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Part II: Current Trends and Actors

Chapter 2
Producing and Selling Minerals

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Chapter 2: Producing and Selling Minerals

The minerals industry is enormously diverse, which means that no easy generalizations can be made about mineral production.[1] Any policy proposal or idea for change or regulation must be based on, and take into account, the distinctive characteristics of different parts of the industry.

Minerals and Mineral Production

Approximately 99% of the mass of Earth's crust is made up of eight elements: oxygen (47%), silicon (29%), aluminium (8%), and iron (4%), followed by calcium, sodium, magnesium, and potassium.[2] The remaining 1% contains about 90 elements of natural origin. Some minerals are geographically abundant in economic terms, such as coal, iron, quartz, silica, and limestone, and can be found in most countries. Others are concentrated in relatively few places, like some minor metals (tantalum and vanadium) and industrial minerals (borates and phosphate rock). The varying patterns of occurrence of minerals depend largely on the processes that form them, whether they be geological, fluvial, or biological.

Definitions of minerals range from strictly geological – 'a structurally homogenous solid of definite chemical composition formed by the inorganic processes of nature' – to commodity-oriented. According to the US Geological Survey, for example, there are at least 80 mineral commodities. The majority are metals but there are also important non-metals, a few of which are known as metalloids (such as silicon, arsenic, selenium, and tellurium) because they have some metallic properties.[3] Some metals have been used for many thousands of years. Copper, for instance, can be traced as far back as 7000 B.C. In contrast, metals such as titanium, tantalum, niobium, molybdenum, and zirconium have been used commercially for only 50 years.

The seven principal classes of minerals are:
- base metals,
- ferrous metals,
- precious metals,
- minor metals,
- energy minerals,
- construction minerals, and
- diamonds and precious gems.

Minerals can also be categorized according to the way they are traded. There are three broad groups:

- Some minerals have a high enough value that they are sold in the global market. These include, among others, gold, diamonds, copper, and aluminium.
- Some minerals have a higher value per unit weight and can therefore be marketed in broad regions (as with many grades of coal, limestone, and steel) even if they cannot be marketed truly globally.
- Some minerals have a very low value per unit of weight, such as sand, gravel, and stone, and are therefore marketed mainly locally.

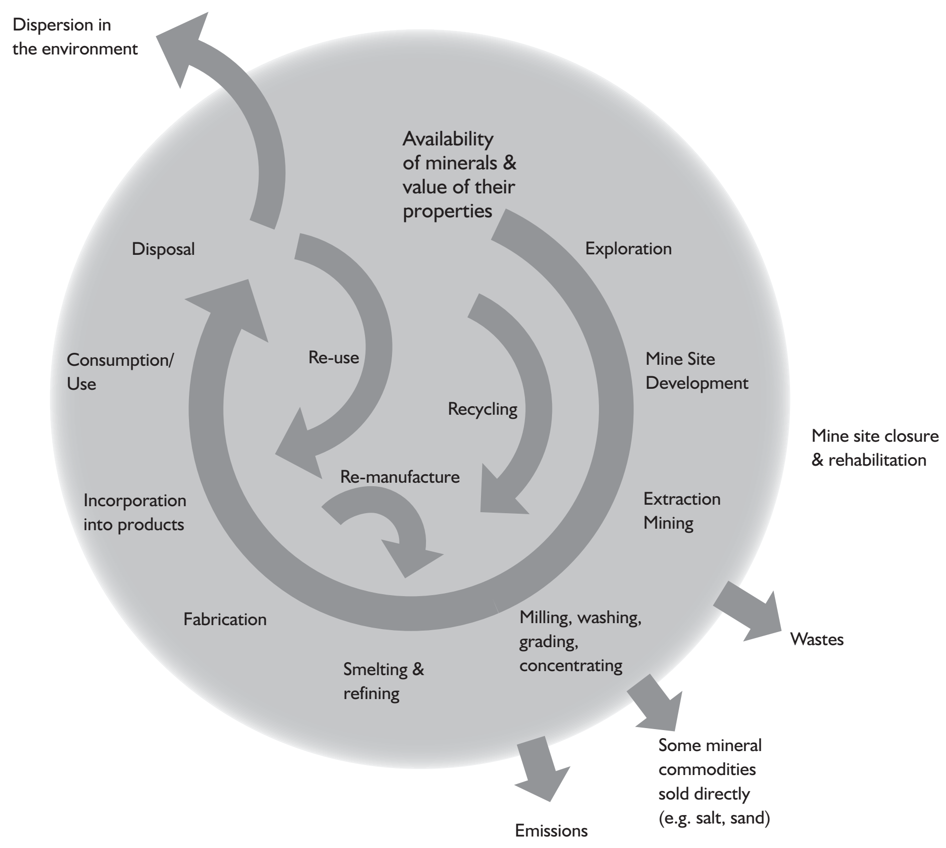
MMSD focuses largely on the first group – globally traded minerals – and on issues related to the sector's contribution at the global level. (See Figure 2–1.) It is worth noting, however, that locally and regionally traded mine products often dominate in volume terms within regions.

In general, more mineral production takes place in countries with a large surface area, if only because a large size increases the probability of finding economically recoverable mineral deposits. Nevertheless, large deposits can often be found in smaller countries as well.

Traditionally, minerals were most commonly produced in deposits in or near the main consuming regions. Today, relatively cheap transport allows the globalization of much production except for ores and minerals that have a low value relative to the transport cost. Where they have ample deposits of high-grade ores, countries such as Australia and Canada are still competitive in mineral production. But there has been a gradual migration of minerals production to many developing countries, largely due to the difficulties and longer lead times in getting environmental permits and the higher labour costs for projects in the most industrialized countries and because mineral deposits in these countries have in many cases been mined out.

Minerals and mineral commodities are supplied in different forms. The volume in which they are used reflects both their scarcity and their value in use. Common minerals and metals can be produced cheaply, as they can be extracted from large deposits with economies of scale. Rare metals and minerals are expensive to produce because they tend to occur as trace elements in only a few deposits. Common metals are chiefly produced from ores where the principal recoverable metal constitutes a high proportion of the weight of the ore. Iron ore, for example, can contain as much as 67% iron. For rare and precious metals, in contrast, the volume of the recoverable metal may be so small that it is measured in grams per tonne.

