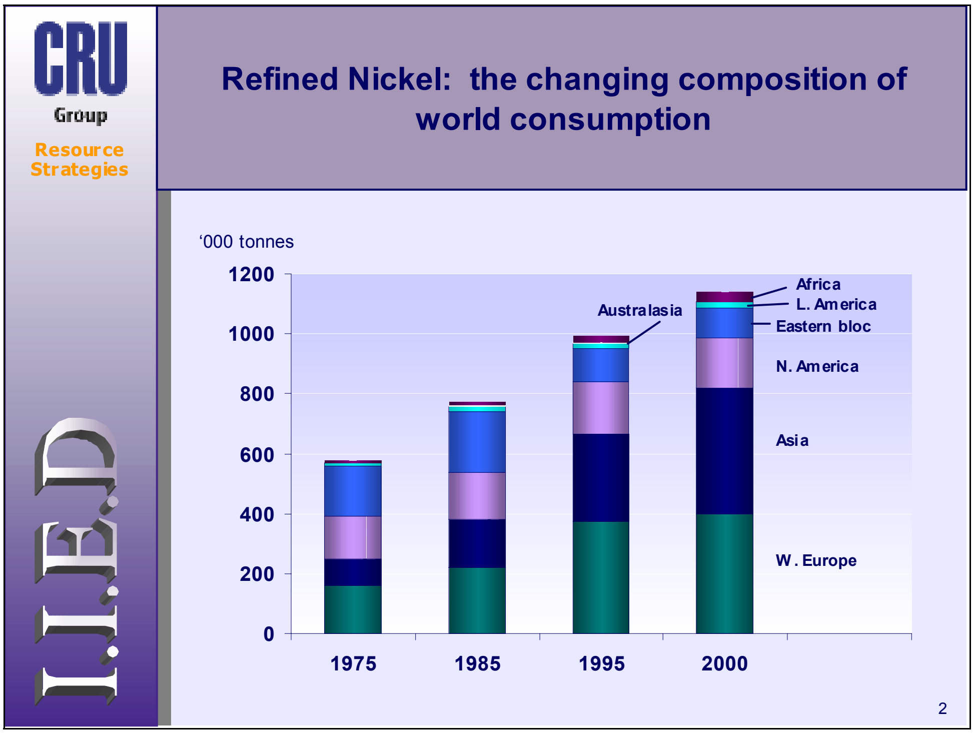
Nickel is a metal which came into widespread use only in the second half of the 20th century. For the first 70 years of that century one company - International Nickel, now known as Inco - was the dominant Western producer and invested heavily in developing new alloys and applications for nickel, and promoting its use in existing applications. The rate of growth in demand was of the order of 7% per year for much of the period 1945-75, largely as a result of this heavy investment in market development.

In the last 25 years many newcomers were attracted into the industry. The more fragmented structure of the industry removed the incentive for one company to undertake market development from which its competitors would benefit. A lower level of investment in market development has led to a lower rate of growth. However, it has remained higher than the rate of growth in consumption for the other major non-ferrous metals, whose applications, with the exception of aluminium, have been established for much longer.

In the last 25 years, many newcomers were attracted into the industry. The more fragmented structure of the industry removed the incentive for one company to undertake market development from which its competitors would benefit. A lower level of investment in market development has led to a lower rate of growth. However, it has remained higher than the rate of growth in consumption for the other major non-ferrous metals, whose applications, with the exception of aluminium, have been established for much longer.

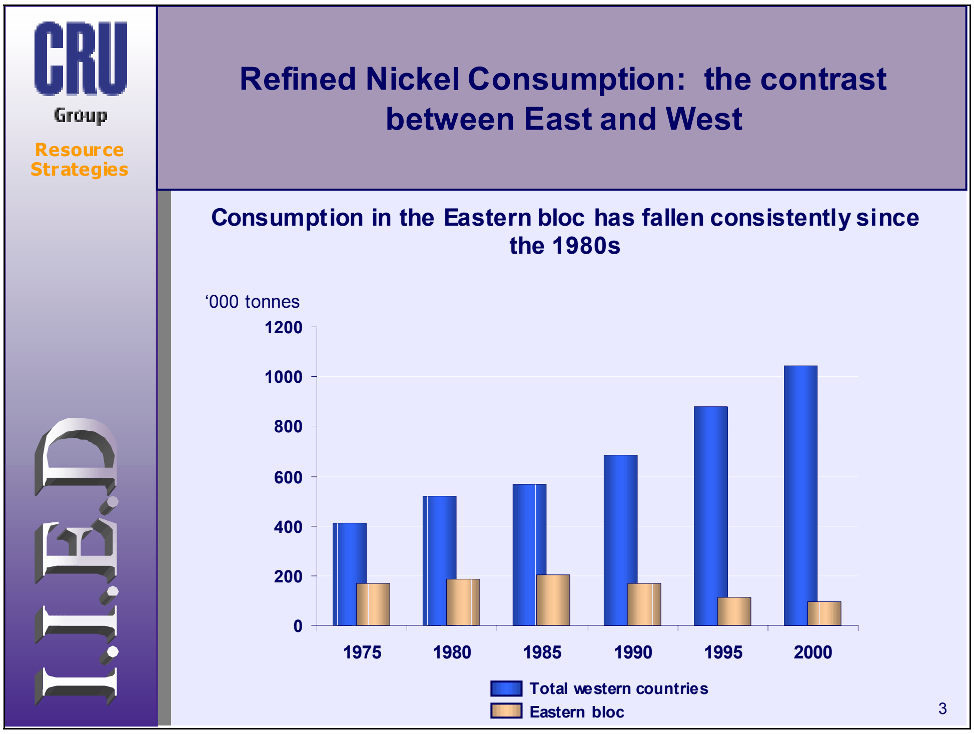
The major application of nickel is in the production of stainless steel. Therefore, consumption figures are very much influenced by the location of stainless steel mills. This accounts for the initially surprising data illustrated above. Africa has achieved a high rate of growth of 6.8%, for example. However, the actual numbers are very small; African consumption in 2000 was only 31,000 tonnes and was very largely accounted for by one new stainless steel mill which came into production in the last five years of the century. The Latin American growth rate of 3.7% is also from a very low starting point.

The North American growth rate is low at only 0.6% per year, because US steel companies have been much less effective at marketing and have therefore invested less in stainless steel production. The USA is a net importer of stainless steel, whereas Western Europe is a net exporter. Australia and New Zealand hardly figure as consumers of nickel because there is no stainless steel production in those countries.

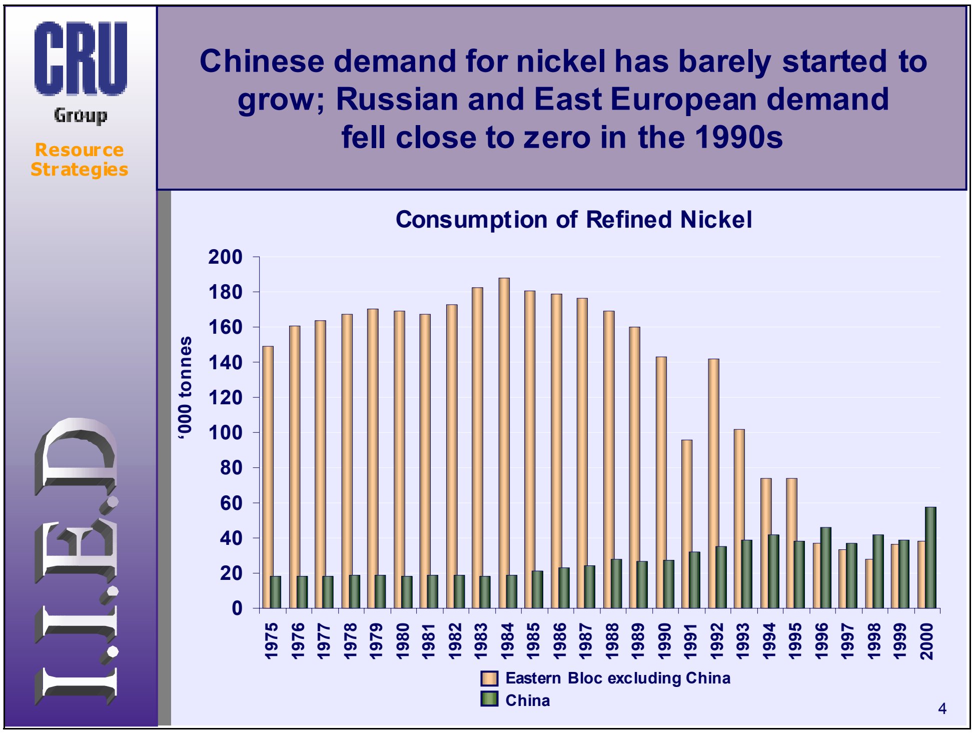


Asia (excluding China and the CIS) is the largest consuming region for stainless steel, and the fastest growing, if we exclude the somewhat unrepresentative African growth rate. Europe is almost as large a consumer as Asia, and both are twice as large as North America.

Consumption in the Eastern bloc has fallen very substantially. From its peak around 1985, East bloc consumption has halved, mainly because Russian consumption of nickel was heavily oriented towards the use of high nickel alloys in aerospace and military applications, which have virtually disappeared. The use of stainless steel in consumer goods and construction applications is almost non-existent in the CIS today.



The contrast between Western world and Eastern bloc consumption is highlighted above, both in volume and in growth rates. Western world consumption grew from 410,000 tones to 1.04m tonnes in 1975-200, while Eastern bloc consumption declined from 167,000 tonnes to 97,000 tonnes.



The chart above explains why Eastern bloc demand has fallen to such a low level, and has not recovered in the past 5 years, in contrast to the other non-ferrous metals where Chinese demand has risen very sharply since 1990. China's production of stainless steel is still small, and nickel consumption in China in other forms is almost zero. The Chinese economy has not yet reached the stage at which the more expensive consumer goods containing stainless steel are much used, and the country is also not a large producer of capital goods containing stainless steel. However, the final demand for stainless steel products is growing in China, and is resulting in increasing imports of stainless steel. There is growing interest now in the construction of new stainless steel production facilities in China. Initially these are likely to take the form of cold rolling facilities which would be supplied by imports of hot rolled coil. New melting facilities for stainless production (which would result in the consumption of nickel as it is defined by the statistical agencies) would follow later.

This is an example of how the recorded consumption of nickel and other non-ferrous metals in a fast-developing economy such as China can lag the actual final consumption of the metal. While a market is supplied mainly by imports of semi-finished or finished products, the consumption represented by these products is recorded in the country which supplies the exports and not in the importing country.

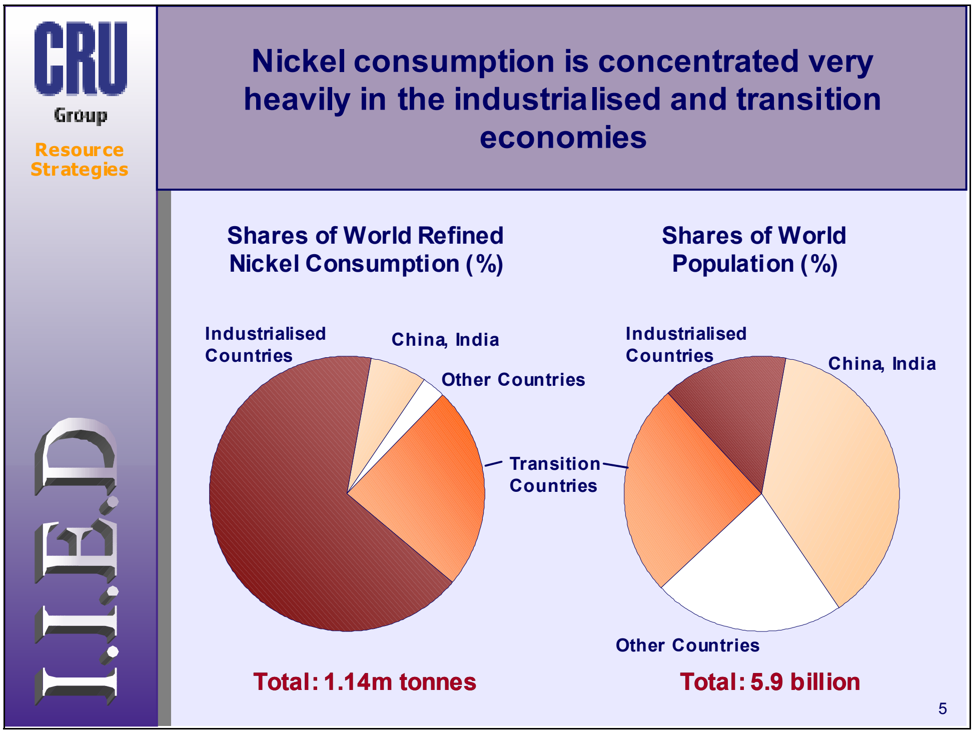
2. Consensus forecasts of demand

CRU International, in mid-2001, was forecasting an average rate of growth of 4.4% in consumption of primary nickel for the period 1999-2005. The area where fastest growth is expected (at 12.2%) is the Eastern bloc. China at the moment imports a considerable volume of hot rolled stainless coils which are cold-rolled and further processed in the country. There are plans to install 1.4m tonnes of hot-rolled capacity (compared to the existing capacity of just 165,000 tonnes), which will have a major impact on nickel consumption in China as it is now measured.

ABARE, early in 2001, was forecast a rate of growth of 4.1% worldwide in the period 2000-2006.

These growth rates are above the average of the past 25 years, but they are consistent with the rate of growth in stainless steel production in the last decade.

3. The distribution of nickel demand



In nickel, even more than in the other non-ferrous metals, there is a notable imbalance between the size of population in the major regions of the world, and their shares in the consumption of nickel.

The industrialised countries, with only 14.6% of the world's population, accounted for 66.7% of nickel consumption in 2000. The transition countries were in close balance, with 25.8% of the population and 23.2% of nickel consumption. China, India and the rest of the world collectively had 60% of the total population but only 9.5% of nickel consumption.

This tells us that nickel remains a rich country's metal, in the sense that stainless steel is a relatively expensive product, used in capital goods and consumer goods that are beyond the reach of the great majority of the world's population. However, the growing demand for imported stainless steel in China shows that this situation can change suddenly as countries advance along the path of industrial development.

CRU Group
Resource Strategies

Contrasts in per capita consumption

	% of World Population	Refined Nickel kg/head (2000)
Industrialised Countries		
USA	4.6	0.56
Canada	0.5	0.50
Western Europe	6.9	0.97
Japan	2.1	1.53
Australia	0.3	0.08
Average / Total	**14.6**	**0.88**
Transition Countries		
Korea	0.8	1.92
Taiwan	0.4	4.81
Other S.E. Asia	7.8	0.03
CIS	4.8	0.12
Turkey	1.1	0.00
Eastern Europe	1.8	0.07
Latin America	8.6	0.04
Average / Total	**25.2**	**0.18**
China and India	37.8	0.03
Others	22.4	0.02

Sources: United Nations, WBMS

I.I.E.D

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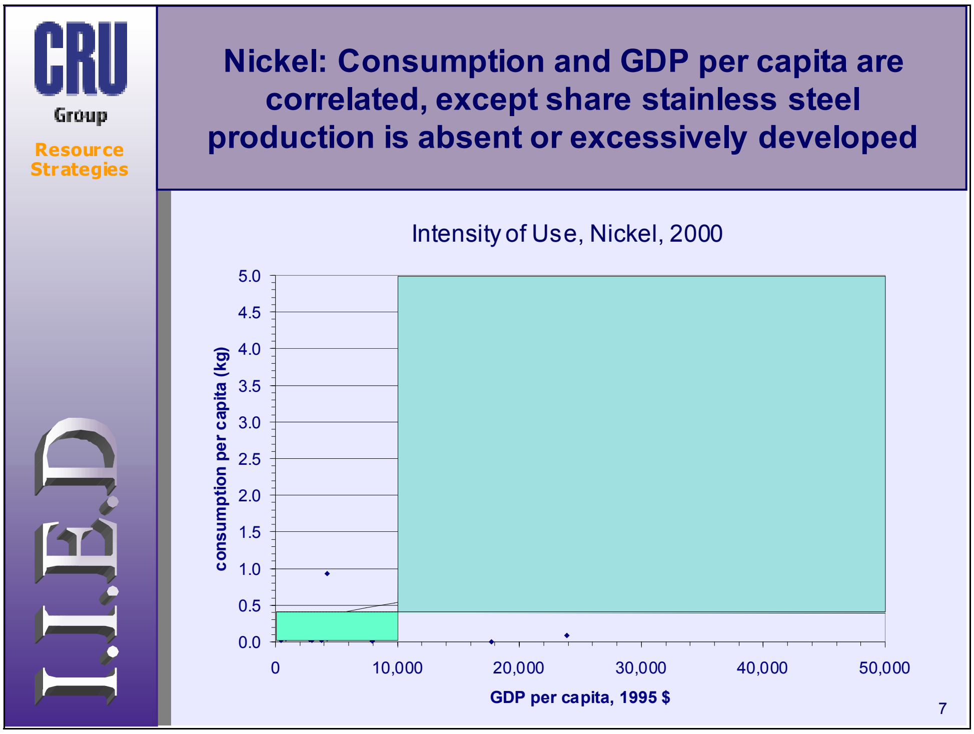
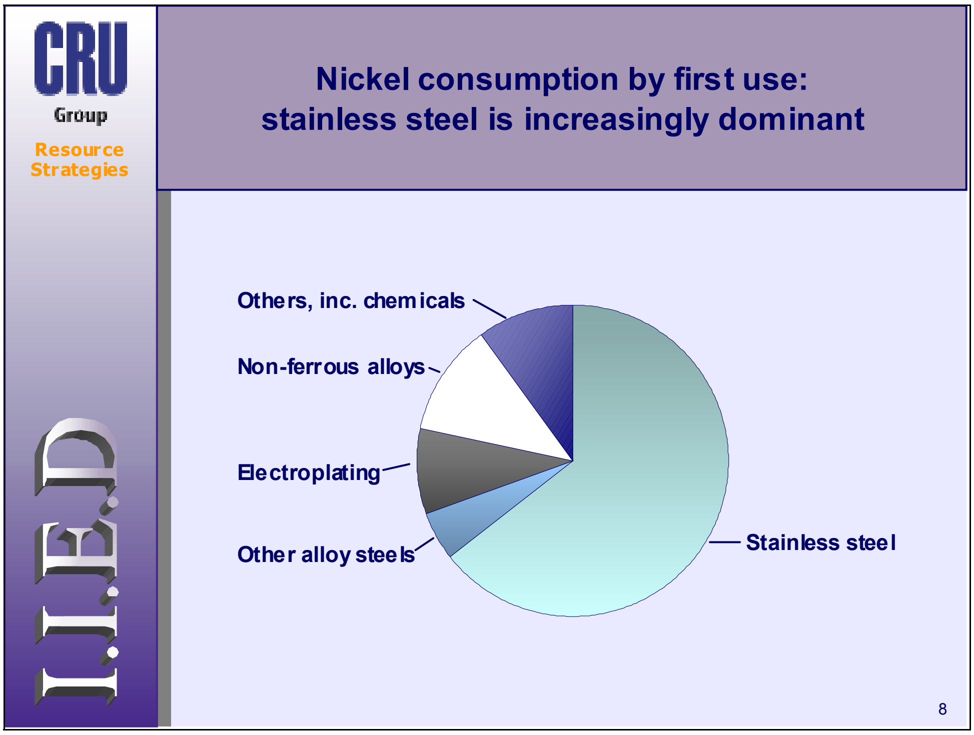
Consumption per head in the major countries shows in more detail the contract between industrialised and developed countries. Among the former, Japan and Western Europe have much higher levels of consumption than the USA, where the steel industry has surprisingly neglected the development of markets for stainless products. Australia has no stainless steel production at all, and imports stainless, whose primary nickel content does not show up as consumption of nickel in Australia under the definitions used.

Among the transition countries, Taiwan and Korea are again far more intensive users than any other countries in the world. Their steel industries supply the surrounding region, particularly China, so what appears to be high nickel consumption in these two countries really represents final consumption in their export markets.



If we ignore the unrepresentative outliers of Taiwan and South Korea, there is a moderately good relationship between the consumption of nickel per head of population and GDP per capita. There is also a clear distinction between those countries with GDP per capita of less than US$8,000, where nickel consumption ranges from zero to 0.5kg per head, and those with GDP per capita of more then US$10,000, where nickel consumption becomes much more significant.

4. Drivers of demand and competition with alternative materials



Over 60% per cent of nickel consumption is accounted for by the production of stainless steel. Nickel is used as an alloying element in the production of austenitic stainless steels, in combination with chromium. There are many specifications, but the most widely used grade is Type 304 which contains 18% chromium and 8% nickel. Nickel imparts corrosion resistance, formability and a fine surface quality which enable the final product to be kept very clean.

Austenitic stainless steel therefore find applications in industrial processing machinery where hygiene is vital; examples are food processing equipment, beverage production and medical or hospital equipment. Domestic applications include kitchen sinks, dishwashers, cutlery and utensils. Architectural uses include siding on buildings, lifts, escalators, rails and other surfaces where a clean, corrosion-free appearance is important.

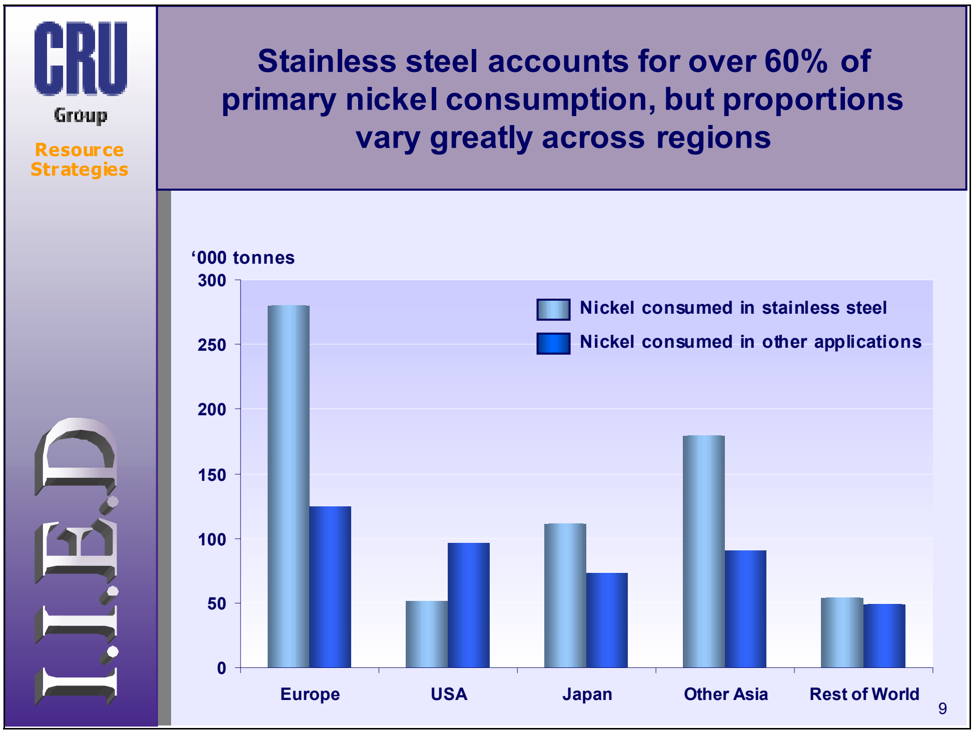
More advanced and complex grades of stainless steel are used for their resistance to corrosion and heat in aggressive industrial environments in the oil, gas, power and chemical industries.

Other more specialised alloy steels containing nickel have been developed for applications where extreme hardness and resistance to heat is required, as for example in turbine blades in jet engines.

Copper-nickel alloys are the second largest application for nickel, and are widely used in tubing to resist corrosion in marine environments such as desalination plants. These alloys can also be bonded to steel tubes, for example. They are also used in coinage.

Electroplating is a well-established process for providing a corrosion-resistant and attractive surface to steel items. Nickel can also now be applied to plastic materials. An important recent application for nickel is in computer hard discs.

Among the miscellaneous applications of nickel, batteries are becoming important. Nickel-cadmium rechargeable batteries are widely used in portable electronic items. Nickel metal-hydride batteries are more recent developments, which provide longer life and greater power for power tools, portable computers and other mobile electronic items.



There are great variations in the importance of stainless steel as an application of nickel. Europe is by far the largest producer of stainless steel, followed by Asia (which means principally Japan, Taiwan and South Korea). The US stainless industry is small; non-ferrous alloys and other applications are much more important in North America.

These variations tell us that nickel is a fairly young metal that is still finding new applications. Consumption therefore develops in the countries or regions where companies happen to have invested in developing alloys, products and markets. Thus, European companies have focussed on developing stainless steel markets; North American companies have focussed on non-ferrous alloys; Japanese companies have focussed on stainless steel applications and more recently on batteries.

The modern industrialised consumer society continues to offer opportunities to companies that develop new products using a relatively young metal such as nickel. It takes time for these new applications to become established and then to migrate to the poorer countries of the world, which is why nickel consumption is so heavily concentrated in the richer countries.

The macro-economic drivers of nickel consumption are closely related to the wealth and disposable incomes of industrialised countries. Alloy steel and non-ferrous alloys containing nickel are expensive materials, and are therefore used in products that themselves are expensive and require high-performance materials. Demand for such products arises when populations attain the level of wealth that enables them to pay for products that perform better, last longer or look better.

Technically, nickel consumption is driven by the qualities that the metal can impart to steel and other alloys. The principal qualities are the ability to resist heat and corrosion, and the ability to be formed, and the ability to impart a smooth and attractive surface that can be kept very clean.

The institutional driver of nickel demand has long been the investment made in developing alloys and applications and in promoting the use of these materials and products in competition with older established products. For a large part of the 20th century, this promotional role was undertaken by International Nickel, which had a market share of 80% and more in the Western world.

The fragmentation of the Western nickel industry starting in the 1970s, and then the huge increase in exports of nickel from Russia to Western markets made it impossible for one company to sustain the research and promotion function, because others benefited from its work and contributed nothing to its cost.

More recently therefore, the Nickel Development Institute has been set up as an industry association to promote the uses of nickel. The Chromium Institute, a chrome industry association, also contributes to this work.

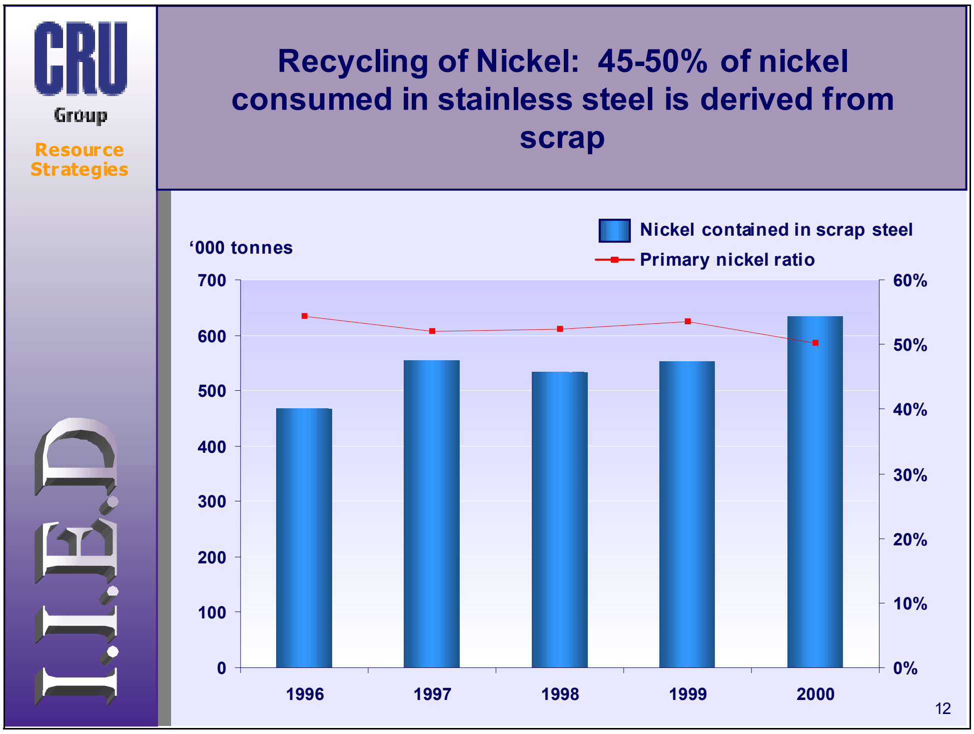
In all its applications, nickel (or the alloys that contain nickel) competes with alternative materials. The outcome of this competition reflects the judgement of the final consumer, or the industrial engineer who balances the benefits of performance against relative prices.

Stainless steel competes with a variety of other steels and other materials in almost all its applications. Painted or galvanised steel, or aluminium may be used in cladding on buildings and some industrial applications. Kitchen surfaces may be made of wood, stone or plastic. Utensils can be made of aluminium, copper or even silver.

In super-alloys (steels with an alloy content of 50% or more), competition comes from such materials as titanium alloys or specialised engineering plastics. In battery applications there are alternative technologies which use manganese, zinc and other materials.

The common feature of all these end-uses is that there is constant competition between manufacturing companies to producer products that perform better, last longer or look better, or offer better value for money to the final consumer. This is a dynamic process involving research, product development, marketing and advertising. The ultimate beneficiary is the consumer who gains a greater choice of products, provided he can afford them.

5. The recycling of nickel

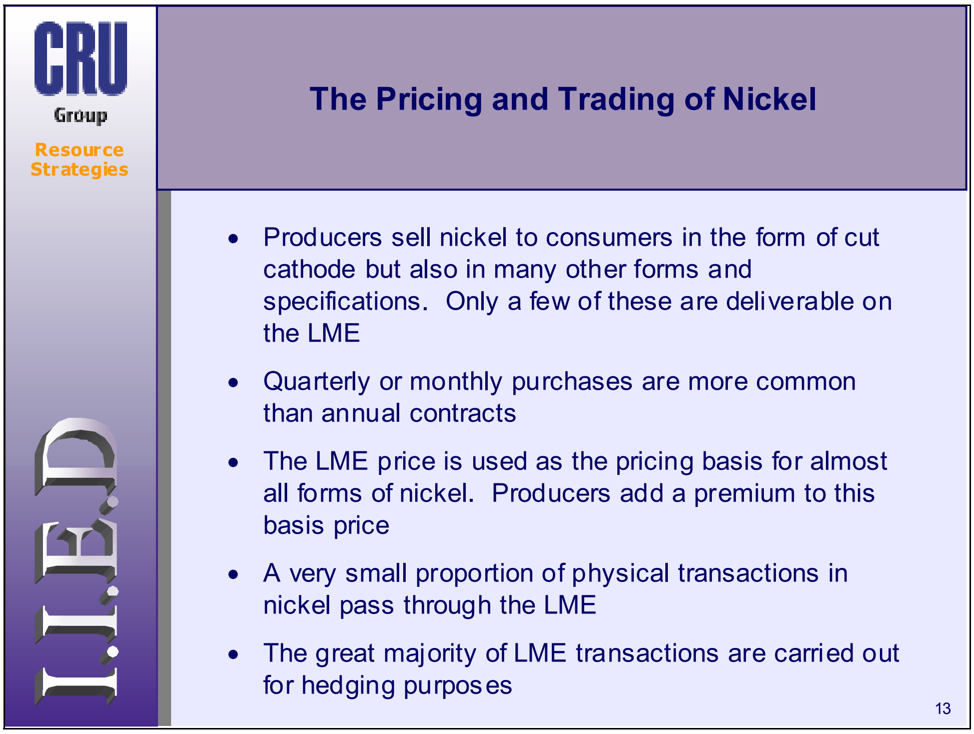


Nickel is almost invariably used as an alloying material. Therefore it is never recovered as pure nickel but is recycled in its alloyed form. Stainless steel scrap is by far the most common form in which it is recycled. Indeed stainless scrap is the preferred raw material for the production of fresh stainless steel. It can be readily remelted and the alloy can be adjusted by the addition of further units of steel or alloying materials to achieve the correct formulation.

Primary nickel is used by producers of stainless steel only when the supply of stainless scrap is insufficient. The reason is that is it more expensive to produce stainless steel from its original constituents (steel, nickel and chromium) than to produce it from scrap.

The primary nickel ratio measures the proportion of primary nickel used in the production of stainless steel. It ranges between 50 and 55%, depending on the supply of scrap and the demand for new stainless steel. In other words 45-50% of the nickel used by the stainless industry is derived from scrap, and the volume of recycled nickel rises steadily as the production of stainless rises.

6. The pricing and trading of nickel



Unlike the other non-ferrous metals, primary nickel is produced and sold in many different shapes and forms; these include cathode (which is generally cut into small squares), briquettes and other small shapes known as crowns, rounds and pellets. Nickel is also produced in the form of ferronickel, an alloy of nickel and iron. The common feature of all these products is that they can be added in carefully controlled quantities to molten steel, where they melt and disperse throughout the steel, to produce the desired alloy.

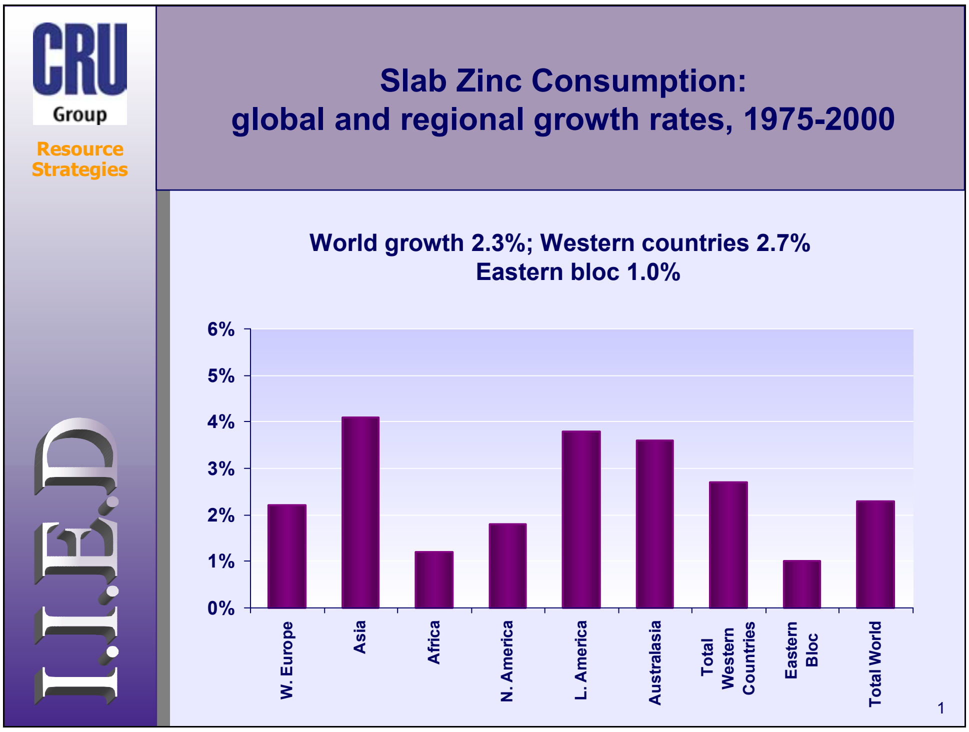
The London Metal Exchange trades nickel, but only cut cathodes and briquettes of a specified purity can be delivered against LME nickel contracts. Nevertheless, since its introduction in 1979, the LME nickel contract has gradually been accepted as the worldwide pricing basis for nickel, even if the metal is produced and sold in forms that arte not deliverable on the LME.

Producers sell to consumers of nickel, normally under annual contracts, but also under quarterly or spot contracts. The metal is delivered direct from producer to consumer and does not pass through the LME. Only the price is taken from the LME. A premium is added to the LME price to reflect delivery costs and other services provided by the producer. Traders play an important role as intermediaries between producer and consumer of nickel, particularly in the handling of nickel exported from Russia. In this case, the producer is not yet sufficiently adept at marketing to undertake this role fully.

A producer of nickel may choose to deliver metal to an LME warehouse if he has no better outlet for his product, and a consumer may choose to take metal from an LME warehouse if he cannot obtain it directly from a producer. However, such physical transactions account for a small proportion of transactions on the LME. The great majority are undertaken to hedge price risks arising from contracts to buy or sell at future unknown prices; some are also undertaken for investment or speculative reasons.

Chapter 6
The need of minerals: Zinc

1. Global and regional growth in demand

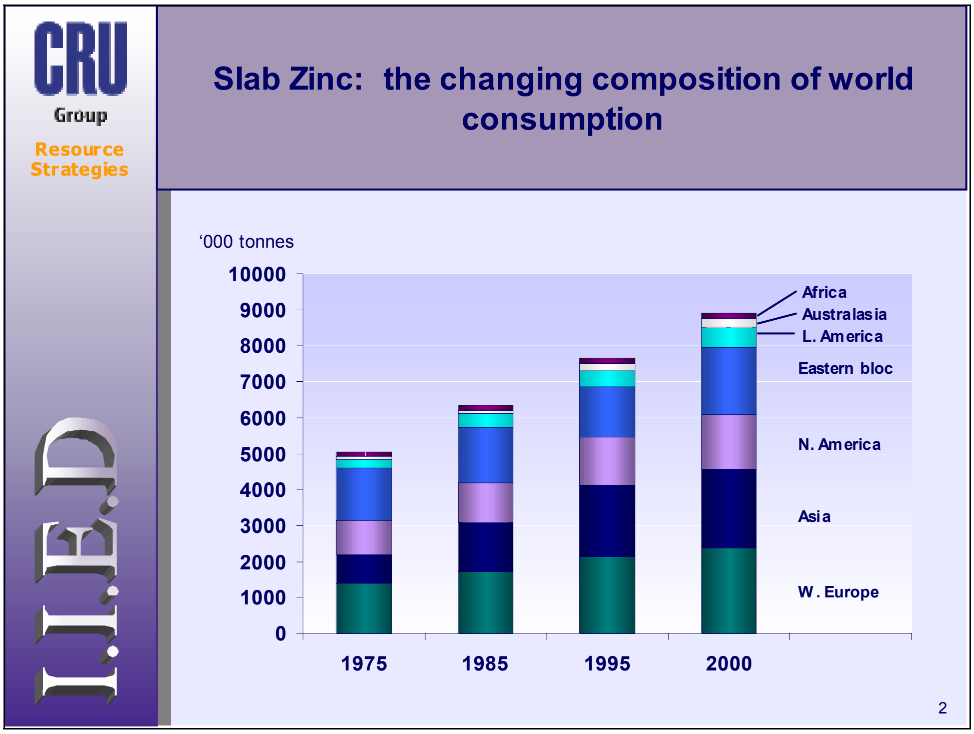


Demand for slab zinc (the term commonly used for refined zinc in the form of ingots or larger cast products) grew by 2.3% worldwide in 1975-2000. As with other metals, there was a sharp contrast between the Western world, where demand grew at 2.7% and the Eastern bloc, where demand grew at only 1% during this period. It should be noted, however, that the quality of data on the consumption of metals in the former Communist countries while they were under Communist rule is poor, and much less reliable than that for the Western world.