Figure 2–1. The Minerals Cycle
Adapted from a diagram produced in Natural Resources Canada (2000)



There is enormous diversity in volumes and dollar values of minerals mined and processed. (See Table 2–1.) In sheer volume terms, aggregates or construction minerals (such as sand and gravel) constitute by far the largest material volumes mined, with world production estimated to exceed 15 billion tonnes per year.[4] Of the metalliferous ores, iron, used mainly in the form of steel, is the largest in volume. In 2000, finished steel production was 763 million tonnes, dwarfing the 24 million tonnes of aluminium, which is the largest non-ferrous metal in terms of volume. At the other end of the scale, 162 tonnes of platinum and smaller tonnages of other rare metals were produced.

The prices of minerals and metals also vary wildly. Platinum prices averaged nearly US$17 million per tonne in 2000, while coal and phosphate rock averaged around US$40 per tonne.[5] Finished steel is the largest mineral commodity traded in sales value, followed by coal. These are the only minerals or metals for which the value of sales exceeded US$100 billion in 2000. Copper, aluminium, zinc, and gold were all in the US$10–100 billion range, while fluorspar, at the low end, was well below US$1 billion in value.

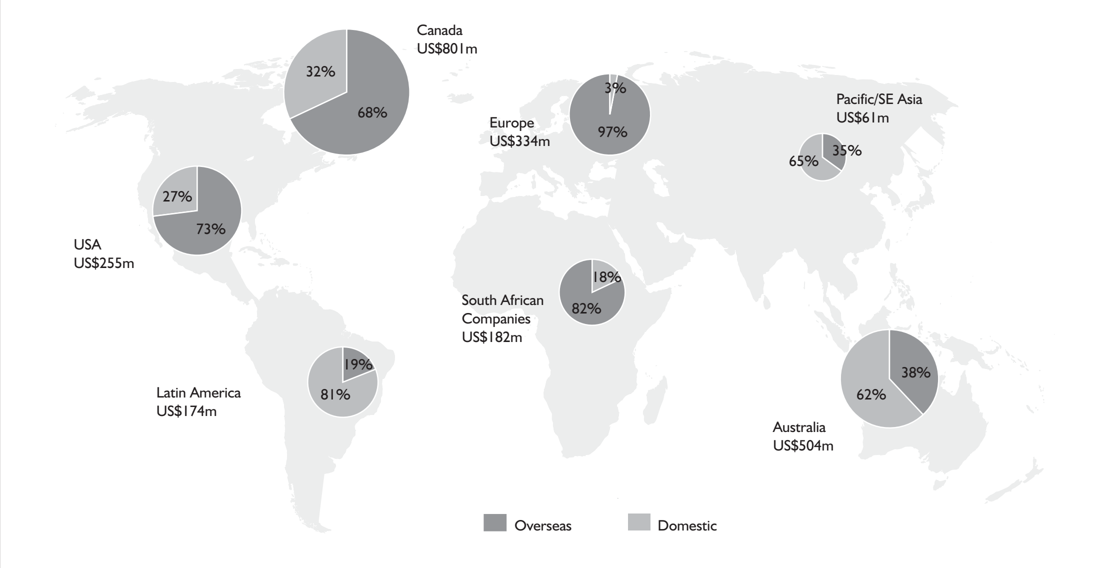
Table 2–1. Production and Prices of Some Major Mineral Commodities, 2000			
Mineral commodity	**2000 Production (thousand tonnes)**	**Price US$/tonne**	**Annual value (US$ million)**
Finished steel	762,612	300	228,784
Coal	3,400,000	40	136,000
Primary aluminium	24,461	1,458	35,664
Refined copper	14,676	1,813	26,608
Gold	2.574	8,677,877	22,337
Refined zinc	8,922	1,155	10,305
Primary nickel	1,107	8,642	9,566
Phosphate rock	141,589	40	5,664
Molybdenum	543	5,732	3,114
Platinum	0.162	16,920,304	2,734
Primary lead	3,038	454	1,379
Titanium minerals	6,580	222	1,461
Fluorspar	4,520	125	565
Source: CRU International (2001)			

Location

Geological sciences are used to estimate the size and grade of ore bodies and to define ore reserves. Different classifications are used to define ore resources and reserves in different parts of the world. A mineral resource is an *in-situ* concentration or occurrence of a material of economic interest in or on Earth's crust that has reasonable prospects for extraction. The resource is subdivided, in order of increasing geological confidence, into inferred, indicated, and measured categories.[6] After appropriate assessments have been carried out to justify extraction under realistically assumed technical and economic conditions, the mineable part of the measured or the indicated resource is known as the mineral reserve. Mineral reserves are sub-divided, in order of increasing geological, technical, and economic confidence, into probable and proven reserves.

In 2001, an estimated US$2.2 billion was spent on mining exploration looking for new deposits. This was 15% less than in 2000 and about 58% below peak exploration spending of US$5.2 billion in 1997.[7] A number of factors may account for this decline, including recent mergers among the major companies, lower expenditures on exploration by the large multinationals, and reduced access to finance for smaller companies. Exploration spending has been more severely affected in the US due to tough environmental laws and in the Pacific and Southeast Asia due to civil unrest, some of which is directly related to anti-mining activities. Metal prices also affect exploration spending by means of their influence on the free cash flow of mining companies and the expected profitability of any discoveries. Today, Canadian companies spend the most on exploration, followed by those based in Australia. Canadian companies have a stronger focus on overseas opportunities. (See Figures 2–2 and 2–3.)

Figure 2–2 Global Exploration Expenditure Flows by Location of Parent Company, 2000
Source: Metals Economic Group (2000)



As in other industries, the pattern of mining in terms of products and location of mineral development has changed over time, and these dynamics have significant implications for the sector's contribution to sustainable development. To mention just a few trends, the last two decades witnessed the decline in coal mining in Europe, a rapid increase in copper production in Latin America, and the emergence of China as a formidable player in the supply of many minerals, such as coal.