Within the Western world, the rate of growth in zinc demand was fastest in Asia, at 4.1%, and in Latin America, at 3.8%. The major end-use of zinc is in producing galvanised steel. This product is widely used in countries at the earlier stages of industrialisation, where heavy use is made of galvanised steel in the construction of infrastructure, and also in basic private housing. This explains the fast rates of growth in the regions which were passing thorough this phase of development in the last quarter of the past century.

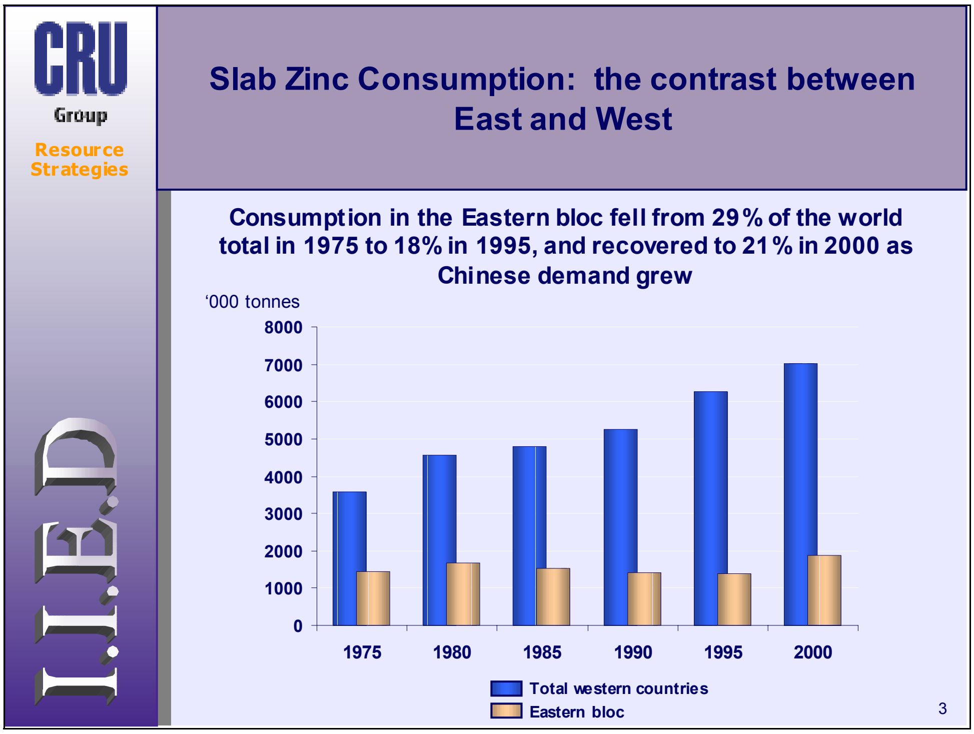
Growth in demand has also been above average in Australasia, at 3.6%. This has been based on the expansion of facilities to produce galvanised steel in Australia, for export to the South-East Asian region. This emphasizes again the point that figures for the consumption of non-ferrous metals measure only the first stage in consumption. Therefore the zinc data does not reflect the consumption of zinc that is imported or exported in the form of galvanised steel or any other fabricated zinc product. Galvanised steel is a widely traded product, so the data in the chart above and other charts reflecting consumption of zinc under-estimates total consumption in countries or regions that are net importers of zinc in fabricated or semi-fabricated products, and over-estimates consumption in net exporting countries or regions.

At the other end of the scale, Western Europe saw growth in zinc demand of 2.2% and North America 1.8%, reflecting the more mature stage of development of these economies.

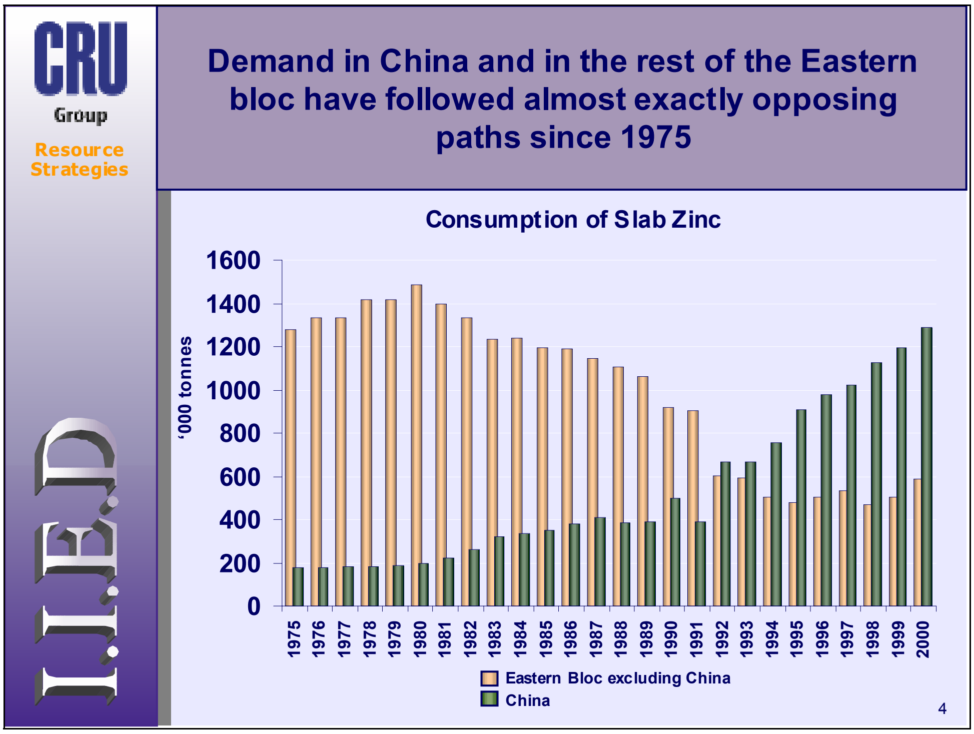


Among the regions shown above, Western Europe remains the largest market for zinc, by volume, at 2.4m tpy, closely followed by Asia at 2.2m tpy. Among individual countries, the USA and China were the largest consumers in 2000, accounting for 1.335m tonnes of slab zinc each. Chinese demand, however, is growing much more rapidly than consumption in the USA, and there is no doubt that China will be the largest zinc-consuming country in the very near future.

Consumption in the Eastern bloc as a whole made no progress at all between 1975 and 1995. Since then, it has grown at 6.2% per year, thanks almost entirely to the rapid growth in consumption in China.



The slide above illustrates the static nature of zinc consumption in the Eastern bloc between 1975 and 1995. These countries accounted for 29% of world zinc consumption in 1975 and only 18% in 1995. That percentage had grown to 21% by 2000. The contrast indicates the large scope for additional consumption of zinc in the former Communist countries, as and when their economies recover. The performance of the Chinese zinc market suggests what could theoretically be possible, given the necessary economic stimulus and sources of finance for state-funded infrastructure and private sector investment.



As with other non-ferrous metals, the growth in demand for zinc in China was almost exactly the mirror image of the fall in consumption in the former USSR and Eastern Europe. Chinese consumption has grown from under 200,000 tpy in the mid-1970s to 1.3m in 2000, while consumption in the rest of the Eastern bloc has approximately halved to around 600,000 tpy and has been growing only very slowly is the last 2-3 years.

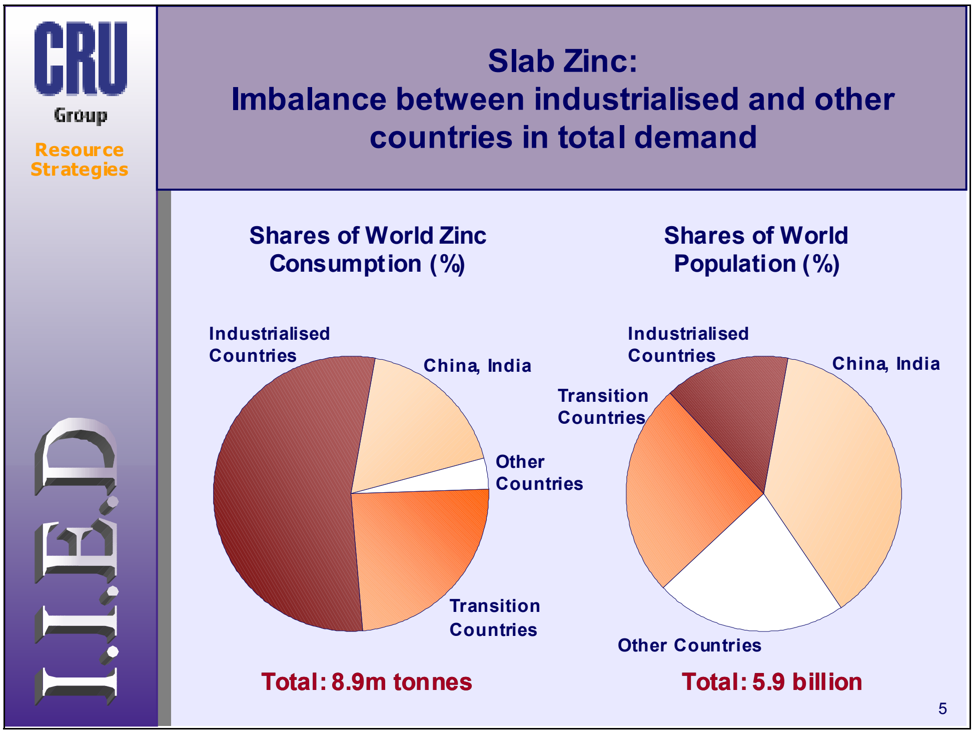
Chinese consumption has grown at an astonishing rate of 8.2% per year for quarter of a century, from 1975 to 2000, while consumption in the rest of the Eastern bloc fell by 5.2% during the same period.

2. Consensus forecasts of demand

In 2000, CRU International's long term analysis of the zinc industry produced a forecast rate of growth in zinc consumption of 2.3% per year in the decade to 2010, with an upper and lower range of 2.9% and 1.6%. ABARE in 2001 forecast a 2.5% rate of growth in the period 2000 to 2006. Both organisations foresee a fall in consumption in 2001 and lower than normal growth in 2002. CSFB in October 2001 was forecasting growth of 0.2% in 2002 and 3.3% in 2003.

The consensus appears to be that the rate of growth over the next 5-10 years will not differ significantly from that of the past 25 years.

3. The distribution of zinc demand



The consumption of zinc is still sharply tilted in favour of the industrialised countries of the world. With only 14.6% of the world's population, they accounted for 54.2% of zinc consumption in 2000. The transition countries have 24% of zinc consumption and 25% of world population. Korea and Taiwan account for 34% of the zinc consumption in this group of countries, and therefore boost the proportion of zinc used by this group, although their distorting influence is not quite as large as it is in other non-ferrous metals.

China and India account for 18% of total zinc consumption, a higher proportion than in any of the other non-ferrous metals. The rest of the world has 22% of the world's population but only 3.7% of zinc consumption.

These apparent imbalances would be slightly reduced if it was possible to trace the final location of consumption of zinc contained in manufactured products, but probably the basic bias towards the more developed countries would not be fundamentally changed.

CRU Group
Resource Strategies

Contrasts in per capita consumption

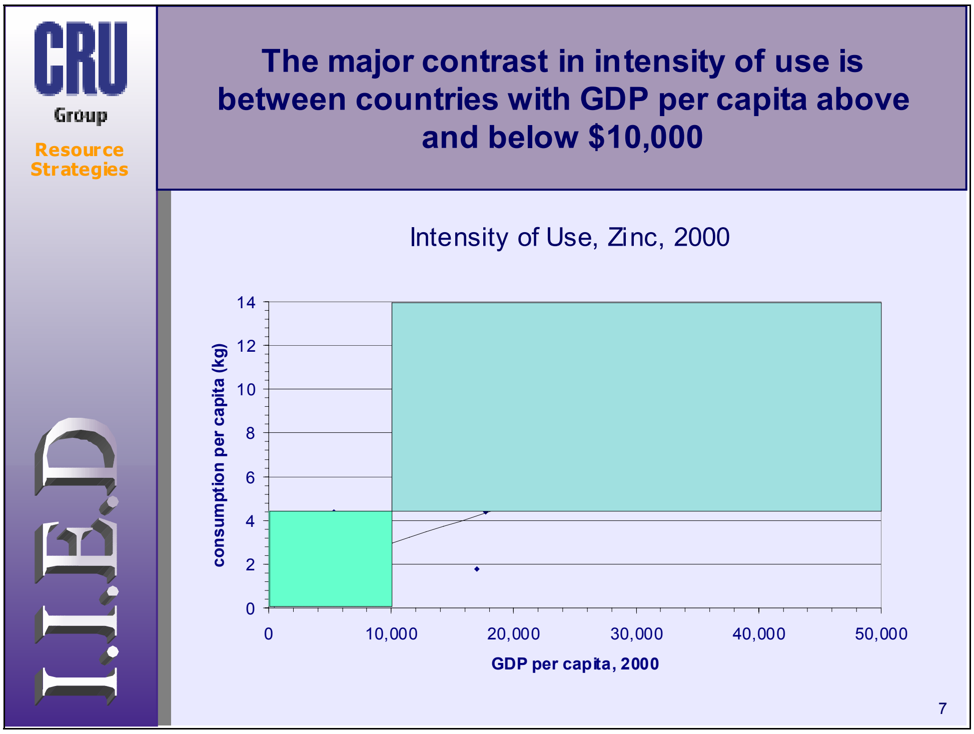
	% of World Population	Slab Zinc kg/head (2000)
Industrialised Countries		
USA	4.6	4.9
Canada	0.5	5.8
Western Europe	6.9	5.8
Japan	2.1	5.4
Australia	0.3	11.4
Average / Total	**14.6**	**5.6**
Transition Countries		
Korea	0.8	9.3
Taiwan	0.4	13.4
Other S.E. Asia	7.8	0.6
CIS	4.8	1.0
Turkey	1.1	1.2
Eastern Europe	1.8	1.8
Latin America	8.6	1.1
Average / Total	**25.2**	**1.4**
China and India	**37.8**	**0.7**
Others	**22.4**	**0.2**

Sources: United Nations, CRU International 6

Among the developed countries, the volume of zinc consumed per head of population is remarkably even at around 5-6 kg per person, with the major exception of Australia, which has a large export-based galvanising industry, and therefore a high apparent rate of consumption per head.

Similarly, consumption in the transition countries is within the range of 0.6 to 2.0 kg per head, with the notable exceptions of Taiwan and Korea. The highly developed export-based steel industries of these two countries accounts for their very high consumption per head, which is far in excess of levels in the USA or Western Europe.

China and India together consume 0.7 kg per head and the rest of the world a mere 0.2 kg per head.

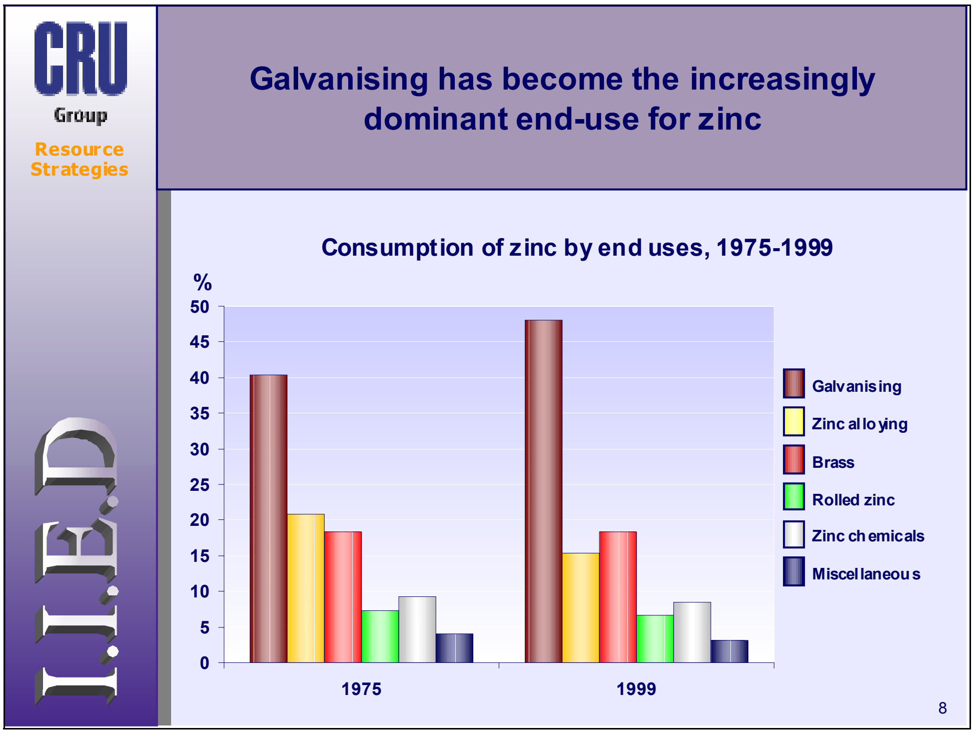


Comparing zinc consumption per capita with GDP per capita reveals the familiar split between the countries which have GDP above and below $10,000 per head. When GDP is below $10,000 per head, consumption is clustered between zero and 3 kg per head. Above that level, consumption is generally in the range of 4.5 to 6 kg per head, with the exception of three countries (Taiwan, Korea and Australia) which have substantial export-oriented galvanising sectors within their steel industries.

There is a trend towards the construction of galvanising lines in developing countries, which would supply most of the future growth in demand in those countries, and eventually produce galvanised sheet to substitute for imports from more developed economies. The driving force is the fact that coating steel sheet with zinc is one of the most basic means of adding value to hot rolled coils. There are no serious technical barriers to investment in galvanising. The major requirement is a sufficiently large national or local market.

The correlation between the two variables shown on the chart above is not particularly strong. In future, the line of best fit may verge even more towards the horizontal as galvanising and other major end-uses gravitate more towards the countries with lower GDP per capita.

4. Drivers of demand and competition with alternative materials



The consumption of zinc by its first use is shown above. Galvanising has long been the dominant application, and has become more important over the past 25 year. It now accounts for nearly 50% of zinc consumption worldwide. Zinc's use in die-casting alloys has fallen from 21% to 15% of the total. The other major applications have remained very stable in proportionate terms: brass at 18%, rolled zinc at 7% and dust and chemical applications at 8-9%.

The industries which account for the final consumption of zinc are estimated by the International Zinc Association as follows: construction 48%, transport 23%, machinery and equipment, 10%, consumer durables 10% and infrastructure 9%.