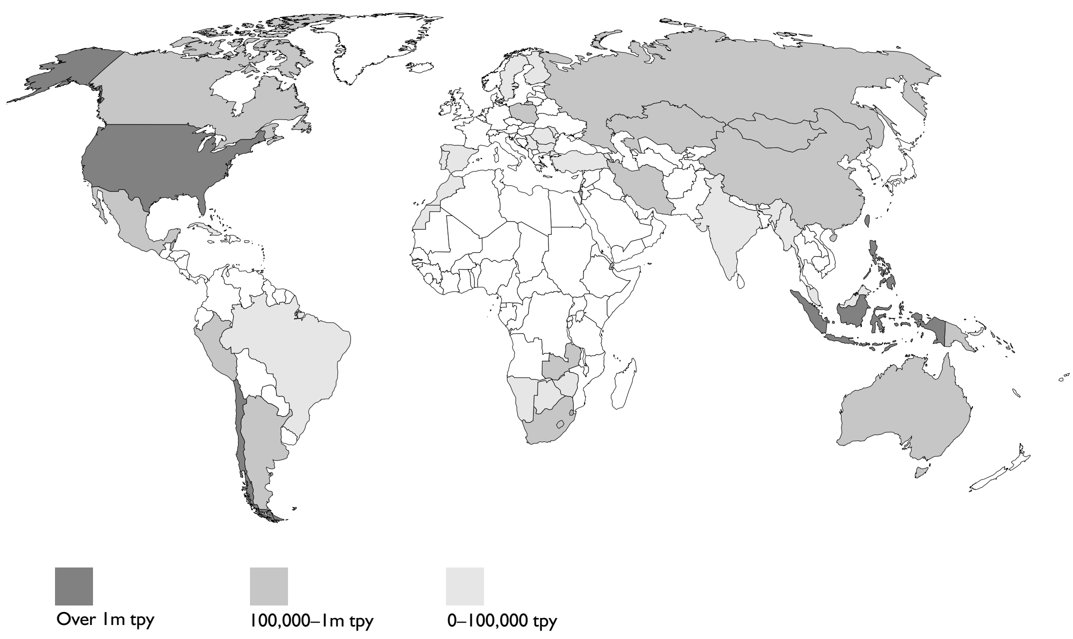
Each mineral resource currently exploited has a unique pattern of geographical occurrence, as indicated by brief descriptions of copper, aluminium, and iron ore and steel production.

Copper

Chile is the biggest producer of copper minerals, followed by the US and Indonesia. (See Figure 2–3.) Copper can be found in many other parts of the world, though less in Europe and much of Africa. Most copper oxide ores are refined *in situ*, but there is significant international trade in copper concentrates from sulphide ores. Morocco, Saudi Arabia, Namibia, Botswana, and Papua New Guinea have copper mines but not refineries. Important countries with refining but no mining are Germany, Italy, Japan, and South Korea.

The four chief producers of refined copper are Chile, the US, China, and Japan. Chile is the world's prime producer of copper ore, while China and Japan are big importers of copper concentrates. (China imports 70% of its concentrates; Japan has no domestic production.) Elsewhere, major smelting and refining facilities are divided among countries that are major producers of copper raw materials (for example, Peru, Zambia, and Indonesia), countries that are major consumers (such as Germany) and countries that are both (the US).

Figure 2–3. Copper Production Locations
Source: CRU International



Aluminium

Bauxite, the main raw material for aluminium, is produced not only in large countries such as Brazil and Australia but also in large volumes in smaller countries such as Jamaica and Guinea. (See Figure 2–4.) There is little production, by contrast, in North America, Europe, or (apart from Guinea) Africa.

Figure 2–4. Bauxite Mines and Aluminium Smelters
Source: CRU International

Alumina is an intermediate product between bauxite and aluminium. Australia, which has many bauxite mines and some major aluminium smelters, is the largest producer of alumina in the world. Alumina is often produced near the mines, such as the high volumes found in Australia, Jamaica, Guyana, and Guinea, before it is shipped to smelters. Elsewhere bauxite is shipped to regions with aluminium smelting capacity, such as Europe and North America, though not necessarily to final destinations. There is no automatic correlation between the location of bauxite mines and aluminium smelters. Aluminium smelters tend to be located in countries where electric power is plentiful and cheap or in industrial countries where utilities grant special power rates to aluminium producers. Aluminium smelting can be an attractive means of exploiting power resources (which may be based on hydro, gas or coal) in countries with few alternative markets for their power. Examples include Norway and Iceland.

Iron Ore and Steel

The big producers of iron ore are Australia, Brazil, China, and Russia. (See Figure 2–5.) Australia and Brazil are big exporters, while China and Russia produce mainly for domestic consumption. Production in Africa is mainly confined to Mauritania and South Africa, while there is little production in South Asia apart from India. Sweden is the biggest producer in Europe. Significant production takes place in North America; in South America, production occurs in Brazil, Chile, Peru, and Venezuela.

Figure 2–5. Producers of Iron Ore by Size Group
Source: CRU International

Most iron ore-producing countries also smelt iron ore (in blast furnaces or in direct reduction plants) and produce steel, except for Norway and Mauritania. Iron ore production and consumption are seldom in balance within any single country. Many consuming countries do not produce iron ore – that is, most of Europe, all of South and East Asia (except China and India), and several countries in South America and Africa.

China and Japan are the largest consumers of iron ore globally but they compete with the US to be the largest steel producers. The US obtains a greater proportion of the iron used in steel making from scrap, hence its need for iron ore is smaller. The number of countries that produce crude steel is much larger than the number that use iron ore. Many smaller countries produce steel by the electric arc furnace method, using scrap as a feed.

Processing and Fabrication

There is significant variation in the processes used to recover minerals, ranging from washing and grading for gravel to converting bauxite into aluminium cans. Some products (such as diamonds) are processed by small enterprises. Others, such as copper, are processed through a series of complex steps by refiners and fabricators who are principally large, technically sophisticated companies. Mineral processing techniques are used in order to concentrate the values contained in the ore by the removal of valueless (gangue) minerals.

Most metallic minerals go through a number of processing stages; most need to be crushed and concentrated. Grinding and flotation are the most common techniques for concentration. The production of concentrates results in the separation of a large proportion of barren rock and thus reduces the bulk of the material significantly. This lowers transportation and smelting costs. Though there are many exceptions, smelters are not usually sited close to a concentrator, since other considerations also affect a smelter's location. Smelting of concentrates can be carried out in a variety of furnaces, using coal, oil, or electrical power (and some concentrates are amenable to autogenous smelting). (This uses the sulphur contained in the concentrate as a heat source, whereas other smelting processes rely entirely on external sources of heat.) High metal recoveries can be achieved in smelting (typically greater than 90%).

Smelting processes that rely on heat to reduce concentrates to a molten state and thus separate metal from waste are known as pyrometallurgical processes. Some minerals can be treated by these processes (commonly known as leaching processes); this involves the use of sulphuric acid or cyanide to dissolve the metal content and thus separate it from the waste rock. The crude metal produced by pyrometallurgical processes must be refined to produce pure metal suitable for use in commercial applications. This is done normally through electrolysis. The smelter product, in the form of an anode, is suspended in a tank containing a weak solution of sulphuric acid. An electric current is passed through the tank, causing the metal particles to migrate to a cathode, where they are deposited. All other elements fall to the floor of the tank and can be recovered through subsequent processing. The product of hydrometallurgical processes is a solution containing metal in suspension. This is recovered in the form of refined metal through a similar electrolytic process.

For most metals, the refined product is sold on for further processing or fabricating, whether rolling, extruding, machining, or forming into semi-fabricated products that will be used in original equipment manufacture. The number of processing stages and the amount of further working depends on the individual mineral and the end-use application.

At various stages through the life cycle, there are opportunities to reuse or recycle secondary or scrap metal.

Recycling, Re-use, and Re-manufacture

Minerals vary in the extent to which they are can be reused, remanufactured, or recycled. Some commodities, once produced, can be used only once, such as coal. Others may stay in use almost indefinitely; supposedly Cleopatra's gold is still in circulation. Many metals also stay in use for long periods. For instance, perhaps 85% of all the copper ever mined is still in use.

Thus 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. Some metals are principally recycled in the form of alloys. Nickel, for example, is largely consumed in stainless steel and other non-ferrous alloys but the stainless steel and the alloys can themselves be recycled.

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. By definition, fertilizer and energy minerals cannot be recycled. Energy minerals are burnt and lost, while the final products of fertilizer minerals disappear into the soil.

Many metals are not available for recycling as they are applied in structural uses that have long lives, such as railways, bridges, pipelines, and electricity distribution systems. Continuing construction means that increasingly more metal will be stored as structures in use (although this should still be counted as part of the world's reserves of metal).

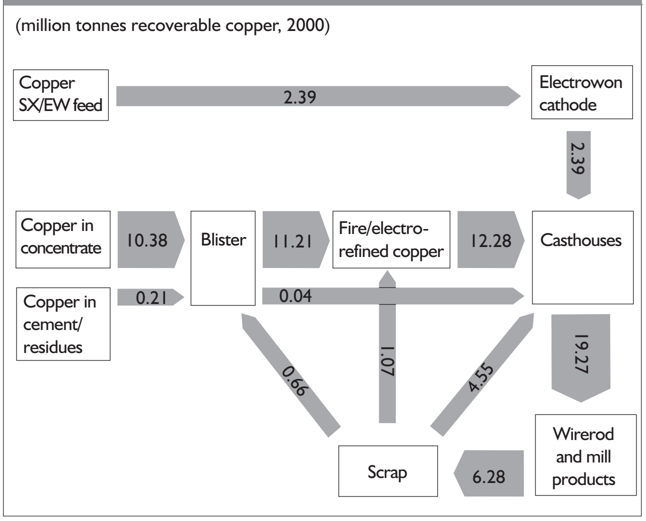
Where possible, recycling reduces the demand for primary metals and requires considerably less energy than producing primary metal would. For example, scrap aluminium requires about 5% and scrap steel about 25% of the energy required to produce the primary metals.

In the iron and steel industry, over one third of production currently comes from scrap, which comes from different sources. Producers generate and recycle their own scrap in steelworks. Foundries and steel fabricators collect scrap and supply it to traders who send it back to the steel producers. A significant volume of scrap also comes back to the industry after use. Steel food and beverage cans can be returned relatively soon after use. Other steel products have a longer life and some are eventually collected and returned. Most old motor vehicles are eventually shredded, and the scrap returns to the steel industry. Demolition scrap, including obsolete building elements, plant and equipment, rails, and so forth, can also be recycled. In recent years, more than 50% of total steel consumption has been derived from recycled material.

Secondary aluminium comes from similar sources. Again, it comes from the producers themselves in casting, rolling, and extrusion applications. It comes from the consumers of primary and secondary aluminium semi-products when they fabricate them into finished products. Beverage cans are a major source of post-consumer scrap. Old post-consumer scrap can also be recovered from buildings, other construction, and motor vehicles. Primary aluminium production totalled 24.4 million tonnes in 2000, while 15.6 million tonnes were recycled. 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 secondary foundries.

Estimates of the residence time for metals in use by society depend principally on assumptions regarding the lifespan of metal containing products.[8] For example, it has been estimated that 40 years is the average lifetime for copper in use in the US.[9] This may mask considerable variation between applications. In Sweden, 80–90% of the copper that has been produced and consumed since the Middle Ages is still either in use or in long-lived products that are no longer in use but have not been discarded into known landfills.[10] This compares with an estimate that 75% of the annual consumption of refined copper (excepting inputs from recycled scrap) in the US is accumulated in use, the remainder being subject to dissipative uses.[11] (See Figure 2–6.)

Figure 2–6. Copper processing routes
Source: CRU International



The systems for collecting, sorting, separating, crushing, and melting scrap need to be improved. Scrap recovery depends on the number of end-use applications and the ease and cost of collection. For example, the recovery of lead from batteries is now about 90% in the US, but recovery from other uses such as radiation shielding, sound proofing, weights, and ammunition is much lower, so that overall recovery of lead is about 55% of consumption.[12] A high proportion of spent batteries is collected and reprocessed, despite the low intrinsic value of a spent battery (typically about US$2). In industrial countries, the recycling rate for batteries is over 90%. Secondary smelting and refining now accounts for 79% of total lead output in the US and about 55% elsewhere (excluding China and the former Soviet Union). The majority of any future growth in secondary lead production will come from greater use of batteries and better recycling rates in these transition countries. This trend is largely driven by the predominance of use in one application – lead-acid batteries – and the existence of an easy system for collection at replacement battery centres.

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 done by one dedicated industry, as is the case with lead. As the recycling routes are diverse, the statistics on the volume of zinc recycled are by no means complete. About 1.7 million tonnes of zinc were recycled in 1999, but many countries lack data on this, so the true total is certainly larger.

Employment in the Minerals Sector

In order to identify the contribution made by the minerals sector to global employment, four key developments need to be considered:

- Most of the industry has become more capital-intensive due to technological change. So even if mineral production has risen, the numbers employed have been on the decline.
- The number of workers varies considerably among regions and sizes of operations, and at different parts of the value chain.
- Employment in mining has fallen in many industrial countries as mines have closed and the sector became less important, as happened with coal mining in the UK and Germany.
- Laying off workers in mining has been an enormous challenge for mineral-producing countries, especially South Africa and those in Eastern Europe and the former Soviet Union.