Galvanising is the process by which a thin layer of zinc is applied to sheet steel, to protect the steel from corrosion, which occurs when steel is exposed to air or water. Galvanised steel is therefore widely used in construction where steel products are exposed to the elements, and in roofing, cladding and structures such as pylons, signposts, lampposts, motorway barriers and fencing. However, the fastest growing application for galvanised steel is in the automobile industry, where sheet used for car bodies is now generally galvanised to protect the body of the car from corrosion.

Zinc is alloyed with aluminium to make diecastings that have a very wide range of application from simple household items such as door knobs, taps and hooks, to precision parts for automobiles, computers and electric machinery.

Zinc is alloyed with copper in varying proportions to make brass. The zinc content can vary from 10% to 40%. Brass is widely used in door fittings, locks, window fittings, light fittings and screws. It is also increasingly used by architects and interior designers for rails, banisters and other decorative applications in public buildings.

Rolled zinc is used for roofing, guttering and cladding. It is resistant to corrosion and is easily formed. This application is particularly popular is parts of northern Europe, and specifically in France, the Benelux countries and parts of Germany.

The chemical applications of zinc include oxide, which is used to harden rubber in tyres, zinc dust, which is used in paints, and zinc compounds which are used in pharmaceutical and cosmetic products, fertilisers and animal nutrients.

The drivers of demand for zinc can be categorised as macro-economic, technical or micro-economic and promotional. At the macro level, we have already seen that there is relationship between the GDP per capita of a country and the intensity of zinc use. This can be readily understood when one remembers that the great majority of zinc is consumed in basic construction and infrastructure, and also in automobiles. Demand for zinc arises almost automatically as expenditure on these products increases. Because of the importance of basic construction and infrastructure as applications for galvanised steel, the demand for zinc is biased towards countries in the earlier phases of economic development, compared to, for example, nickel which is a metal used more heavily in the later stages of economic development.

The properties of zinc have been widely known and exploited for many years, so growth in demand from the technical point of view is driven by the exploitation of its special properties that are not readily found in alternative materials. Protecting steel against corrosion is the property most difficult to replicate. There are considerable economic benefits from extending the lives of steel products and reducing maintenance costs (such as painting) by using galvanised steel. These benefits have an environmental aspect also, in that making metal products last longer reduces the demand made on primary resources. This is the principle technical and economic driver behind the use of galvanised steel. Similar motives lie behind the use of rolled zinc as a roofing material.

Zinc die-casting alloys have good casting properties and the final products have good strength to weight ratios. Die-castings can also be designed to replace machined metal parts. However, the technical properties of zinc die-casting alloys are not unique or impossible to replicate, so this driver is less powerful.

The use of zinc in brass is driven partly by the ease with which brass parts can be machined, and partly by the attractiveness of brass as a finished product. The latter is a question of fashion and taste, and can therefore change over time. The former is a permanent feature but not unique. There is therefore a substantial element of fashion in the choice of brass as a material.

The zinc industry is both fragmented, in the sense that there are many small and medium-sized participants, and poorly integrated, in the sense that mines, smelters and consuming industries are very largely in separate ownership. There are no single companies which have sufficient market share to undertake research and promotion on behalf of the entire industry. Promotion is therefore undertaken by national industry associations, and coordinated by the International Zinc Association. However, the amount of money devoted to market development and promotion is small in relation to the size of the industry.

Zinc faces competition from alternative materials in almost all its end-uses. Galvanised steel competes with steel that is painted or coated with other materials such as plastics. The choice of material may depend on the degree of forming that the steel will be subjected to, and the quality of surface finish required on the final product.

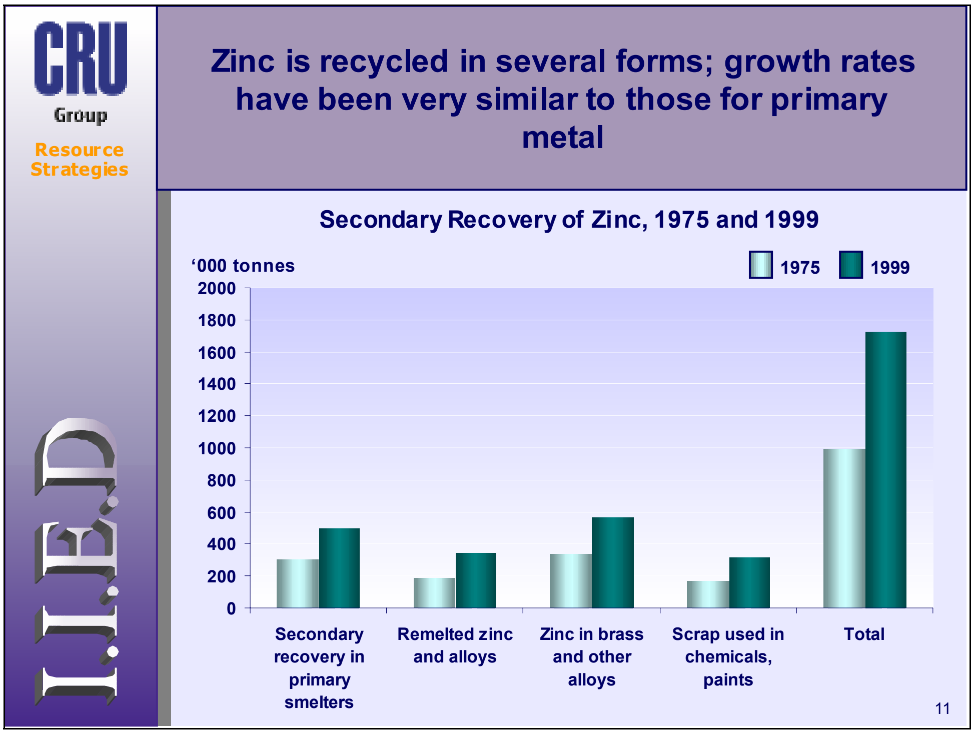
Zinc die-casting alloys face strong competition from aluminium alloys. Zinc alloys are cheaper in relation to volume, but aluminium alloys are lighter and therefore tend to have better strength to weight ratios. Aluminium alloys have therefore gained end-uses in automobile components at the expense of zinc.

Rolled zinc faces strong competition from copper and other roofing materials. The choice of material is often determined by local tradition and fashion, and by the familiarity of construction workers with one material or the other.

Brass competes with aluminium and steel and even with plastics. The choice is determined by price, fashion and design.

The chemical applications of zinc have few, if any, substitutes. However, zinc is used in comparatively small quantities in these applications.

6. The recycling of zinc



The great majority of zinc is used either as an alloying material or as a coating to steel. At the end of the life of products containing zinc, the metal cannot readily be separated and recycled as pure zinc. The recycling of zinc therefore takes many forms and is not undertaken by one dedicated industry, as is the case with lead, for example. Because the recycling routes are diverse, the statistics on the volume of zinc recycled are by no means complete. The chart above traces about 1.7m tonnes of zinc recycled in 1999, but there are many countries for which no data exists, so the true total is certainly larger.

Zinc used in galvanising can be recovered when the galvanised product reaches the end of its useful life. Scrap galvanised steel will normally be returned to an electric arc furnace, where the zinc content can be re-captured in the form of flue dusts. The steel-maker must dispose of these, either by landfilling them or by passing them to a zinc smelter which can add them to the primary concentrate feed. This accounts for the great majority of the zinc recycled through primary smelters. The limitation is that the Imperial Smelting Furnace is the only zinc production process that can accept zinc dust as a feed, after it has been up-graded into oxide. The ISF process accounts for only 13% of primary zinc capacity in the Western world.

Die-cast scrap is recycled into further die-casting alloys. The scrap may arise in the production process or at the end of the life of the product. The obstacle to full recycling may be the difficulty of identifying the alloy correctly, and also the fact that die-cast parts are small and are used in many different applications, so there is no major simple source of this scrap.

Brass is readily recognised and is recycled as brass in large quantities. Almost certainly the figures shown above understate the amount of zinc recycled in this way. Some zinc scrap, notably galvanisers' drosses and ashes, are directly recycled in the production of zinc oxide and dust.

Rolled zinc can be directly remelted and recycled as rolled zinc.

When zinc is used in the form of an alloy or in the form of rolled zinc, there are natural economic incentives to recycle it, provided the scrap arises in sufficient volume to make it worthwhile for a scrap merchant to collect the materials and re-sell it.

The problem in zinc recycling arises with EAF dusts. In 1992, CRU International estimated that more than half of the EAF dust generated was dumped in landfill sites. The cost of landfilling is rising, and the process is environmentally undesirable. The volume of zinc dusts that can be expected to arise will increase as cars that contain galvanised steel are scrapped in greater numbers.

Steel-makers operating electric arc furnaces face the choice of paying treatment charges for the disposal of EAF dusts in zinc smelters, or paying land-fill charges for dumping them. The recycling choice is becoming more attractive economically, as landfill charges rise faster than treatment charges. However, processing plants are required to treat the dusts before they can be fed to a smelter. New processing plants will probably require higher treatment charges, which may alter the balance again between the two disposal routes.

There is a case for external intervention to prevent the landfilling of these dusts, and to force the companies that generate the dusts to recycle them into zinc metal.

There is also a considerable amount of research and development into new processes for the treatment of dusts. Direct metal production from dusts is possible but very energy-intensive; it uses about 2.5 times the electricity required to produce primary zinc in an electrolytic process. Two-stage processes are also technically possible but not commercially proven. A leaching process has also been taken to the pilot plant stage.

Encouragement and financial support for any or all of these processes could lead to the recycling of much greater quantities of zinc in future.

5. The pricing and trading of zinc

The pricing and trading of zinc is very similar to the pricing and trading of copper. Slab zinc is sold by smelters to consumers, normally under annual contracts, and sometimes on spot contracts. Some zinc is sold through traders also. The metal is priced at the LME price plus a premium for grade, location and services supplied by the producer. This does not mean that all zinc metal passes through the LME. On the contrary, a very small proportion of slab zinc is sold onto the LME by producers, and a very small proportion is bought from the LME by consumers.

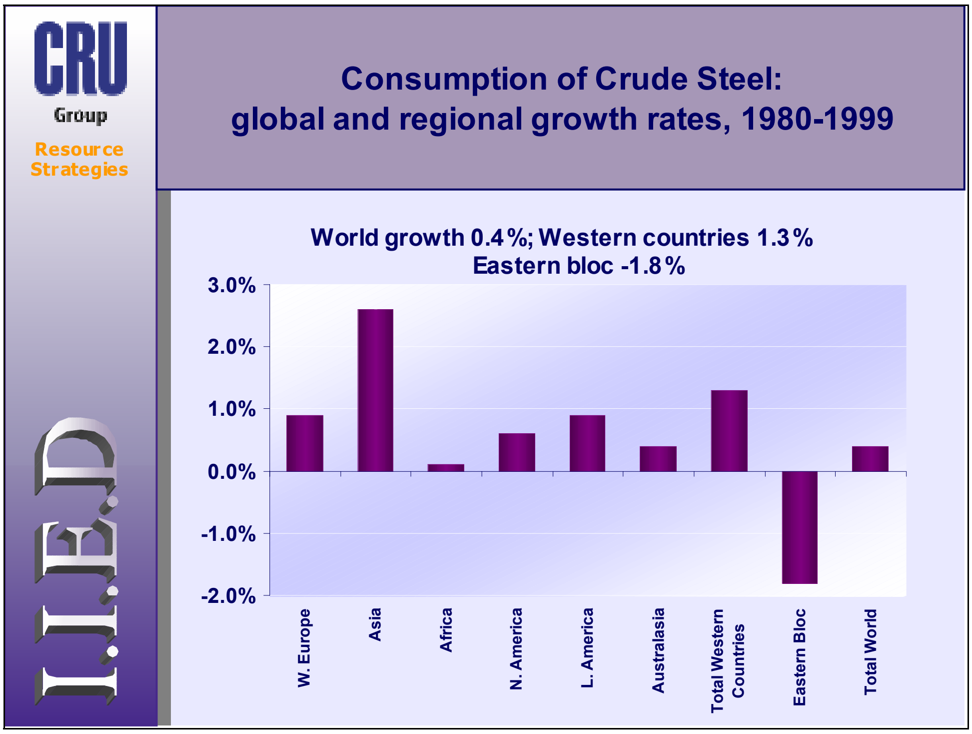
Both producers and consumers regard the LME as a market of last resort. Producers get no premium when they deliver metal to an LME warehouse in fulfilment of a sale contract, and consumers who take physical delivery in fulfilment of a purchase contract must pay for delivery from the LME warehouse to their plant. They also have no control over the location of the warehouse in which their metal is located, and no control over the origin or grade of metal, so long as it meets the minimum LME specifications.

The LME is therefore the marginal market for physical trade, and thus provides an accurate indicator of the balance between supply and demand. Its price is therefore accepted as the world market price for zinc, and is used as the reference price for all physical transactions, at least in the western world. The major use of the LME is for hedging purposes, in the same way as it is used in the aluminium, copper and lead industries. The difference in the case of zinc is that more consumers are willing to accept the price risk inherent in buying metal on a future, unknown LME price basis, because the price of zinc is not so crucial to the cost of producing galvanised steel, for example. Consumers who take this view do not use the LME for hedging.

The LME price is also used in pricing zinc concentrates. The formula used in the pricing of zinc concentrates is a little different from that used in the copper industry but the underlying principle is the same. The zinc content in a shipment of concentrates is valued at the LME price of zinc, minus a treatment charge which reflects the cost and profit attributable to the smelter which converts the concentrate to refined metal.

Chapter 7
The need for minerals: Steel

1. Global and regional growth in demand



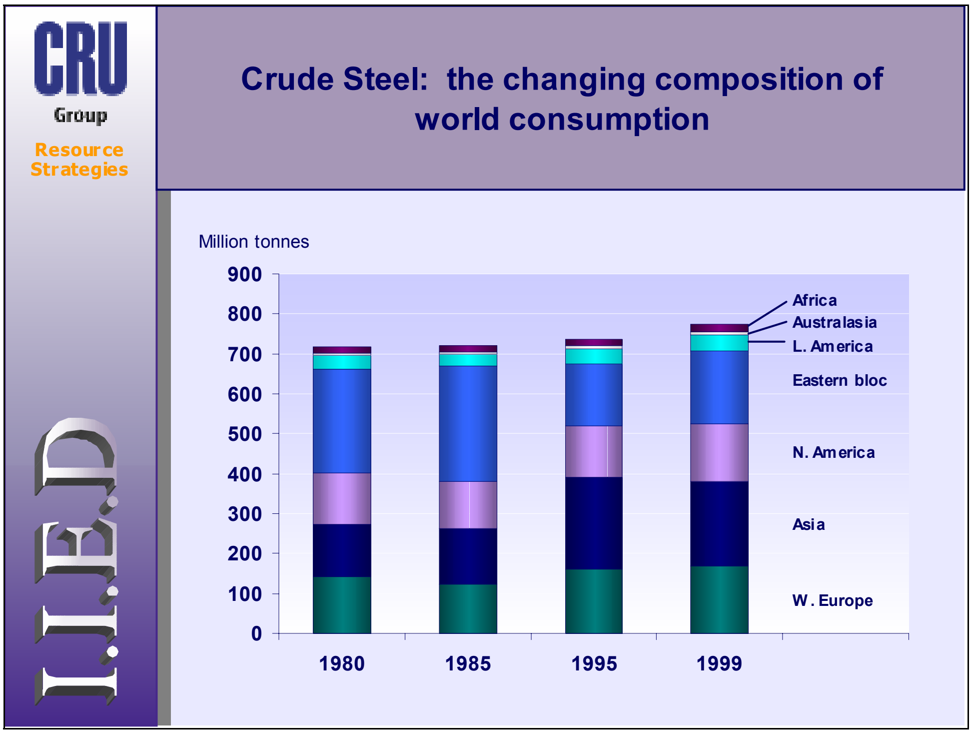
Steel is by far the most important of the industrial metals in terms of volume produced and consumed, and also in terms of value. World consumption reached 837m tonnes in 2000, which exceeds the consumption of primary and secondary aluminium, the next most widely used industrial metal, by a factor of 25. Steel is the most basic of all industrial raw materials and is now a thoroughly mature metal. Its growth rate over the period 1980-99 was therefore only 0.4% worldwide. However, in the Western world consumption grew by 1.3% in that period, while Eastern bloc consumption fell by 1.8% as a result of the collapse of the economies of the former USSR and of Eastern Europe in the early 1990s. The former USSR was a particularly large user of steel because of the tendency to over-design industrial structures and equipment by using greater volumes of steel than were really needed.

In the industrially mature economies of North America and Western Europe, growth in demand for steel has been only 0.6% and 0.9% respectively since 1980. Latin American consumption has grown by 0.9% and Asian demand by 2.6%. Asian demand was growing at an even faster rate in the period 1985-95 but then fell at 2.0% per year in 1995-1999 as a result of the Asian economic crisis.

The most convenient form in which to measure steel production is the consumption of finished steel (i.e. steel that has been semi-fabricated into sheet, plate, rods, bars, rails etc.). In order to obtain a measure that is comparable across all these categories of product, finished steel is often measured on a crude steel equivalent basis. This means that finished steel consumption is grossed up to the crude steel equivalent, taking account of the proportion that is produced by continuous casting methods and the proportion that is produced by rolling slabs into semi products. This is the measure used in this chapter.

The figures shown in the chart above therefore take account of international trade in finished steel products. However, they do not take account of trade in manufactured goods (such as cars or trucks, for example) that contain steel. If this adjustment could be made, the final true consumption of steel would be seen to be lower in the countries which are net exporters of manufactured products, and higher in countries that are net importers of manufactured products.

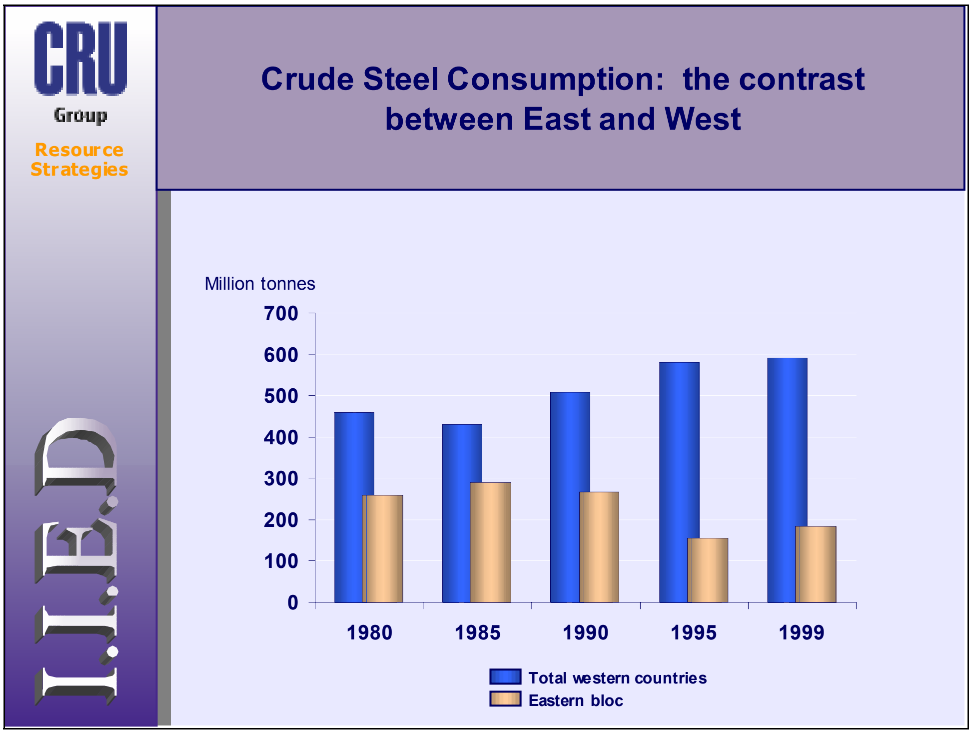
In other words, as in the other industrial metals, when we measure demand for steel we are measuring steel going into all manufacturing processes, and not steel going into the hands of the final consumer of the manufactured products.



Asia, excluding China, is the largest steel-consuming region of the world, accounting for 213m tonnes in 1999, and has also been the fastest growing steel consuming region in the Western world over the past two decades. The consumption of steel here has been very closely linked to the rapid rate of economic development in the South-East Asian countries, and before that in Japan.

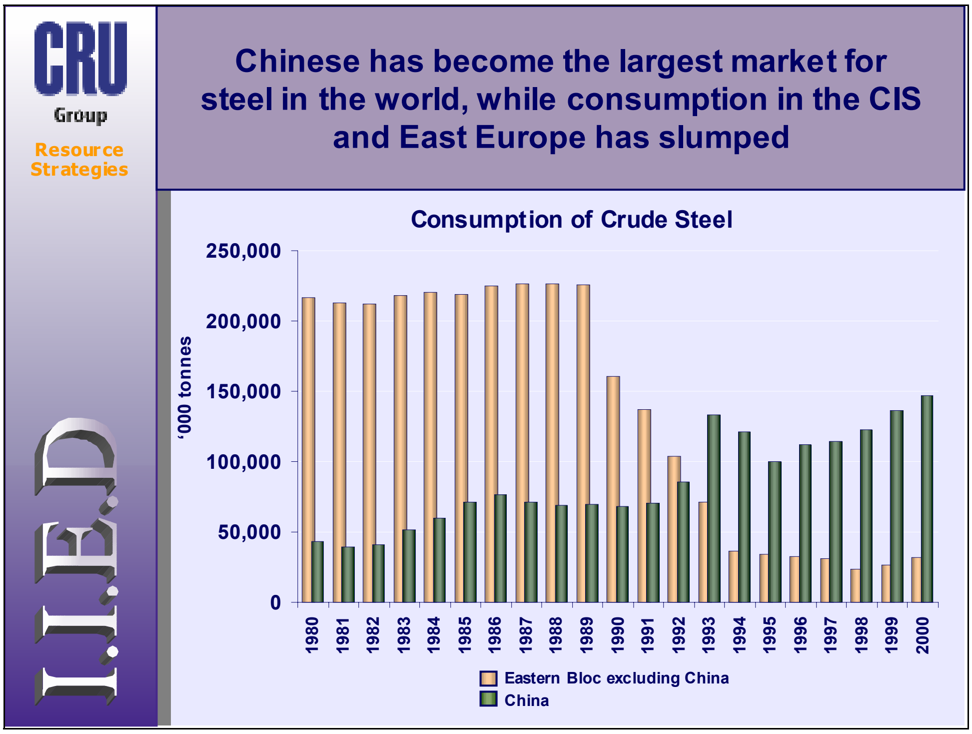
Western Europe is the second largest consuming region, with 168m tonnes in 1999, ahead of North America with 144m tonnes. Latin America is surprisingly small as a consumer, considering that its economies have been at a similar stage of development as those of South-East Asia for much of the past two decades. Africa barely figures at all as a consuming region, accounting for only 17m tonnes in 1999.

The Eastern bloc has seen a huge fall in steel consumption between 1980, when it accounted for 260m tones and was the largest consuming region in the world, and 1999 when consumption was only 183m tonnes. Between 1990 and 1995 steel consumption in this region fell at a rate of 10% per year as a result of the collapse of the Communist political system and the economies of Eastern Europe and the former USSR. Since then, consumption has grown at 4% per year, which is faster than in any other region. However, the total market in the Eastern bloc is still far from its former peak.



In 1985 steel consumption in the Eastern bloc accounted for 40% of world steel consumption. By 1995 this figure had fallen to 18%, which was a mark of the contrasting results achieved by the Communist and capitalists economic systems. The gap has closed slightly since 1995, as a result of the growth in Chinese steel consumption.

However, even this contrast fails to show the extent of the collapse in the steel market in the former Soviet Union and Eastern Europe, which is revealed in the following slide. There is clearly scope for recovery in steel consumption in parts of the Eastern bloc, but total consumption will not reach the levels of the 1980s for many years. High levels of Eastern bloc consumption in the past were driven not only by heavy expenditure on military equipment, which is unlikely to be resumed, but also by very inefficient design in the construction and engineering industries. Western standards will gradually be adopted in these areas and are leading to the more economical and cost-effective use of steel.



The slide above shows the extent of the collapse in Russian and East European steel consumption since 1990. The Chinese steel market has been growing in almost exact contrast to this, and reached 147m tonnes in 2000, which made China the largest steel consuming country in the world. China is also the largest steel producing country and nevertheless remains a substantial importer of steel.

The appetite for steel in China has been driven by the gradual liberalisation of the economy and by sustained investment in construction and infrastructure over the past decade. There remains a very large potential demand for cars and consumer goods among China's huge population. Increasing personal incomes and continuing investment in infrastructure in the form of construction, transportation and power generation and distribution can therefore keep the total demand for steel on a rising trend in China for some time to come.

Russia, meanwhile, has become a large exporter of steel products as its domestic market has collapsed, to such an extent that tariffs and duties have been imposed on its products in many importing countries, to protect the local steel companies from what is seen as unfair Russian competition.

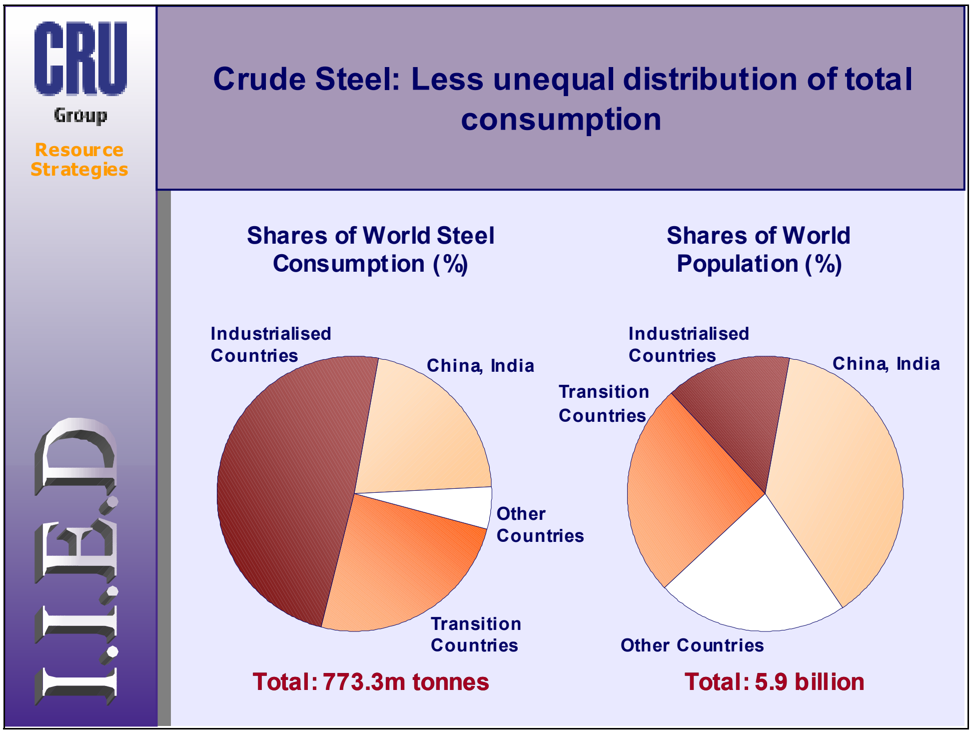
2. Consensus forecasts of demand

The steel industry comprises a mass of individual product and regional markets, rather than a homogeneous international commodity market, which is the case with the major non-ferrous metals. There is less need therefore for forecasts of overall consumption growth worldwide. Forecasts of markets for individual steel products (such as hot rolled coil or wirerod or stainless steel, for example) or for regional markets are much more useful to investors in the industry.

Nevertheless, CRU International forecasts crude steel production and finished steel consumption (which embraces all long and flat products, excluding stainless steel). Currently, CRU International forecasts a growth rate of 1.8% in crude steel production in the period 2000-2005. Crude steel demand is expected to grow at between 1.8% and 2.1% per year. The lower end of that range is considered to be the more likely outcome.

The implication is that steel demand is expected to continue to grow at a rate close to the trend seen in the past 20 years, despite the strong likelihood of a recession in the important US and European markets in 2001-2002.

3. The distribution of steel demand



Steel demand is unequally distributed between the industrialised and the developing countries of the world, but the degree of inequality is smaller than in the case of the non-ferrous metals. The reason is that steel is a very basic industrial raw material which is essential to even the earliest stages of economic development. Carbon steel products and implements will come into general use in a developing economy long before copper or aluminium (which are intrinsically much more expensive materials) are used to any significant degree. It is also quite normal and relatively easy for developing countries to create their own steel industries, producing at least basic products such as wirerod or structural bars and beams. The fact that such products do not then have to be imported provides a natural boost to local steel consumption.

The industrialised countries accounted for 49% of crude steel consumption in 1999, with only 15% of world population. The transition countries achieved almost exactly the same proportions by each measure: 24.7% of crude steel consumption and 25.2% of world population. China and India are major consumers of steel (China is the largest steel market in the world). Together they account for 21.5% of crude steel consumption and 37.8% of world population.

The rest of the world (principally Africa and the poorer Asian countries) has 22.4% of the total population and 5% of steel consumption.

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Steel consumption per capita is biased towards the industrialised countries

	% of World Population	Steel Consumption kg/head (1999)
Industrialised Countries		
USA	4.6	458.2
Canada	0.5	606.4
Western Europe	6.9	381.1
Japan	2.1	562.8
Australia	0.3	340.7
Average / Total	**14.6**	**438.4**
Transition Countries		
Korea	0.8	756.8
Taiwan	0.4	1,112.3
Other S.E. Asia	7.8	68.4
CIS	4.8	90.0
Turkey	1.1	188.8
Eastern Europe	1.8	193.5
Latin America	8.6	81.8
Average / Total	**25.2**	**128.4**
China and India	37.8	74.4
Others	22.4	29.3

Sources: United Nations, IISI

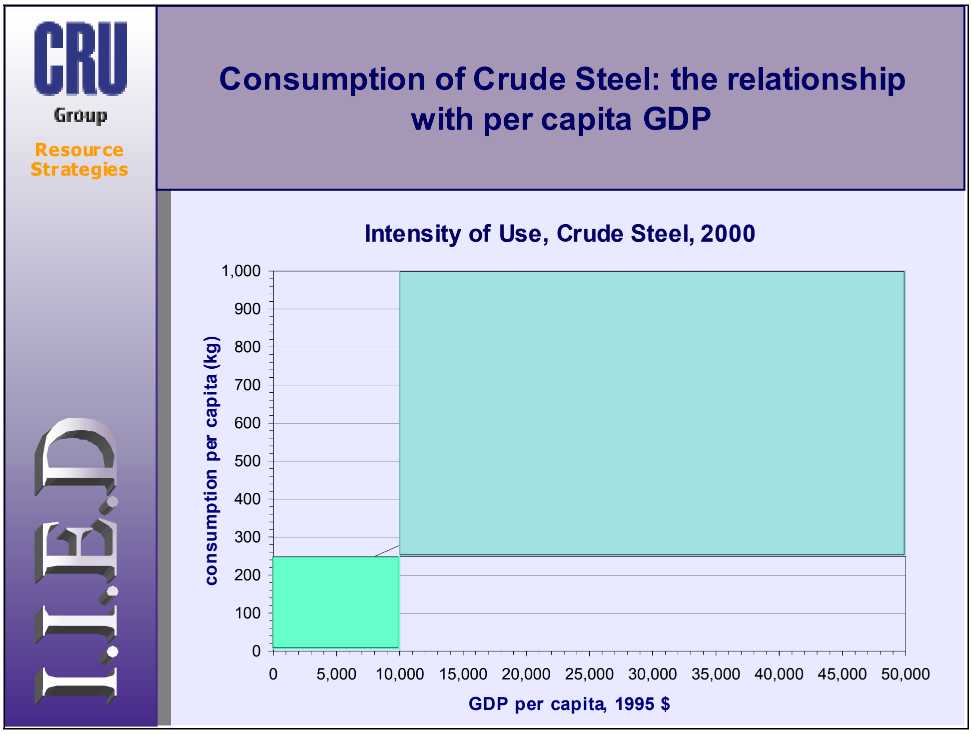
I.I.E.D

Steel consumption per head still displays a wide range of values between our categories of countries and even within the categories. Among industrialised countries, consumption ranges from 341 kg/head in Australia to 606 kg/head in Canada. Western Europe is surprisingly at the lower end of the range. One explanation for the high level of consumption in Canada would be that the country is physically very large, but has a small population. The quantity of infrastructure, in the form of roads, railways, ports, power transmission lines and so on (all of which require steel in some form), is high in proportion to the population. The more densely populated Western Europe has a lower ratio of infrastructure investment to population. The service industries also probably play a much greater part in the Western European economies than in that of Canada, which still has major natural resources and agricultural industries.

Australia's low consumption per head does not fit this hypothesis, but may be explained by the fact that huge parts of the country have no infrastructure or population at all.

Within the transition countries, South Korea and Taiwan again stand out as having economies that are extremely metal-intensive. As we have pointed out before, these two countries have followed a path of industrial development that has placed extremely high reliance on metal manufacturing and the export of manufactured goods. Their consumption of steel per head is far higher than that of even the most steel-intensive industrialised countries.

China and India have a rate of consumption per head that is quite close to that of many transition countries, when Taiwan and South Korea are excluded, which reflects the extensive steel industries and industrialisation of the more heavily populated regions of China and India.



We can see a familiar relationship between GDP per capita and steel consumption per capita. Most countries are clustered at the low end of the trend line, with GDP per capita of less than $10,000 and steel consumption of less than 200 kg per head.

With the exception of the outliers represented by Taiwan and South Korea, there is then a gap before we come to countries with GDP per capita of more than $20,000. Among these countries, there is a level of consumption that broadly rises in line with GDP.

This analysis simply supports the conclusion that steel consumption is intimately linked with overall economic development. It is notable that one cannot yet detect any obvious bell-shaped trend line which would develop if industrialised countries had reached the stage when steel consumption started to decline as very large proportions of their economies were accounted for by service activities, rather than manufacturing. So far, it appears that steel is an indispensable commodity required in very large quantities even in the richest countries of the world.

4. Drivers of demand and competition with alternative materials

Steel is by no means a homogeneous product. Steel is used in a wide variety of forms and alloys, each or which has a large range of end-uses. The main distinction in form is between flat rolled products (namely sheet, strip and coil, and tubes formed from coils) and long products (namely bars, beams, section, rails and wirerod).

Among the flat rolled products, steel can be used in hot or cold rolled form, and can also be coated in various ways to provide protection from corrosion. Zinc-coated or galvanised steel is the commonest form of coated steel, but plastic-coated and painted sheet is also used, and tinplate is widely used in packaging applications.

There are many grades and specifications of carbon steel, including different tempers, which are determined by the need for the steel to be formed. The major category of alloy sheet steel is stainless steel, which has a high nickel and chromium alloy content.

Long products can also be produced in a variety of specifications of carbon steel, principally for use in the construction sector. Alloy steels are also produced in bar form, for applications where very high strength, hardness or resistance to heat is required.

The steel industry is poorly served with statistics on the end-use breakdown of finished products. There are several obstacles to the production of these statistics. First, a large proportion of steel products are sold through service centres and distributors. In these cases, the mills do not know the final destination of the steel, and the service centres generally do not have any well-established system for assessing the final end-use. Secondly, most parts of the world simply do not have any regular system at all for attempting to produce an end-use breakdown.

The American Iron and Steel Institute does produce annual figures for the USA (shown in the chart below for flat rolled products in the year 2000). However, these do not break down the destination of the large proportion of sales made through service centres. There is no breakdown of the end-uses for products that go for further processing before reaching the final user; this category consists of coils that are used for making tubes, and also for forming and stamping. There is also a large unclassified category which represents shipments made by steel producers who refuse to disclose the end-use breakdown. The resulting picture is therefore very incomplete. In Europe, there is no annual survey at all. Occasional surveys have been commissioned by Eurostat, but with similarly incomplete results.

This data, though unsatisfactory, does tell us that transportation (in the widest sense, including cars, trucks, buses, farm equipment and railcars) and construction are the two largest end-use industries for flat rolled steel. Household goods such as kitchen equipment and furniture are also important, though many of these users will be supplied through service centres. Packaging (in the form of tinplate) is an important end-use in Europe and the USA. Beyond this, there are a huge number of diverse end-uses in the manufacture of all types of machinery and industrial equipment.

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Steel in the USA has a wide range of end-uses; and the available data is far from complete

End-use	Hot rolled sheet	Cold rolled sheet	Coated sheet	Total
Further processing	12.7%	13.3%	1.1%	**8.7%**
Service centres	30.2%	30.4%	22.2%	**27.4%**
Automotive industry	10.5%	14.3%	39.4%	**22.1%**
Construction	4.8%	3.5%	20.5%	**10.1%**
Electrical equipment	0.6%	6.8%	3.8%	**2.4%**
Export	1.8%	2.1%	3.8%	**2.6%**
Others and unclassified	39.4%	29.5%	12.3%	**26.7%**

I.I.E.D

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Estimated Breakdown of the Consumption of Hot-Rolled Steel in 1997

End-use	USA	EU	Japan	Total
Automotive	26%	15%	47%	**26%**
Construction	20%	10%	15%	**14%**
Appliances	5%	4%	3%	**4%**
Metal goods	17%	21%	8%	**17%**
Tubing	23%	33%	20%	**27%**
Containers	2%	3%	2%	**2%**
Other	8%	13%	5%	**10%**
Total (tonnes)	**24.2m**	**31.4m**	**15.3m**	**70.9m**

Source: CRU International

I.I.E.D

CRU International has attempted to improve on the published data on end-use breakdown for steel consumption. The chart above shows the estimated breakdown in the USA, the European Union and Japan for hot rolled coil consumption (excluding all material that is subsequently cold rolled or coated). All the hot rolled coil sold through service centres has been allocated to end-use sectors. This reveals some large differences between regions, notably in the proportion of hot rolled that is used in automotive construction and tubing.

According to this breakdown, tubing emerges as the largest end-use, but of course tubing itself is not an end-use sector; steel tubes are used in the automotive and construction sectors and also in the oil, gas and chemical industries.