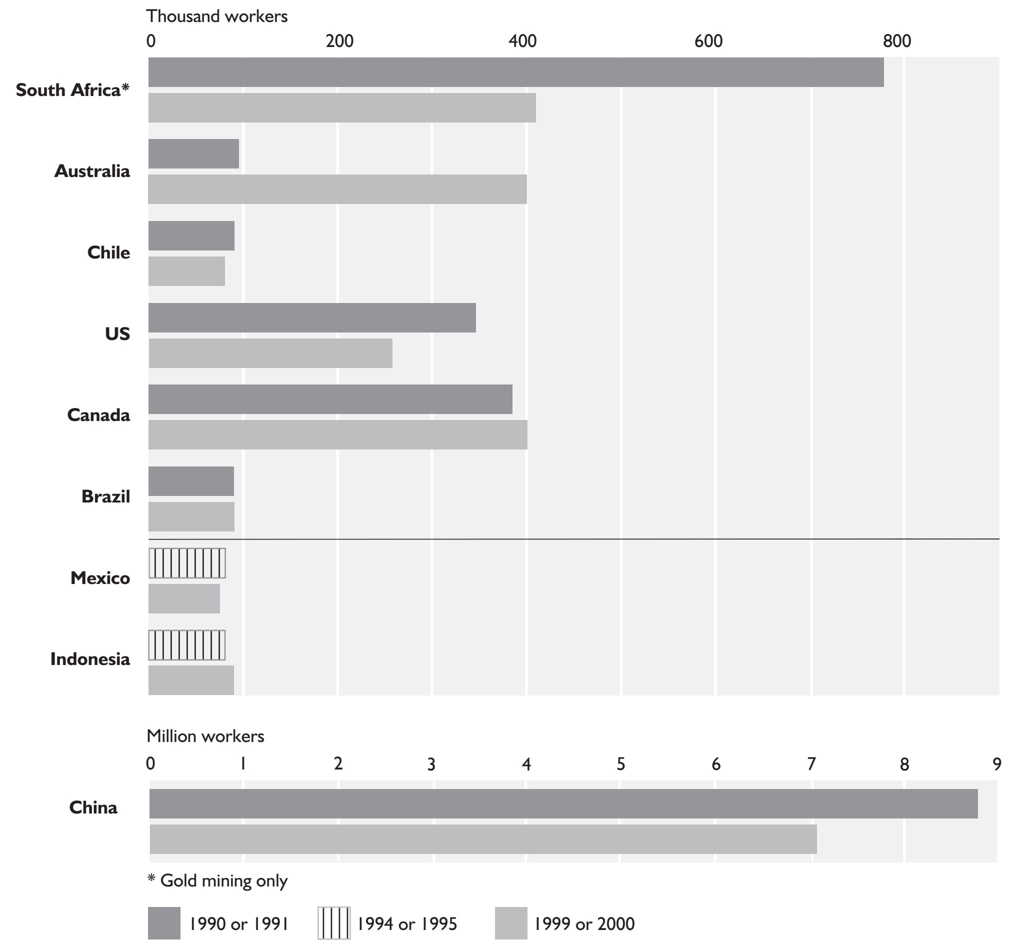
No one knows how many jobs the minerals industries provide worldwide. The uncertainty becomes even greater further down the minerals value chain. For instance, is someone who works in a recycling yard that handles both metals and other materials working in the minerals industry? Is a bricklayer, working all day with bricks and mortar – both made wholly from minerals – working in the minerals sector? What about a jeweller? Even if answers to such questions were available, statistical agencies often do not gather employment data in ways that are collated or broken down to provide the correct information.

Miners and smelter workers clearly belong to the minerals industry. Even for them, however, the available information is less than clear and does not allow cross-national comparisons.[13] The most comprehensive source of employment statistics is the International Labour Organization (ILO), which reports data for the extractive industries from 73 countries extending back at least 10 years.[14] As the ILO acknowledges, however, there are some problems with these statistics. Since country-specific data include employment for both mining and oil and gas exploration, in countries where both are important – such as Russia, Mexico, and Indonesia – there remains great uncertainty.

In addition to the country-specific data, the ILO provides a global estimate of 30 million people involved in mining itself (excluding oil and gas), 10 million of whom produce coal.[15] This represents 1% of the world's work force but it excludes at least 13 million small-scale miners. The estimate of the numbers engaged in informal and artisanal mining may be far from accurate. Taking into account dependants, the ILO estimates that the number of people relying on mining, both large- and small-scale, for a living is likely to be about 300 million.[16] The ILO country-specific data also indicate that the largest concentration of mining employment (60%) is in Asia.[17] This is concentrated in China, which has about half the world's mining employees.

Recycling is an important employer in the minerals sector, particularly for metals. For example, the Bureau of International Recycling estimated that there were 1 million workers employed in ferrous and non-ferrous recycling industries in 1996.[18]

Figure 2–7. Changes in Employment in Mining and Minerals Processing, Selected Countries, 1990s
Source: Government databases and websites (see note 19)



Employment statistics for the minerals sector in a selection of the most important mineral-producing countries are given in Figure 2–7.[19] Many of these data relate to mining whilst others include smelting and refining. Several examples illustrate the importance of accurately defining the part of the minerals sector to which data relate. In Australia, 78,000 people were directly employed in the minerals sector in 1999–2000 but this figure is 120,000 if smelting and refining of metals and the petroleum industry are included.[20] The inclusion of small-scale mining is important in many regions. For instance, according to the Mining Unit of the Southern African Development Community (SADC), the total labour force in the mining industry in the 12 mainland countries of this region was 2 million in 2000.[21] With the exception of Tanzania, this figure does not include artisanal and small-scale miners. In Tanzania the number of small-scale miners is substantial (about 0.5 million), the total in the whole SADC region may number 1.5 million.[22]

The importance of the minerals sector as a source of employment can be demonstrated by comparison with the total workforce. In both Australia and Chile employment in the minerals sector for the period 1999-2000 both represented almost 0.9% of the total workforce in these countries. [23] The number of employees in the mining industry in South Africa in 1999 represented 2.7% of the economically active population or some 9% of all workers in the non-agricultural formal sectors of the economy.[24]

As shown in Figure 2–7, there have been significant changes in employment in many countries where minerals production remains important. The general trend for a decrease in employment is most clearly illustrated by the case of South Africa where 360,000 mineworkers, or 46% of the industry's 1990 work force, lost their jobs between 1990 and 2000.[25] In many cases a decrease in employment is not due to a fall in output, but rather the changing structures of mining enterprises (such as in the former Soviet Union and Eastern Europe) and from technology that is bringing capital-intensive methods to the industry worldwide.