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I.I.E.D

Estimated Breakdown of the Consumption of Hot and Cold Rolled Steel in 1997, USA, Europe and Japan

End-use	Hot Rolled	Cold Rolled	Total
Automotive	26%	33%	**28%**
Construction	14%	10%	**13%**
Appliances	4%	11%	**7%**
Metal goods	17%	22%	**19%**
Tubing	27%	7%	**19%**
Containers	2%	9%	**5%**
Other	10%	9%	**9%**
Total (tonnes)	**70.9m**	**42.5m**	**113.4m**

Source: CRU International

The chart above combines the CRU International estimates for the end-use sector breakdowns for hot and cold rolled steel, in the USA, the EU and Japan in 1997. The first lesson of this chart is that the applications for hot and cold rolled sheet are quite different. Cold rolled sheet is obviously thinner; it generally has a better surface finish, and it is more suitable for painting or coating with tin.

Thus, cold rolled is used increasingly in the automotive industry, especially where weight-savings are important; it is used in household appliances, where finish is important and weight is undesirable; it is used in beverage cans and other tinplate packaging products. On the other hand, there is less demand for cold rolled steel in tubing and in construction applications, where strength rather than surface quality is generally more important.

The two charts above thus illustrate the versatility of steel and the way in which different qualities and grades of steel can be selected for different applications. Note that these charts do not analyse the end-uses for galvanised steel or for long products.

Galvanised sheet is used principally in the construction industry, in roofs and siding. Hot dipped galvanised steel is mainly used in these markets. A host of other steel products such as road signs, railing and parapets are also protected against corrosion by hot dipped galvanising. The auto industry is a major user of electro-galvanised steel. This process deposits a thinner layer of zinc and provides a much better surface which is suitable for painting.

Steel long products are used very largely in the construction industry. Reinforcing bars are used to strengthen concrete; structural beams are used in the construction of office blocks, factories and more recently houses. Steel tubes are used in scaffolding and water pipes. Merchant bars are used in a broad range of mechanical and engineering applications.

Steel: the drivers of demand

- Macro-economic drivers: population growth, GDP growth, industrial production, stage of economic development
- Micro-economic drivers: exploitation of the characteristics of steel:
    - Weight/strength ratio
    - Formability
    - Ease of recycling
    - Versatility
- Price and performance in comparison with alternative materials
- Comparatively little market and market development

Steel is the cheapest and most versatile of all the industrial metals. Therefore it is the first choice for any industrial application where metal starts to replace timber or any other more primitive material. Thus steel enters into the economy of developing countries earlier than any other metal, and is almost always the first metal to be produced in a developing country.

Because steel has so many applications, the use of steel is very closely linked to the level and rate of growth in industrial production. This is the principal economic driver of steel consumption. Steel is used from the very beginning of the industrialisation process, but, as we have seen earlier, steel consumption continues to grow in line with GDP even when countries become relatively wealthy.

The inherent qualities of steel which determine its use are its strength, and the ease with which it can be formed or rolled into a wide variety of shapes and forms. The ability to protect steel against corrosion by coating with zinc or tin has also extended the applications for steel greatly. The metal can also be recycled very easily in the same production facilities that are used to produce steel from primary raw materials. The more complex steel alloys (such as stainless steel) are recycled within those alloy industries; carbon steels and coated steel are recycled in carbon steel facilities.

Price is an important driver of steel demand. At $300-400/tonne for hot coil, steel is considerably less expensive than non-ferrous metals such as copper or aluminium which can compete with it in some end-uses. The price of steel is also less volatile than that of non-ferrous metals, which is also helpful to users.

In general, steel is used when there is no need for a material with more advanced properties (such as electrical conductivity, resistance to extremes of heat or corrosion, or very light weight in relation to strength).

Because it is such a diverse and fragmented industry, the steel industry has a smaller and less effective system (in relation to the size of the industry) for cooperative promotion and market development than is found even in the non-ferrous industries. However, some more imaginative research work has been organised recently on a cooperative basis. Major steel producers also have technical support teams which work with customers on the selection and even the development of steel specifications for particular applications.

Because it has tended to be the first metal used in most of its applications, steel is generally on the defensive in the area of substitution. Thus steel was the only metal used apart from copper wiring and lead batteries in the construction of motor vehicles. The need to reduce the weight of automobiles has led to the introduction of aluminium in engine parts and increasingly in body parts, at the expense of cast iron and steel. The steel industry has started to fight back by demonstrating that cars can be built of steel and still achieve much of the weight saving associated with cars containing high proportions of aluminium.

The European and US steel industries have recently cooperated in a programme to produce the Ultra-Light Steel Automotive Body (ULSAB), a prototype car body using alloy steels and a novel construction technique to show how the use of steel can be combined with weight reduction in the car body. Further programmes are under way, designed to develop the same theme even further.

In the beverage packaging industry, tinplate was the first material to be used to make beer cans. Aluminium entered the market after World War II, and gradually made great inroads into this market, to the extent that tinplate was eliminated from this end-use in the USA and to a large extent in Europe. The was a marketing triumph for the aluminium industry, which sold the concept that aluminium is recyclable (which is equally true of tinplate) and that aluminium cans are lighter and more convenient to the user.

In the past decade, the tinplate industry in Europe has fought back very successfully, by developing better designs and safer opening systems, and exploiting the lower and more stable price of tinplate compared to aluminium sheet. The loss of market share to aluminium has been stopped and even to some extent reversed, so that aluminium canstock is no longer a strong growth market for the aluminium producers.

In the construction industry, galvanised steel has always been seen as the simplest and cheapest form of metallic roofing or siding, and tends to be replaced with better looking or more technically efficient products as incomes rise. However, the zinc industry is now promoting galvanised steel quite effectively on the basis of long life and low maintenance.

Structural steel competes with timber in the construction of residential housing. There has been a campaign to promote steel-framed houses, especially in the USA, but so far without any great success.

In engineering applications, the choice of materials is determined partly by tradition and familiarity, but also very much by production engineers who work on the selection of the most cost-effective and technically suitable material for components.

The winner in the constant process of competition and substitution between metals and non-metallic materials is the consumer, who receives the benefit of continual improvements in product performance and better value for money through more cost-effective use of materials.

5. The recycling of steel

The recycling of steel scrap plays a large and growing role in the production of steel. All carbon steel scrap is potentially recyclable, and the main production processes depend heavily on the availability of scrap as a raw material.

The traditional steel-making process consists of a blast furnace which produces molten iron which is fed to a basic oxygen converter where impurities are removed to produce crude steel. Scrap is added in large quantities to the converter in order to control the temperature and increase the output of steel.

In electric arc furnace (EAF) steel-making, scrap is the principal raw material and can be the only source of iron units. The alternative raw material is direct reduced iron (DRI), which is used in electric arc furnaces only when the steel-maker has its own source of DRI production. All other EAF steelmakers consume a charge that it composed principally or exclusively of scrap. In addition, foundries use about 45-50m tonnes of scrap per year.

EAF steel-making has been growing as a percentage of total steel-making capacity and production. In 1996 EAF production accounted for 40% of total Western world production of crude steel, and had been growing at 4% per year since 1983. The process is estimated to account for about 43% of total Western world steel production in 2000. The trend towards electric arc steel-making is expected to continue, as it has the advantages of lower capital costs and operating costs, compared to the blast furnace and basic oxygen converter route. The EAF process is also more environmentally acceptable. Initially the EAF route was used only to produce long products, but the introduction of thin slab casting has now made the EAF route popular as a means of producing flat products as well.

The volume of scrap used per tonne of steel production varies from region to region, according to the penetration of the EAF process and according to the availability of DRI (or its alternative, hot briquetted iron). Recent data shows that in North America 792 kg of scrap was consumed per tonne of steel produced; in Western Europe the figure was 554 kg per tonne of crude steel; in East and South East Asia it was 523kg, and in other Western countries it was 457 kg. In other words, well over half of the total raw material used in the production of crude steel in the Western world derives from scrap. Only in the Eastern bloc is the figure much lower, because EAF production has so far made little progress in Russia, China and other formerly Communist countries.

Total steel scrap consumed in the Western world was 307m tonnes in 1997 and is estimated to be approximately 340m tonnes in 2000. The consumption of scrap has been increasing at a rate of about 2.5% per year, which is slightly faster than the rate of growth in crude steel production itself. This indicates that scrap is providing an increasing proportion of the raw materials used in steel-making in the Western world.

Scrap is most intensively used where it is most plentiful. Transport costs constitute a major part of the delivered price, and the economics of EAF steel-making are considerably improved if the steelmaker has a good supply of local scrap. The largest sources of scrap tend to be major population centres and heavy manufacturing centres. Thus the developed economies tend to be the major generators of scrap, which is why the USA has been the country that has adopted EAF production most readily. Developing regions such as in South and East Asia tend to have smaller funds of obsolete scrap and therefore rely more on blast furnace production, or alternatively rely on imports of scrap for EAF steel production.

The use of steel scrap has become so intensive in the Western world that the region has come to depend on exports from the Eastern bloc of approximately 8-9m tonnes per year to make good the deficit in the West. East and South East Asia is the major deficit region and Taiwan and South Korea in particular are major importers.

Given the vital role of scrap in the steel-making industry, and the importance of trade in scrap to balance out local surpluses and deficits in scrap availability, governments should ensure that they do nothing which could hinder the free movement of scrap. In this regard, the provisions of the Basle Convention on the movement of hazardous waste need to be very carefully reviewed to ensure that they do not prevent steel scrap from being transported to the locations where it can best be used.

6. The pricing and trading of steel

Steel is not a homogeneous commodity. It is produced and traded in a huge variety of shapes, sizes and specifications. Steel is not therefore traded on any commodity exchange such as the London Metal Exchange, and it is virtually inconceivable that this could ever happen. Instead, steel product prices are settled by negotiation.

In principle, every steel company has a price list which covers all its products, with variations in price depending on details such as the finish or temper or packaging required. However, the market for most steel products is reasonably transparent, and general price trends are widely reported in the trade press. Therefore the producer does not have the power to impose prices unilaterally on the market, especially when there is any tendency towards over-supply, which is a common condition in the steel industry.

As a result, steel mills find it necessary to negotiate with their customers, who are generally either major manufacturers or service centres and stockholders. For products such as hot rolled coil or wirerod, which are available from many sources, it would be common to negotiate prices every quarter for that quarter's deliveries. Stockholders may also buy on a spot basis, particularly when they are importing material from a distant source such as the CIS.

Trading companies have a function in the marketing of steel. They normally act as intermediaries between producers and consumers who have difficulty in dealing directly with each other. The obstacles to direct dealings may be geographical (the two are far apart) or cultural (the two speak different languages or do not understand each other's trading practices); the obstacle may also be financial, in the sense that the producer wants rapid payment while the consumer wants late payment. In these cases, the trading company will often supply temporary finance and take the credit risk involved in selling to the final consumer.

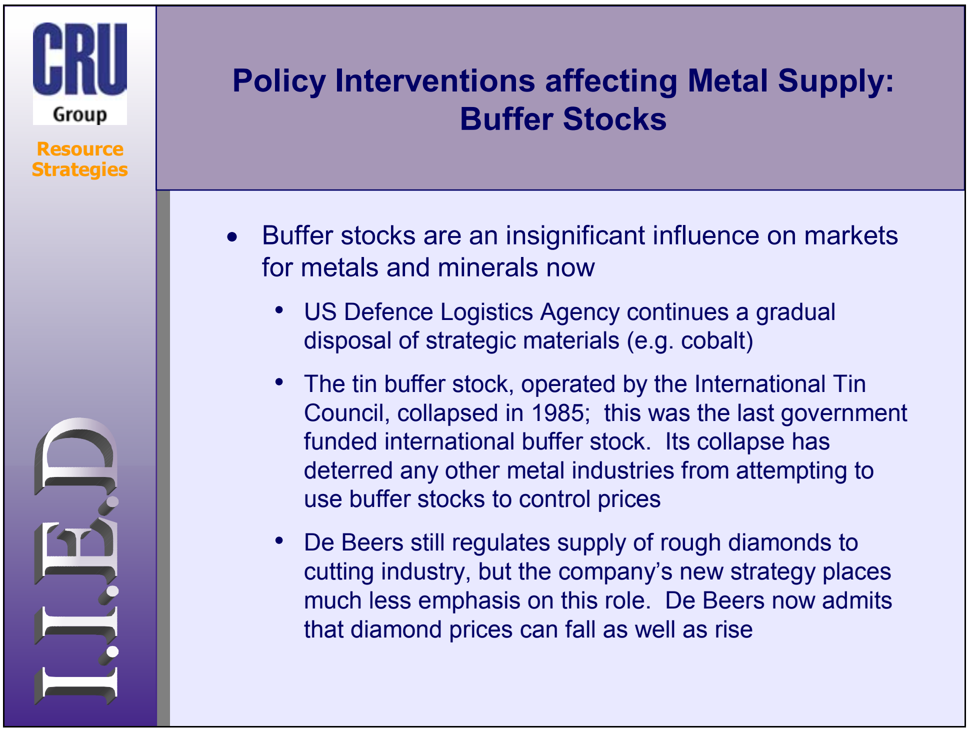
Major consumers such as car manufacturers or car component makers will normally have a longer term contractual relationship with their steel suppliers. Quality of product, just-in-time delivery and a sales support service are vital aspects of this type of business, in addition to price, and it may take some time for a producer to be accredited as a supplier to a car or component manufacturer. In these cases, a long term contract may well be signed by the purchaser, which could extend for the life of the car model for which the steel is required.

Raw materials such as iron ore and scrap, and intermediate products such as slabs or billets are also traded and priced through negotiation. Iron ore contracts, including tonnages and prices, are settled annually. Post-consumer scrap is normally sold on a spot basis, but new scrap will be returned to the steel supplier under a contract linked to the purchase of steel. Slabs and billets are normally also sold on annual contracts.

Chapter 8
The impact of policy interventions on metal markets

Introduction

This chapter discusses some ways in which government actions can affect the supply and demand for metals, and the potential consequences of these actions. Two principal types of intervention are considered: the first is the imposition of tariffs or duties in order to protect a national industry from foreign competition. The second is a change in legislation which has the effect of greatly enlarging or reducing the demand for a metal. The less important issue of stockpiles and their effect on metal supply is also briefly considered.



Buffer stocks have been created in some metal or mineral industries for various reasons, normally by government agencies and occasionally by private sector companies. The US government has maintained a stockpile of metals and minerals for some 50 years. It contains materials that do not naturally occur in the USA (or occur only in very small quantities), and that could be vital to the USA in the event of war. Thus the stockpile, which is managed by the Defense Logistics Agency, contained tin, cobalt, bauxite, manganese and industrial diamonds, among many other materials, when it was first set up.

The original concept was that the stockpile should contain sufficient quantities of each material to supply the country's vital strategic requirements for a period of three to six months. The concept is now out-dated, since the prospect of the USA being cut off from supplies of raw materials is quite remote. It is also clear that the types and qualities of metal supplies that are required change over time, and that material accumulated 40-50 years ago is likely to be unsuitable for use now. A stockpile of strategic metals makes little sense in the political context of the early 21st century.

The Defense Logistics Agency has therefore adopted a policy of gradual disposal of the contents of its stockpile. In most cases the volumes contained could be sold back to the market without any serious disruption. In a few cases, the volumes held were large enough to constitute an important source of additional supply. Tin was one example, but the holdings of tin have now been disposed of completely. Cobalt is another such metal. The DLA now conducts regular tenders of cobalt in order to dispose of its holdings in an orderly and transparent manner.

The tin buffer stock was created and managed by the International Tin Council, an agency whose members were the governments of most tin producing and consuming countries. The purpose of the buffer stock was to control fluctuations in the tin price in order to encourage the consumption of the metal and protect the revenues of producers in times of recession. The buffer stock manager used the funds subscribed by members to buy tin when it fell close to a pre-determined floor price and sell tin when it reached a pre-determined ceiling price. The floor and ceiling prices could be changed when appropriate.

The buffer stock failed on more than one occasion, and finally collapsed in 1985, when the buffer stock manager ran out of funds with which to buy tin at the set floor price. The situation was made much worse by the fact that the buffer stock was unable to meet substantial liabilities to broking firms on the London Metal Exchange. The survival of some of these firms was threatened as a result, and the survival of the London Metal Exchange itself was in question for a time. The fundamental mistake was that the floor price was set too high.

The collapse of the tin buffer stock marked the end of the concept of controlling international commodity markets through managed interventions. Market forces are always likely to overwhelm any attempt to fix a price for an internationally traded commodity at a level which does not bring supply and demand into balance. Some governments have learned the same lesson at considerable cost in attempts to fix foreign exchange rates.

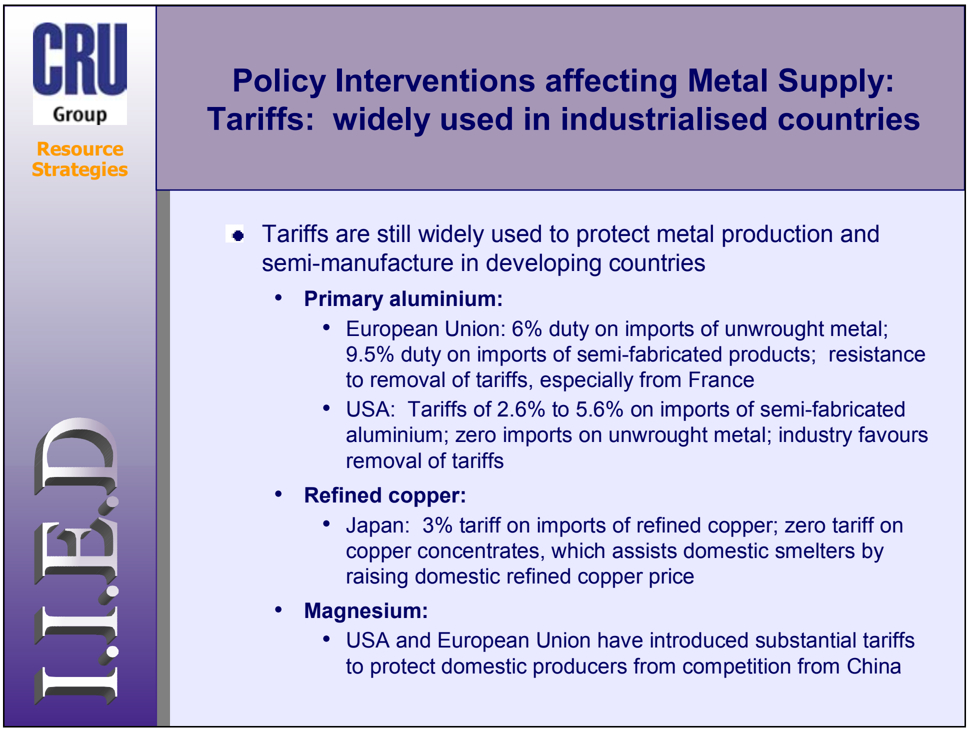
A final example of a buffer stock comes from the diamond industry. De Beers Consolidated Mines is a major producer of diamonds from its own mines, and has since the 1930s also bought in the production of many other diamond producers, in order to supply rough diamonds to the cutting industry worldwide. The purpose was to match the supply of rough diamond to the demand for polished diamonds in the jewellery industry, and thus prevent any decline in the price of diamonds during recessions. Such a decline was considered to be harmful to the image of diamonds in the eyes of the final purchaser of diamond jewellery. When supply exceeded demand De Beers accumulated and financed a stockpile of rough diamonds.

This stockpile was unusual, perhaps even unique, in that it was funded and managed by a company in the private sector. To be successful, the company needed to have the necessary finance to buy and hold large quantities of rough diamonds. It also had to produce or buy the great majority of the world's rough diamond production. At its peak, De Beers claimed to control about 85% of the annual production of rough diamonds.

This buffer stock has also been abandoned, mainly because new producers of rough diamonds in the 1980s and 1990s did not choose to sell all their output to De Beers and instead marketed some or all of their production direct to the cutting industry. As De Beers' control of diamond supply slipped down to around 60%, its ability to control diamond prices declined. Fluctuations in the price of rough diamonds became a regular feature of the market, and the purpose of the buffer stock was undermined. The finance tied up in the De Beers stockpile came to be seen as capital that was been used unproductively, and the strategy of the company was consequently changed.

De Beers still has agreements to buy production from other mining companies, and sells this output together with its own, but it no longer aims to control the whole rough diamond market. It now regards changes in production levels as the better way in which to match supply with demand.

The cases of tin and diamonds, though very different in detail, illustrate the same basic truth that attempts to control the price of metals or minerals, independently of changes to supply or demand, are doomed to failure ultimately. Price is only a symptom or indicator of the balance between supply and demand. It is impossible, and therefore pointless, to attempt to control the symptom without acting on the underlying fundamental factors.



Tariffs are a widely used mechanism to raise the price of imports and thus protect domestic producers of the material. Some tariffs affecting metals or metal products have been in place for many years; others have been recently introduced in response to specific complaints or crises.

The European Union, for example, has for many years imposed a 6% ad valorem duty on imports of primary unwrought aluminium. This was originally imposed when it was thought vital to ensure the survival and viability of an aluminium smelting industry within the EU. A higher tariff of 9.5% applies to imports of most semi-fabricated aluminium products. There are various exemptions from the 6% duty; the main ones are in favour of some developing countries such as Ghana and Egypt, which are permitted to export aluminium to the EU free of duty.

The USA imposes small tariffs on semi-fabricated aluminium but none on primary metal. In the magnesium industry, producers in Europe and in North America have argued successfully for similar tariffs on primary magnesium, in order to protect their industries from competition from cheap imports from China.

In the copper industry the Japanese smelters have for many years imposed a controversial tariff on the imports of refined copper. The country is a major importer of copper concentrates, so the tariff, which raises the domestic price of copper, acts as a hidden subsidy to the Japanese smelting and refining industry. This has permitted Japanese copper smelters to offer very competitive treatment and refining charges to their suppliers of copper concentrates (although is should be said that the Japanese smelting companies strongly dispute this interpretation of the effect of the tariff). The level of the tariff has recently been reduced.

The impact of all such tariffs is to distort the pricing structure and the normal forces of competition in the relevant industry. This general effect is discussed later in the chapter.

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Policy Interventions affecting Metal Supply: Tariffs are also widely used to protect industry in developing economies

- India: Massive tariff protection for domestic base metal producers:

Imports:	Basic Duty	Countervailing Duty	Add. Duty	Total
Aluminium	25%	16%	4%	50.8%
Refined copper	35%	16%	4%	62.9%
Copper wirerod	35%	16%	4%	62.9%
Lead	35%	16%	4%	62.9%
Zinc	35%	16%	4%	62.9%

- Consequences:
  - Preservation of inefficient, high cost metal producers in India
  - Very high domestic metal prices deter downstream processing and therefore the consumption of metals

I.I.E.D

Tariffs on metal imports are not confined to industrialised countries who fear competition from cheaper producers in the developing world. India pursued a policy of self-sufficiency and economic isolation until recently. Many consequences of this policy still live on. One such consequence is a very high level of tariffs and duties on imports of non-ferrous metals. These range from 51 to 63%, as shown above.

The result of this policy was to raise the domestic price of these metals within India to such an extent that it discouraged their use and prevented the export of any goods in which metals were a large component. The Indian metal producing industries became very high cost and inefficient, under the influence of this protection, because they did not have to compete with suppliers elsewhere in the world. And because the producers were high cost, they failed to attract investment in new projects.

India provides an extreme example of the damaging effect of tariffs: they have damaged consumers of metals by raising the prices of metal, and they have failed to assist the production of metals, because existing producers regarded tariff protection as a natural right which permitted them to operate high cost mines and plants without attempting to reduce costs or improve efficiencies.

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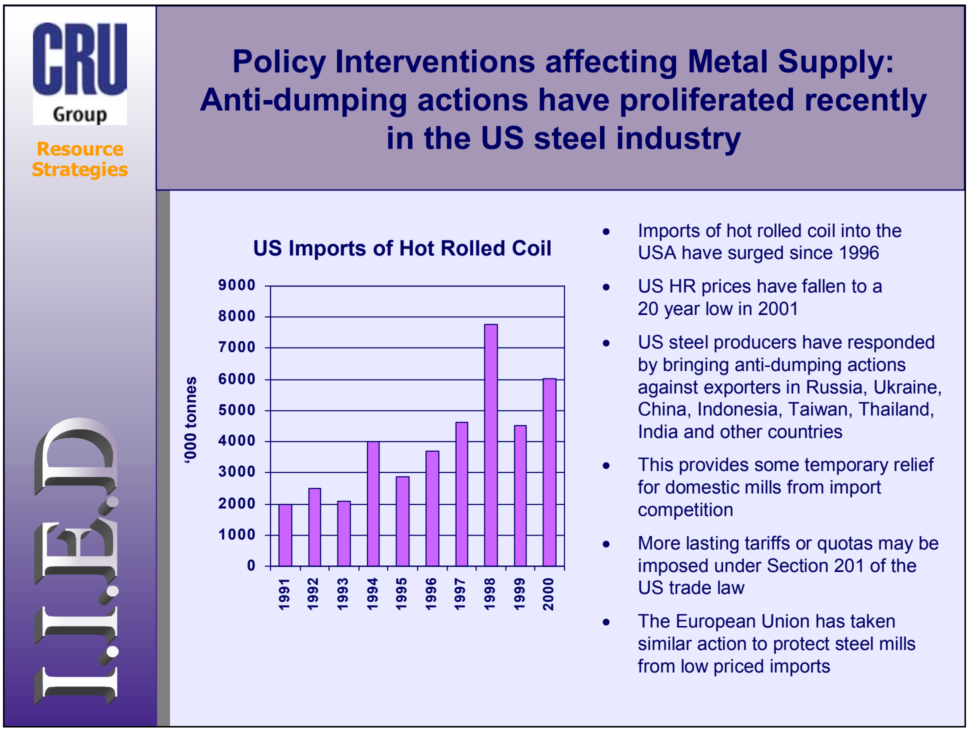
Policy Interventions affecting Metal Supply: Tariff policy can also be used to protect a developing region, rather than a single country

- Mercosur:
  - Free trade within Brazil, Argentina and Uruguay, but common external tariffs averaging 14% and ranging from 0 to 23%
- ASEAN Free Trade Association:
  - 97.8% of intra-ASEAN trade by value were subject to 5% tariffs at maximum by by 2000
  - Base metals (among the last 2.2% of trade) will have maximum internal tariffs of 5% by 2003
  - External tariffs remain in place
- Objectives are to foster competition within the regions, but protect producers against external competition
- Consequences have been high internal metal prices in Mercosur; less damaging results in ASEAN where high economic growth rates have been little affected by tariffs

I.I.E.D

There are many examples of tariffs being used to protect an entire region, rather than a single country. We have already seen an example in the EU tariffs on aluminium imports. In the developing economies, economic groupings such as Mercosur and ASEAN use tariffs for the same purpose of promoting internal production by discouraging imports. They can claim that they are encouraging competition within their regions, but nevertheless by distorting prices they distort the normal economic responses to price, both in the production and the consumption of the protected products.



The steel industry has seen a proliferation of anti-dumping actions in the last two years, mainly in the USA and in Europe, as producers in those regions seek protection from cheap imports from the CIS and from developing economies. Over-production is the source of the problem. This leads producers to seek new export markets and to price their products low enough to penetrate those new markets, which are typically the major consuming regions of Europe and the USA.

In the case of steel, the higher cost producers are located in Europe and the USA. Their response is to bring actions against the importers, claiming that imports are damaging their industry and even threatening their survival. The threat is that domestic producers may be driven out of business by a temporary surge of cheap imports, and that consumers will then suffer in the next upturn because they will have lost their local suppliers.

Anti-dumping duties have been imposed in Europe and the USA on a range of steel products from developing countries during the downturn in the steel market in 2000-2001, and further trade protection could now be imminent under Section 201 of the US trade law. However, these actions, undertaken at great expense of time and money, have not saved the US steel industry from serious financial trouble, nor have they raised steel prices to a level which European or US steel companies find tolerable.

Imports of hot rolled coil (and of other steel products) into the USA have fallen from their peak in 1998, but they remain high by earlier standards. The short term protectionist policy is clearly failing, and governments must address the longer term issue of where their best economic interests lie: whether in preserving uncompetitive industries or in taking advantage of low cost supplies from whatever sources they may be available.

Policy Interventions affecting Metal Supply: Magnesium provides another example of protection via tariffs and duties

- Magcorp, the only USA producer of magnesium metal, has pursued anti-dumping cases against:
  - Norsk Hydro (Canada); anti-dumping duties of 31.33% were set in 1992, but reduced to zero in 1996; countervailing duties were reduced from 21.6% in 1992 to 1.2% in 1999
  - China and Russia: anti-dumping duties were set at 108.3%against all Chinese producers in 1994, and 100.25% against some Russian producers
  - Anti-dumping cases brought in 2000 for a wider range of products. No final decision yet.
- The European Union has one magnesium metal producer, Pechiney:
  - An EU anti-dumping duty of 31.8% was imposed in 1998 on imports from China, and was raised to 63.4% in 2000
- Despite these measures, Magcorp is bankrupt, Pechiney has ceased production and prices in the USA and Europe remain at very depressed levels

The magnesium industry provides yet another example of the unsuccessful application of tariff protection. The one producer of primary magnesium in the USA, Magcorp, has obtained anti-dumping duties against the Canadian producer and against Chinese and Russian producers. Very substantial anti-dumping duties were imposed on the producers from the latter two countries, and further cases against a wider range of magnesium products from China, Russia and Israel were brought in 2000.

In the EU, where there was only one primary magnesium producer, Pechiney, an anti-dumping duty was imposed in 1998 and raised in 2000.

Despite these protective measures, Magcorp has gone into bankruptcy proceedings and Pechiney has ceased to produce magnesium. Competition from China has been so great that it has reduced the international price of magnesium to a level where neither of these two producers could survive. The question that arises is whether it is better to try to protect the small number of jobs involved in the production of magnesium, in this case, in the EU and the USA, or whether it is better to allow consumers to take advantage of cheap supplies from elsewhere in the world.

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Anti-dumping attacks the symptom and not the cause of metal surpluses

- **High fixed costs and complex production processes make metal production slow to respond to changing market conditions**
- **Surplus production can therefore easily arise, and tends to be sold at low prices in export markets**
- **Anti-dumping (AD) rulings are intended to give temporary relief against imports sold at less than production cost or market price in their countries of origin**
- **AD actions are often aimed at producers suspected of receiving subsidies, or not operating in market economies (e.g. CIS)**
- **AD actions are a crude implement because:**
  - They are driven by political motives (e.g. employment, security of supply)
  - They are often based on imperfect data about exporters
  - They only shift the surplus to another, unprotected export market
  - They conflict with the interests of consumers
  - They delay re-structuring in industries with structural over-capacity (e.g. steel)

I.I.E.D

Tariff protection and anti-dumping measures appear to be a very ineffective response to low prices which arise from surplus production. Their weakness is that they attack one symptom of such surpluses (i.e. low prices in one country or region) and do not attack the cause of the surplus (i.e. over-production).

The metal industries tend to have high fixed costs and long, complex production chains. Producers therefore tend to respond slowly to the market signals given by falling demand and low prices. They are reluctant to reduce production when they cannot sell in their accustomed market, and instead often try to export their surplus production at low prices.

Producers in the countries that receive these low priced imports can bring anti-dumping actions on the grounds that the sellers are pricing their exports at below their cost of production, or below the prices that rule in their home markets. However, such actions give at best temporary relief, because the surpluses are simply shifted to another market and still depress the overall level of prices.

There is often a political motive behind the request for protection: producers will often complain that competition is unfair because their competitors receive subsidies, or are not required to meet the same environmental standards; they will also appeal to the desire of politicians to preserve employment or ensure security of supply from a domestic source.

Government agencies charged with determining these issues often have incomplete data and knowledge about the exporters, particularly if the exports come from developing countries which are not well skilled in presenting their case in US or European trade actions. Most seriously of all, tariffs and duties penalise the consumers of the protected materials and thus damage the economies of the importing countries by raising costs.

The overall impact of tariffs and duties is thus to distort the normal dynamics of competition, raise prices in the importing countries or regions, and protect high cost producers. The only long term solution to over-supply is a reduction in output and, if necessary, a reduction in capacity. Tariffs and duties delay or prevent these steps from being taken.

It can also be observed that it takes much longer to remove a tariff than to impose it, so they tend to linger on, long after even partial justification could have been claimed (as in the case of the EU tariff on imports of primary aluminium). The implication is that governments should resist the short term blandishments of tariff protection in favour of the sterner longer term process of restructuring industries that suffer from structural over-supply.

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Resource Strategies

Policy Interventions affecting Metal Demand: Catalytic Converters on Car Exhausts

- In all developed countries tight restrictions have been placed upon emissions from car exhausts
- These standards require the use of converters using catalysts based on platinum group metals
- Autocatalyst demand (net of recycling) for platinum rose to 35% of total demand in 1994.
- Price then caused palladium to be substituted for platinum. Autocatalyst demand rose to 61% of total demand for palladium in 1999, and fell to 21% of platinum demand (net of recycling)
- Tetraethyl lead additives to petrol improve the performance of petrol engines but poison pgm catalysts. Therefore lead in petrol has been eliminated in almost all countries and accounts for only 0.6% of total lead consumption (v.11% in 1970)

I.I.E.D

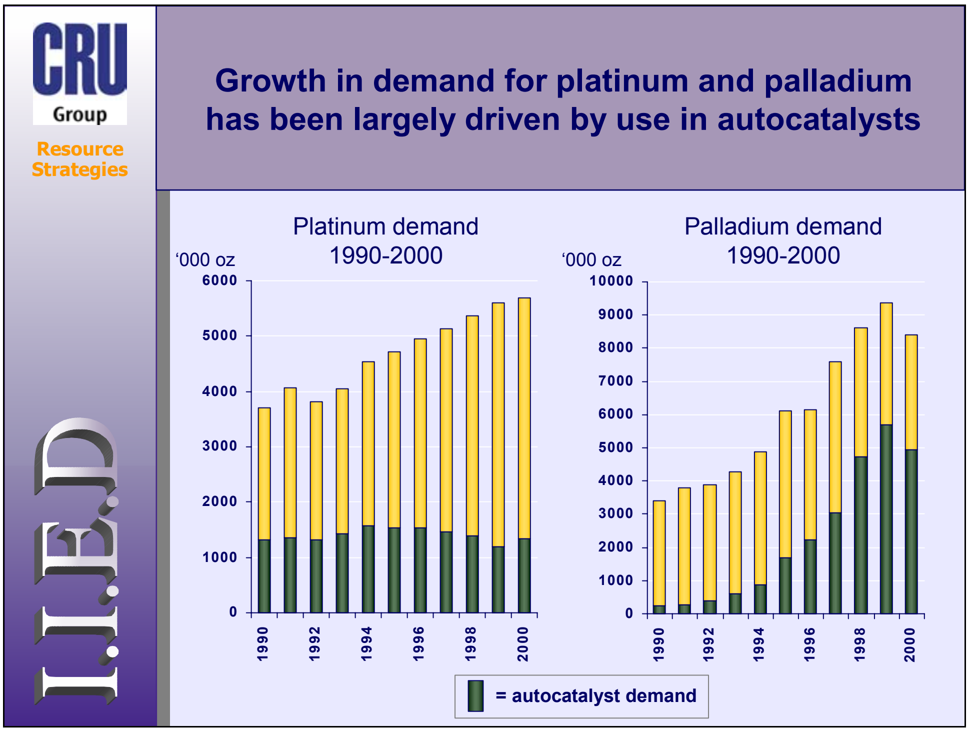
A different type of government intervention in metal industries can be found in legislation, often driven by environmental concerns, that results in the banning of some substances or the creation of a sudden increase in demand for others. An example can be found in the car industry, where many governments in developed countries have introduced legislation that places severe limits on the polluting elements contained in exhaust gases.

The best way to clean car emissions is to install catalytic converters on the exhaust systems. These converters contain small but significant quantities of platinum group metals. Initially platinum was the metal used but now increasingly palladium is preferred.

The legislation has had two important effects on the demand for metals. First, a major new market has been created for platinum and palladium (see the following slide). Secondly, the lead industry has lost the market for tetraethyl lead. This substance was previously added to petrol to assist the smooth running of internal combustion engines. However, the lead particles emitted in exhaust gases poison the platinum or palladium catalysts and quickly prevent them from functioning. The particles can also cause a dangerous accumulation of lead in the air and soil alongside busy roads.

In 1970, tetraethyl lead accounted for the consumption of 320,000 tonnes of lead per year in the countries where end-use statistics are available. In 1999, the same end-use accounted for only 27,600 tonnes.

The opposite effect has been seen in the platinum group metals industry, where catalysts accounted for 35% of platinum demand in 1994, when this application for platinum reached its peak. The price of platinum was also driven up, which caused the producers of catalysts to switch to palladium. Catalysts now account for 61% of total demand for palladium.



The importance of the demand for catalysts to the platinum and palladium markets is illustrated above. Substitution away from platinum started around 1994. In 1993 the platinum price averaged $376/oz, while the price of palladium averaged only $122/oz. In January 1999, platinum stood at $354/oz and palladium at $322/oz.

Russia is the second largest producer of platinum, after South Africa, and by far the largest producer of palladium in the world. Exports of both metals were severely disrupted in 1999-2000 as a result of confusions and failures of the Russian budgetary process, and in the granting of export licences. Both metals, but particularly palladium, surged in price as a result of the growing demand for catalysts and the unexpected interruption in Russian exports. The palladium price reached a peak of $1,094/oz in January 2001, and platinum rose to $645/oz at the same time. Supply has since increased and consumers have chosen to delay purchases and use up stocks, with the result that the palladium price fell to $360/oz by the end of September 2001, and the platinum price to $429/oz.

Nevertheless, over the past decade, the production of platinum and palladium has increased to meet the demand created by this end use.

CRU Group
Resource Strategies
I.I.E.D

Lessons of the autocatalyst example

- Government regulations can lead to requirements for major developments in technology, followed by major changes in the demand for metals
- The platinum and palladium industry was able to respond to both challenges: product development and investment in new supply
- In the platinum industry there has been close cooperation between producers (principally in South Africa) and fabricators of the metal
- In palladium, the major supplier is Russia, from stock and from mine production. Despite uncertainties, demand has been met
- Prices have been very volatile but demand and supply have both responded in classical style to price signals
- Recycling now supplies 25% of gross platinum needs for autocatalysts and 4.5% of gross palladium requirements for autocatalysts

The autocatalyst example illustrates well several aspects of the ability of the metals industries to respond to policy interventions from governments concerned to improve environmental standards. First, research work carried out mainly by refineries of platinum, demonstrated that platinum group metals (previously used very largely for electrical and jewellery applications) provided the best means of cleaning exhaust emissions through catalysts.