In many countries certain parts of the minerals industry are crucial determinants of employment levels. In Australia, the black coal industry is the largest minerals sector employer, approximately 25% of the workforce in the minerals sector in 1999.[26] In India, the coal industry is estimated to have accounted for 70% of the 0.7 million formally employed in mining in 1999.[27] In Chile, the copper sector accounts for over 30% of the mine labour force.[28]

The changes in employment levels depend on the part of the minerals industry that is being examined. For instance, in Chile between 1995 and 1999, the copper sector reduced the number of employees by 21%, while the gold/silver sector registered a decrease of 60%.[29] However, the non-metal mining sector in the same period increased employment by 61% – from 3,290 to 5,313.[30] Although employment in the US mining industry (including extraction, processing, and administrative activities) decreased by 31% between 1985 and 2000, this hides a loss of 38% in the extractive sector.[31] Within this sector, the coal industry is the biggest employer and showed the largest decrease – almost 60%.[32] In Canada, direct employment in the minerals industry experienced a modest increase of about 3% in the 1990s.[33] Despite this, the chain of production that includes metal, non-metal, quarrying, and coal mining registered a decrease of 26%, with the biggest losses in the metal and coal sectors (35% and 40% respectively).[34] The structural materials sector showed an important recovery over this period, increasing the number of employees by about 60%.[35]

Steel production in the world has risen by approximately 30 percent in the past 25 years.[36] Over the same period, estimated employment in the major steel-producing countries (excluding China) has fallen from around 2.5 million to less than 900,000 people. (See Table 2–2.) This enormous reduction – more than 60% – has been the result of major capital investments by steel companies in steelmaking processes and technologies.[37]

Table 2–2. Steel Industry Employment in Selected Countries ('000s), 1974 and 2000			
Country	**1974**	**2000**	**Change**
European Union	996	278	-72%
UK	197	51	-85%
France	158	37	-77%
Yugoslavia	42	15	-64%
US	521	151	-71%
Brazil	118	63	-47%
South Africa	100	47	-53%
Japan	459	197	-57%
Australia	42	21	-50%

Source: International Iron and Steel Institute website http://www.worldsteel.org.

When employment information is organized in the production of individual minerals, two important points can be made. The first, illustrated by the case of copper, is that employment in the minerals sector is sometimes focused on particular parts of the world. Furthermore, the regional distribution is not proportional to production. Of the estimated 400,000 people employed directly in mining, smelting, and refining of copper, nearly 60% of them are in China and the former Soviet Union.[38] This is despite the fact that these regions produce just over 10% of the world's output.[39] In contrast, South America employs 10% of the labour force to mine over 40% of global copper supply.

The second point, illustrated by the case of zinc, is that greatest employment in the minerals industry is often not at the mining stage. When all parts of the zinc industry are considered, it is estimated that this provides direct employment to about 210,000 people worldwide.[40] Zinc mining, excluding that occurring in China, employs about 55,400 people, or 26% of the total.[41] Zinc refining and smelting employs an estimated 65,000 people and the zinc oxide industry a further 6,000 people.[42] Most of the employment in the zinc industry is in galvanizing (where zinc is coated on iron and steel for corrosion resistance); the total for this activity is about 85,000 people.[43]

Mineral-Dependent Economies

Mineral production and processing are important economic activities in many parts of the world. Classifying mineral dependence is difficult because of the number of ways in which this can be measured. Common measures record mineral output as a percentage of GDP or the value of minerals in realtion to exports. In 34 countries, mainly developing ones and those in transition, mineral exports represent at least 25% of total merchandise exports. (See Table 2–3.) These countries, often known as 'mineral-dependent economies', differ not only in terms of their reliance on fuel or non-fuel minerals (see Figure 2–8), and geographical location, but also in terms of their broader development performance. (See Chapters 8 and 9 for discussion of the impact of mineral development on national and local economic development.)

In evaluating mineral dependence for any one country, it is important to examine the full range of minerals produced. For instance, sales of all primary mineral exports constituted

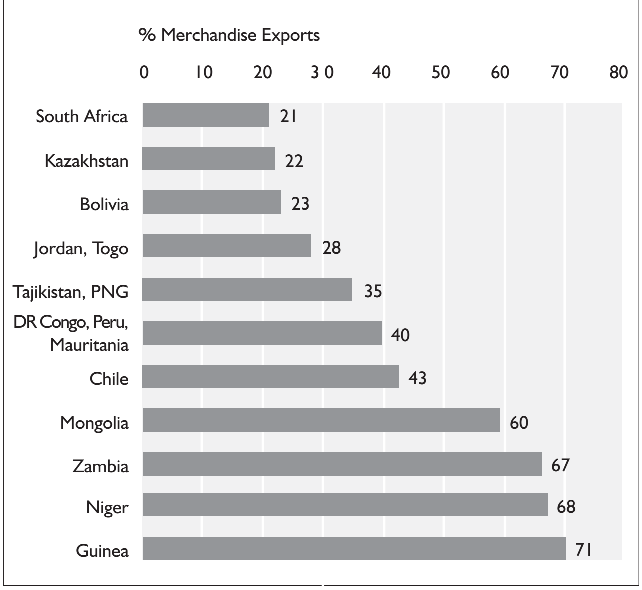
33.5% of South Africa's total export revenue in 2000.[44] This contrasts with 21% for metals and ores in Table 2-3.

Table 2–3. Mineral Dependence in the Structure of Exports, 1999

Country	Ores and Metals	Fuels	Total
Nigeria	0	99	99
Algeria	0	96	96
Libya	0	95	95
Yemen	0	93	93
Saudi Arabia	1	85	86
Venezuela	4	81	85
Kuwait	0	79	79
Oman	1	77	78
Guinea	71	0	71
Azerbaijan	1	69	70
Syrian Arab Republic	1	68	69
Niger	67	0	67
Zambia	66	..	66
Kazakhstan	22	42	64
Mongolia	60	..	60
Norway	7	50	57
Trinidad and Tobago	0	54	54
Russian Federation	11	41	52
Peru	40	5	45
Chile	43	0	43
Colombia	1	40	41
Egypt	4	37	41
Congo, Dem. Rep.	40	..	40
Mauritania	40	..	40
Australia	17	19	36
Papua New Guinea	35	0	35
Tajikistan	35	..	35
Ecuador	0	33	33
South Africa	21	10	31
Bolivia	23	6	29
Indonesia	5	23	28
Jordan	27	0	27
Senegal	10	17	27
Togo	27	0	27

Source: Eggert (2001), based on World Bank and UNCTAD data.

Figure 2–8. Countries Dependent on Ore and Metal Exports, 1999
Source: Based on data arranged by Eggert (2001). Data source: World Bank (2001c) and (for data on ore and metal exports in D.R. Congo, Mauritania, Mongolia, Tajikistan, and Zambia) UNCTAD (2001).