Secondly, the producers were able to respond to the increase in demand by investing on additional mining and processing facilities, despite the fact that the major producers are located in Russia and South Africa, neither of which was a favoured location for investment in the 1970s and 1980s, when the catalyst application was being developed. The development of autocatalysts required close cooperation between the suppliers of the metal (particularly the South African producers) and the manufacturers of catalysts.

The two metals have seen extreme volatility in prices, first because of growing demand and more recently because of the difficulties in obtaining supplies from Russia. However, movements in price have been a valuable signal of the underlying state of the markets, which has prompted producers and consumers to respond in a logical fashion, by increasing supply and reducing stocks when prices have been rising, and by switching from the more expensive to the less expensive material.

Finally, the inherent value of the platinum group metal content in autocatalysts has created a recycling industry. Catalysts are removed from cars that reach the end of their lives and the metal is recovered. Because platinum was the metal first used in this application, the majority of cars now being scrapped have platinum catalysts. Recycling now accounts for 25% of the gross platinum requirements to autocatalysts. Because palladium has been in wide use for less time, recycling provides only 4.5% of the palladium requirements for catalysts, but that figure is growing.

In addition, lead pollution has been removed from exhaust gases, in addition to the other pollutants which the platinum group catalysts remove. Thus, the metals industries have contributed to an improvement in living standards in all countries where legislation controls the emissions from car exhausts.

Chapter 9
Metal market forecasting

The accuracy of forecasts of metal markets and metal prices is a subject of constant debate within the metal industries. It is immediately obvious that no forecasts can be completely accurate, or even accurate to within a small margin of error, or accurate over a long period of time. Anyone who could forecast metal prices to this degree of accuracy would not sell or publicise the results. Nevertheless, it is worth considering the role of forecasting in the metal industries, and asking whether forecasts are necessary. If they are, do they tend to assist the process of rational investment, or do they contribute to the tendency towards over-capacity which has consistently beset the metal industries for several decades?

The large number of commercial bodies that produce forecasts of metal prices testifies to the demand for forecasts. Some are sold and some are distributed nominally free of charge as part of a package of services, but even in the latter case the recipient is paying for the forecasts indirectly.

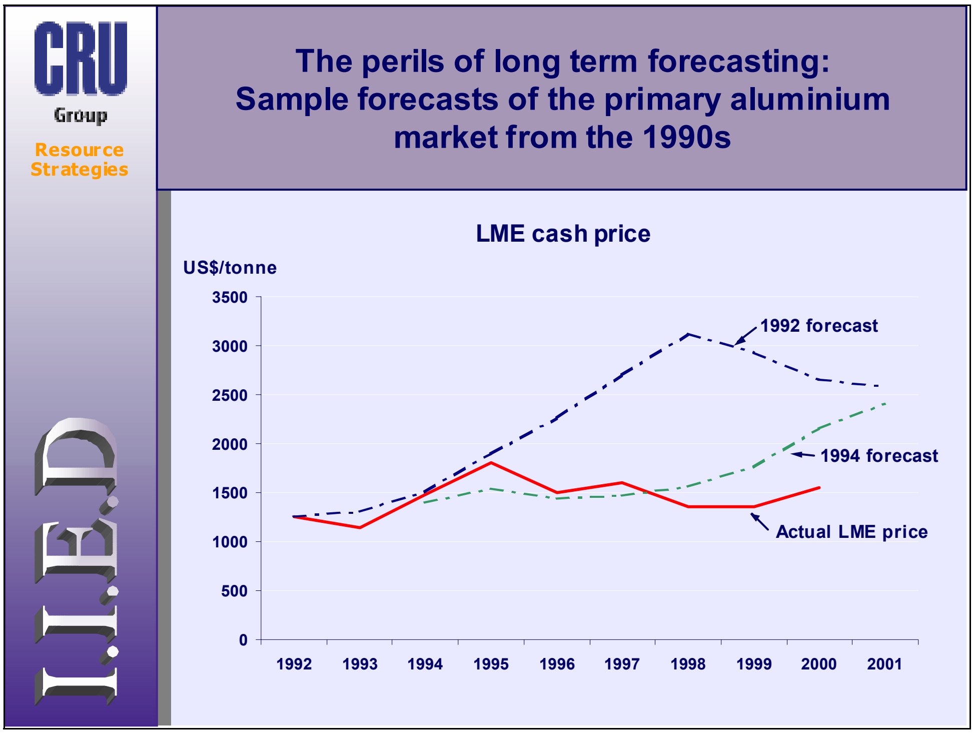
Short term forecasts (which typically range from one week to six months into the future) are required essentially for trading or speculative reasons. Investors may want them in order to assist decisions on whether to buy or sell the shares of metal producing companies. Buyers or sellers of metals may require them in order to decide when to time their transactions, or whether to hedge in order to offset their exposure to price risk. These are all examples of participants in the metals industries whose natural activities involve some degree of exposure to metal price risk. It is natural that they should seek opinions on the likely trend in metal prices. Forecasts are just one of many inputs into the commercial decisions which they take, and the risk that the forecasts may be wrong is considered acceptable

Metal price forecasts over periods of 12 to 24 months are required, for example, by producers and consumers of metals for budgeting revenues or costs, and for forecasting cash flow and working capital requirements. Again, the risk of error is known, but for planning purposes, the best available opinions on future trends are required. Many other important inputs into business plans and budgets are also subject to uncertainty, but this does not prevent companies from making the best assumptions that they can.

Long term decisions in the metal industries typically relate to levels of production and to investments in new equipment, or decisions to expand capacity, build new capacity or close existing capacity. Metal prices are among the most important determinants of revenues for metal producers, so it is natural and prudent for them to obtain the best forecasts available before committing themselves to decisions whose success will depend largely on the price of the metals produced.

This tells us that operators in the metal industries need price forecasts precisely because metal prices are unknown and because metal prices are a source of considerable risk. Short and long term business decisions inevitably require constant exposure to risk, and it is prudent when making these decisions to obtain the best view available.

Do price forecasts help or hinder the process of rational investment? The answer depends on the quality of the forecasts and the degree of reliance that is put upon them. The following section therefore reviews some past price forecasts, in order to illustrate the typical sources of error, and the way in which this can be mitigated.



The chart above illustrates two ten year forecasts of the LME cash aluminium price, made by CRU International Limited in 1992 and 1994 respectively, together with the actual development of the price. Forecasts made at this time have been chosen because they allow us to compare 9-10 year forecasts with the subsequent reality.

1989-1992 was a period of economic downturn in the Western world, and therefore of weak metal prices; it was also a period of great political change. The former USSR had abandoned its control of Eastern Europe in 1989 and then broke up into the 17 constituent republics that had made up the Soviet Union. The economies of the former USSR and of Eastern Europe moved into sharp decline when the central planning system collapsed. One consequence was a major surge in exports of aluminium and other primary metals produced in the former USSR, which were previously consumed within that territory but which were now available for sale in external markets. At this time there was still a poor understanding of the quantities of metal produced by the former USSR, and no clear information on whether these industries could sustain production after the collapse of the Communist system, or how much metal would continue to be consumed within the former USSR.

In practice, the consumption of aluminium in the former USSR fell to 10-15% of its level in the 1980s, and there was a huge increase in the exports of aluminium to Western markets. At the same time, there was a general recovery in Western economies, starting in 1993-94.

Against this background, we can see that the 1992 price forecast was reasonably accurate for the first three years but much too high thereafter. The 1994 forecast was much more subdued, and even too low for the first three years, but clearly too high for the latter part of the period.

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Five year copper forecasts: analysis of the errors

Forecast errors (annual averages, forecast data compared with actual data):

	1990	1995
W. World production	1.9%	1.7%
W. World consumption	- 2.0%	- 4.0%
Net E. Bloc imports	-257,000 t	-306,000 t
LME cash price	9.4%	16.2%

- Small movements in the world balance can have large impacts on the LME price
- Forecasting models link production, consumption, stocks and price, so an error in one leads to an error in another
- The greatest source of error was again in the balance of East/West trade, for which previous history provided no guidance

I.I.E.D

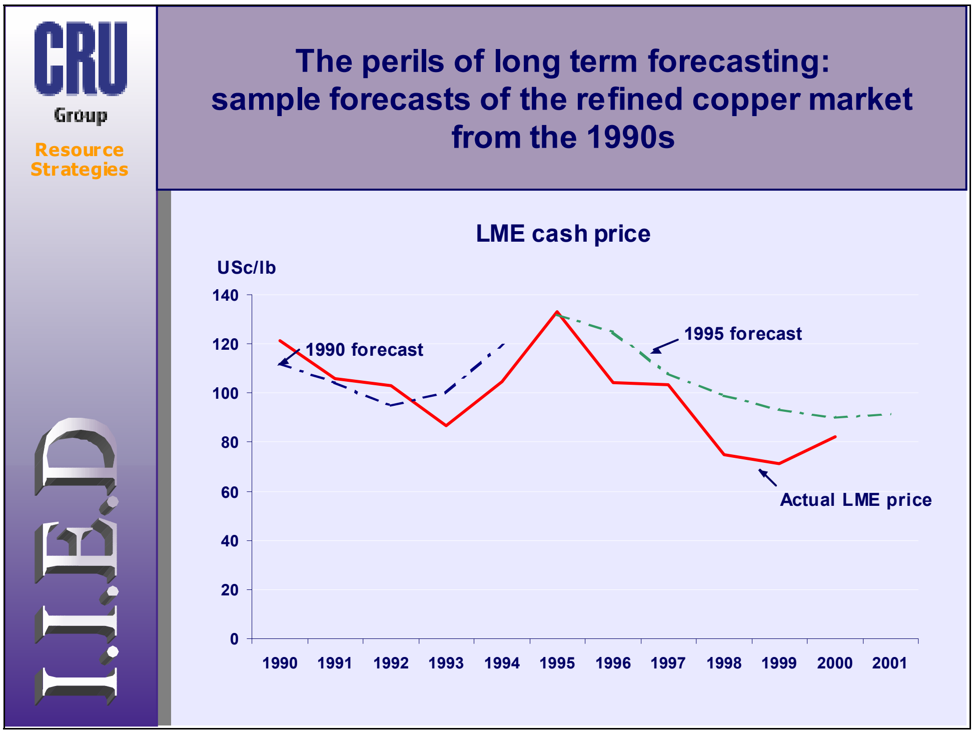
An analysis of the sources of errors in the two aluminium price forecasts shows how easy it is to misread the longer term trends. In 1992, when the Western economies were still at the early stages of recovery, the speed and extent of the upturn in consumption of aluminium was under-estimated. On average, the consumption forecasts throughout the 10 year period were 4.3% too low.

However, the major source of error was a failure to foresee how Russian exports of aluminium would grow. Forecast net exports from the Eastern bloc were 1.64m tonnes per year too low. To some extent, this mistake was offset by a Western world production figure that was too high, by 5.9% per year on average. In reality some Western capacity remained closed for a long period, and was substituted by exports from Russia.

The resulting forecast LME price was on average 51% too high throughout the period, although in the first three years the forecast was within 10% of the actual figure.

In 1994, the strength of consumption growth was again under-estimated, this time by 5.9% per year. The principal failure was in forecasting the speed of economic recovery in Western markets. The estimate of Russian exports was closer to the truth but still too low by 730,000 tonnes per year on average. Production was also under-estimated, though this would have been a natural consequence of under-estimating demand. The price forecast, however, differed from the actual by only 17% on average throughout the forecast period.

This brief analysis shows that the failure to forecast accurately one major input into a price forecasting model (e.g. the major driver of consumption, or the volume of exports from the Eastern bloc) can throw out the whole forecast. The impact of errors is likely to compound in the later part of the forecast period. The analysis also highlights the fact that the greatest source of errors is likely to consist of events which arrive without precedent and with little warning, at least as to timing and extent.



The chart above shows two copper price forecasts made by CRU International of the LME copper price, one for five years starting from 1990 and another for ten years starting from 1995. Both happen to have been closer to reality than the aluminium forecasts shown previously. The 1990 forecast, made during a period of recession, also came close to identifying the turning point in the copper price cycle in 1993. The 1995 forecast identified the trend in prices correctly but was too high throughout the forecast period.

The copper market was less disturbed by exports from the former USSR during the 1990s than was the aluminium market, but copper exports nevertheless did increase, and were very hard to foresee with accuracy.

CRU Group
Resource Strategies

Five year copper forecasts: analysis of the errors

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- The greatest source of error was again in the balance of East/West trade, for which previous history provided no guidance

I.I.E.D

The 1990 forecast consistently under-estimated consumption of copper by 2% on average. Production forecasts diverged from the actual by 1.9% on average, but were sometimes above and sometimes below the actual figures. Net imports from the Eastern bloc were under-estimated throughout and were 257,000 tonnes per year too low on average. The resulting forecast of the LME price, however, was only 9.4% different from the actual, on average.

The 1995 forecast under-estimated consumption consistently by 4% on average, as a result of a too conservative overall economic outlook. Production was again over-estimated but sometimes above and sometimes below the actual figure. The estimate of East bloc exports was worse than it had been in 1990, indicating that an economic recovery was expected in the CIS which did not occur. The price forecast was 16% too high on average throughout the forecast period.

These forecasts show the sensitivity of price forecasts to small changes or errors in the components that make up the world balance in the copper market. The same is true of other metal markets, where the world price is the marginal price required to bring overall supply and demand into balance.

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Forecasting metal markets: Summary

- Forecasts beyond 1-3 years are prone to very substantial errors
- Errors in forecasts of economic growth rates are probably the fundamental cause of most errors in price forecasts
- Small errors in the components of a metal balance can cumulate into a major error in the balance and therefore in the price forecast
- Unprecedented events (e.g. the collapse of the Communist system, and its consequences) are almost impossible to forecast
- Despite these difficulties, price forecasts play a vital role in investment decisions, and therefore influence future supply and prices

This brief analysis of some sample forecasts from a professional forecasting company demonstrate the difficulty of making forecasts, especially for periods beyond 3 years into the future. It should be noted that major investment decisions specifically require forecasts for periods beyond three years in the future, since new production arising from these investments will normally become available only after three years, and often even later.

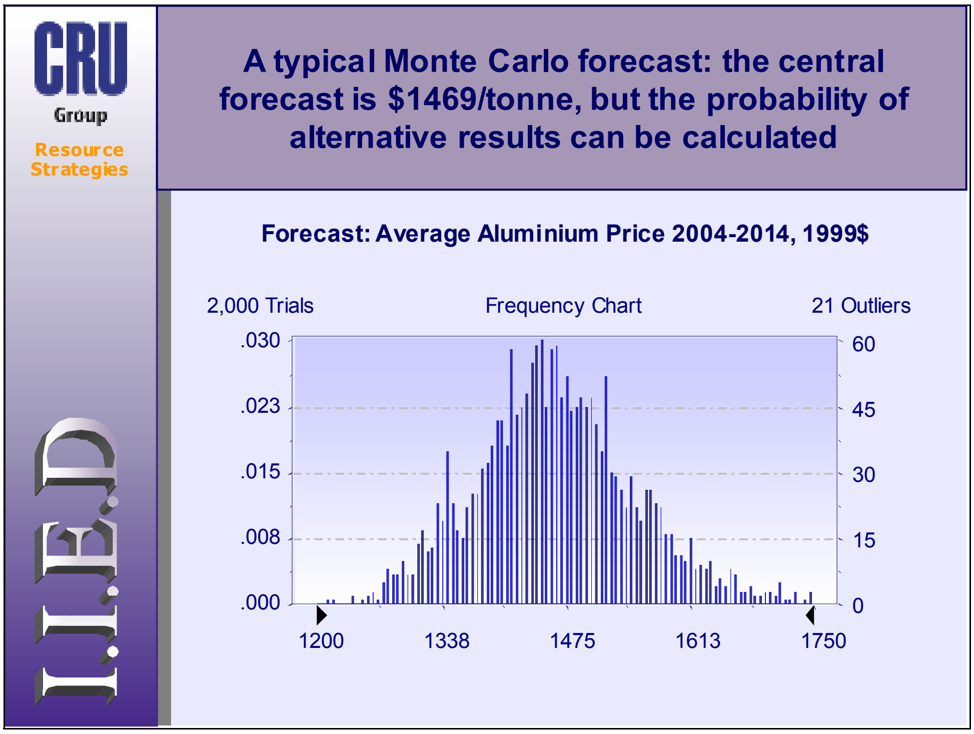
The major source of errors in price forecasts is probably a mis-reading of the rate of growth or the turning points in the economies of the major consuming countries. The second major source of error is unprecedented events such as the collapse of the former USSR, which are virtually impossible to forecast. The terrorist attacks in the USA on September 11, 2001, would fall into the same category.

Thirdly, any forecasting model will consist of a number of inter-linked variables which generate the components of a metal supply balance. Small errors in the components of the balance can cumulate into a larger error in the overall balance. Price is very sensitive to small differences between two large numbers (i.e. total supply and total demand).

Finally, there is a natural tendency among forecasters to be heavily influenced by the conditions prevailing at the time when the forecast is made. This can result in a reluctance to make forecasts that diverge greatly from the recent trend or the starting point of the forecast. Financial companies are prone to the same error, and are more enthusiastic to finance investments in metal projects when prices are high then when prices are low, thus adding to the cyclicality of investment and prices.

The surprising aspect of many forecasts is therefore that they are sometimes very close to reality.

Despite these drawbacks, price forecasts are required by the metal industries, and long term forecasts are essential to the financing of new investments in productive capacity. Thus, the forecasts themselves become an integral part of the future supply of metal, and therefore can influence the balance of the market in years to come.



The underlying weakness of all the forecasts shown on the previous pages is that they are single line forecasts. It is acknowledged that reality is likely to differ from them, but the forecasts give no indication of the likely direction or extent of any error. Sensitivity analysis can be carried out to assess the impact of alternative assumptions, but this too produces only single line forecasts for each alternative assumption.

An alternative approach to forecasting is made possible by the use of Monte Carlo analysis. This enables the forecaster to specify a range within which he expects each exogenous variable in the forecasting model to fall. It is also possible to specify the distribution of risk around the central forecast of each variable. The forecasting model can then be run, using random numbers within each specified range, to generate a very large number of results (typically 2,000, for example). Each individual result may be driven by any combination of the numerous possible values for the exogenous variables.

The resulting forecasts can be shown in the form of a cumulative chart (an example is shown above). The benefit of this approach is that it does not produce a single forecast; instead it produces a range of forecasts, which reveals the most likely forecast value and also the probability of the actual outcome falling within specified limits. This analysis adds a valuable element of risk analysis to a forecast.

The company using the price forecast can then select the forecast range associated with the probability interval (e.g. 90% or 80%) that it is prepared to accept. This is a much more powerful tool to support investment decisions than a simple one line forecast or a set of high, central and low forecasts. There is, of course, still room for error if the exogenous variables are very different from subsequent reality, or if the model is wrongly specified. However, a Monte Carlo forecast will be very much more useful than a single line forecast derived from the same model, because it allows risk to be assessed.

The example shown above is a forecast of the long run average aluminium price for the period 2004-2014. The mean forecast (equivalent to the one line forecast) is $1469/tonne. However, the chart tells us more. First, there is a greater chance that the price will be above this level than below it. Secondly, the probability of the price falling within specified ranges around the average can be calculated.