Australia relies substantially on mineral commodities for export income – 45% of its merchandise export income and 36% of all export income, accounting for 9% of gross domestic product (GDP), come from basic mineral commodities.[45]

In the SADC region, mining output constitutes about 8% of regional GDP. In South Africa, which is responsible for more than 70% of the region's mining output, the figure is 6.5%.[46] The range within Southern Africa is considerable – from 34% of GDP in Botswana to less than 1% in Mozambique.[47] Mining contributed 43% to the region's exports, with Botswana, Democratic Republic of the Congo, Namibia, and Zambia deriving over 50% of their export earnings from mining.[48]

In Latin America the contribution is also important. Bolivia gests 3.6% of its GDP and 32% of the value of its national exports from mining.[49] In Brazil, the mining activities account (including oil and gas extraction) for 8.5% of the GDP and 32% of the national exports.[50] Chile obtains 10.3% of its GDP and 44% of the values of its nationals exports.[51] And mining in Peru contributes almost with 50% of the exports and 5.5% of the GDP.[52]

The US has the largest minerals sector in the world by volume, although less than 0.5% of its GDP comes from direct mineral extraction (20% of which is from the metals sector).[53] In Canada, the mining industry contributes 3.7% of GDP and about 14% of exports.[54] Construction and industrial minerals form a significant percentage of total mineral production in the US and Canada. (See Figures 2–9 to 2–12.)

Europe has significant mineral production, mostly of natural aggregates (sand and gravel), crushed rock aggregates, and other construction minerals. Countries in the European Union represent around 20% of world production of industrial and construction minerals.[55] Some of these are among the world's largest producers of natural stone, feldspar, and kaolin.

Composition of Mineral Production in the US and Canada
Source: MacDonald (2001)

Figure 2–9. Value of Non-fuel Mineral Products in Canada, by Type, 1999

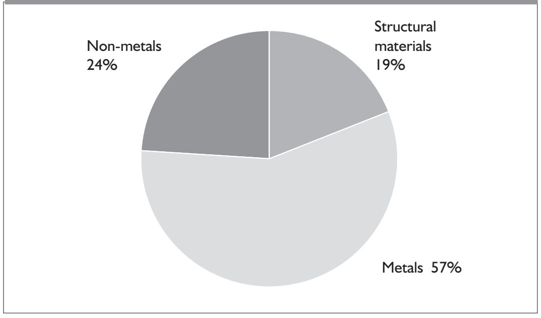


Figure 2–10. Top Five Mineral Products from Canada, by Value, 1999

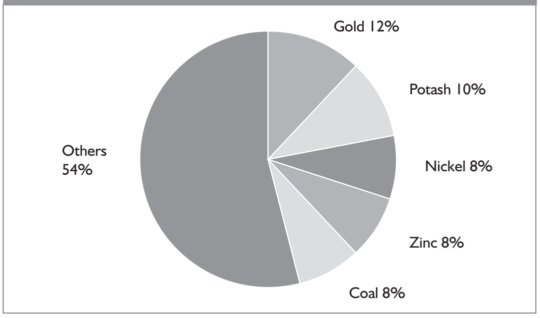
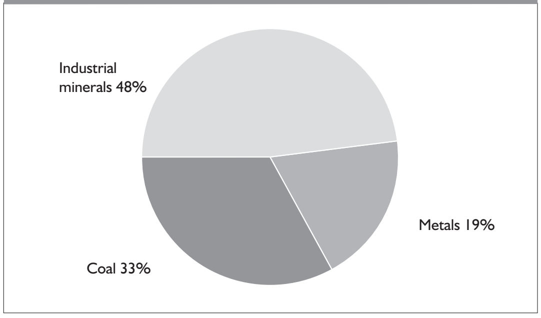


Figure 2–11. Non-fuel Minerals Production Value, 1995 and 2000

Figure 2–12. US Mineral Production Value, by Sector, 1998



Foreign direct investment (FDI) is now a major driver of development and the dominant external resource in developing countries. In principle, FDI in mining can bring the potential for employment, enhanced export orientation, and technology and skills or spill-over effect in recipient countries. FDI flows to developing economies have more than quadrupled over 10 years: between 1988 and 1993 FDI flows averaged US$47 billion a year, but then they reached US$208 billion in 1999.[56] By comparison, official development assistance over the same time was approximately US$50 billion.[57] FDI in mining has also been growing, though at a slower pace than FDI as a whole.[58] Foreign direct investment has not of course been evenly spread among developing countries. In 1999, for example, just 10 countries received over 80% of the total; the least developed countries received little more than 2% of the total.[59]

Mineral Markets

Historically, Europe, Japan, and the US have been the largest mineral-consuming regions. But this is changing as markets mature, especially in Brazil, China (see Box 2–2), and other Asian countries, such as Malaysia and Thailand. Americans use about 600 kilograms of metals per person a year.[60] During an average 70-year lifetime, West Europeans on average use about 460 tonnes of sand and gravel, about 39 tonnes of steel, 100 tonnes of limestone, and more than 360 tonnes of fuel to heat houses, produce electricity, or keep cars running.[61] The European Union is the world's single largest user of minerals and mainly depends on imports for its raw materials supply, with a negative minerals trade balance in 1998 of about 8 billion euros (US$7 billion).[62]

Box 2–2. Focus on China

One of the most important developments in the global mining industry in the last decade has been the rapid development of China in the world market. From a small but significant exporter of minor mineral commodities such as tungsten and magnesite, China has become a significant influence in virtually all the major mineral markets by virtue of the sheer volumes it is now consuming, importing, and exporting during its rapid industrialization. Annual consumption grew at double-digit percentage rates through the 1990s. Chinese consumption accounted for one-third of the entire world growth in copper use between 1990 and 2000 and 40% of world growth in aluminium use. More than 60% of this copper must be imported, and it is increasingly being imported as concentrates rather than metal or semi-fabricated products.

China is the world's largest steel producer and consumer. The growth in production has moved China's share of the sea-borne market for iron ore from 4% in 1990 to 16% in 2000, accounting for 60% of all growth in this market. China is expected to import more than 80 million tonnes in 2001. In the last two years, China has also become a significant exporter of coal, doubling its share of the traded coal market from 6% to 12%, and it is expected to export in excess of 75 million tonnes.

Source: Humphreys (2001a).

Europe and Asia are the two principal consuming regions for most of nine metals and minerals: aluminium, lead, zinc, copper, nickel, steel, gold, coal, and phosphate rock. (See Table 2–4.) North America is also important, especially for aluminium, lead, and coal. Coal is perhaps the most anomalous of these commodities. Regional consumption as a share of the world total is much higher for coal than for other commodities in the former Soviet Union and Australasia. 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 in this case. Africa is also an important consumer, largely because Morocco is the largest producer in the world.

Table 2–4. Consumption of Selected Metals and Minerals, 2000

	North America	South America	Europe	Former Soviet Union	Asia	Africa	Other
	(thousand tonnes)						
Aluminium	7,291	823	6,632	612	8,819	294	421
Lead	1,924	212	1,854	179	1,866	118	47
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
Steel (million tonnes)	170	33	206	25	377	18	9
Gold (tonnes)	306	83	906	42	2,423	179	7
Coal (million tonnes oil equivalent)	613	37	241	197	767	123	158
Phosphate rock	44,580	6,298	11,008	8,965	43,210	23,087	2,718

Source: CRU International (2001).

On a per capita basis, it is clear that the industrialized regions of Europe and North America use the lion's share of metals and minerals. Just taking one example, only 0.7 kilograms of aluminium is used a year in Africa per capita compared with 22.3 kilograms in the US.

Several studies have proposed that intensity of use of a mineral (the consumption of a mineral divided by GDP) depends on the level of economic development, as measured by GDP per capita, and that the pattern of intensity of use follows an inverted U-shape as economies develop.[63] As development takes place, countries focus on building infrastructure (such as rails, roads, and bridges, and water supply and electricity transmission) and people buy more durable goods, which rapidly increases the demand for minerals. As economies mature, all other things being equal, they move to a less materials-intensive phase, demanding more on education and other services, which reduces the intensity of mineral use. Other factors that affect intensity of use include government policies, shifts in demographics, materials substitution, and new technologies.

The available empirical evidence suggests that the intensity of use of many important minerals is falling over the long run.[64] But it remains difficult to forecast future demand given all the factors that can affect intensity, some of which, such as new technology, are impossible to predict.

Location of Mineral Markets by End-Use

The list of applications for metals and minerals is endless – aerospace, automotive, electronics, energy generation and transmission, high-rise construction, wide-span bridges, railway tracks, weapons of war, and so on. (See Table 2–5.) In addition, most manufacturing processes for most products in the world use metal equipment as an integral part of the process.

Table 2–5. Common Uses of Mined Products

Aggregates	Building construction, roads, bridges, sewer & water systems
Aluminium	Aircraft parts, automotive parts (truck and automobile engine blocks and cylinder heads, heat exchangers, transmission housings, engine parts and automobile wheels), railroad cars, seagoing vessels, packaging (foil, cans, cookware), building construction (siding, windows, skylights, weather-proofing, doors, screens, gutters, down spouts, hardware, canopies and shingles), electrical applications (overhead power lines, wires and cables), pharmaceutical uses (antacid, antiperspirants), water treatment
Antimony	Alloys, flame-proofing compounds, batteries, plastics, ceramics, glass, infrared detectors & diodes, cable sheathing, small arms, paints, medicine
Arsenic	Glass production, semi-conductors, wood preservation, pesticides, bronzing, pyrotechnics, laser material
Asbestos	Cement building materials (roofing, cladding, pipes), heat & acoustic insulation, fire proofing
Beryllium	Structural material for high performance aircraft, missiles, spacecraft and communication satellites, automotive parts, computer and laser technology, X-ray windows, ceramics, nuclear industry
Bismuth	Malleable irons, thermocouple material, carrier for uranium fuel in nuclear reactors, low-melting, fire detection & extinguishing systems, acrylic fibres, medicine, cosmetics

Table 2–5. Common Uses of Mined Products (continued)	
Borates	Fertilizers, disinfectant, detergent, water softener, a corrosion inhibitor for antifreeze, a flux in brazing, ceramics, paint, coated paper, enamels, heat resistant glass (Pyrex), pharmaceuticals, food preservative
Cadmium	Electroplating, nuclear reactor parts, television phosphors, batteries
Chromium	Metal plating, alloys, pigments, corrosion resistance, glass and ceramics, catalyst, oxidizing agents, anodizing aluminium, tanning leather, refractory products
Clays	Ceramics, nutritional additives, concrete, mortar
Coal	Electricity generation, steel making, chemical manufacture
Cobalt	Superalloy (used in jet engines & gas turbine engines), magnets, stainless steel, electroplating, batteries, cemented carbides (hard metals) and diamond tools, catalysts, pigments, radiotherapeutic agent
Copper	Building construction (wire, cable, plumbing and gas tubing, roofing and climate control systems), aircraft parts (undercarriage components, aeroengine bearings, display unit components, etc), and helicopter motor spindles), automotive parts (wire, starter motor, bearings, gears, valve guides, etc), industrial applications and machinery (tools, gears, bearings, turbine blades, etc), furniture, coins, crafts, clothing, jewellery, artwork, musical instruments, cookware
Dolomite	Building stone, nutritional additives
Feldspar	Glass, ceramics, enamel frits and glazes, source of alkalies and alumina in glazes, paint, plastics, mild abrasives, welding electrodes
Fluorspar	Steelmaking, aluminium, fluorocarbons (used in refrigerants, blowing agents, solvents, aerosols, sterilants, fire extinguishers)
Gallium	Compound semiconductors in mobile cellular phones, wets glass or porcelain, and forms a brilliant mirror when painted on glass, transistors, gallium arsenide converts electricity into coherent light, alloy
Germanium	Semiconductors, infra-red imaging and detector systems, optical fibres, phosphor in fluorescent lamps, catalyst, radiation detectors, lasers and light detectors, medical and biological uses
Gold	Ornamental, electronics, dentistry, decorative plating of costume jewellery, watchcases, pens and pencils, spectacle frames and bathroom fittings, decoration of china and glass, store of value
Graphite	High-temperature lubricants, brushes for electrical motors, brake & friction linings, battery and fuel cells, pencil fillings, seals & gaskets, conducting linings on cables, antistatic plastics and rubbers, heat exchanger, electrodes, apparatuses & linings for the chemical industry
Gypsum	Building construction (plasterboard, plaster and cement), agriculture, glass, chemicals
Iron	Steelmaking, alloy
Kaolin	Filler for paper, rubber, plastic, paint & adhesives, refractories, ceramics, fibre glass, cement, catalyst for petroleum refining
Lead	Batteries, cable sheathing, lead crystal, solder & radiation protection, antiknock compound in petrol, plumbing, ammunition
Limestone	Aggregate, cement, fertilizer, soil conditioner, iron flux, paints, plastics, livestock feed
Lithium	Lubricants, glass and ceramics, lithium carbonate (used for aluminium reduction, batteries; pharmaceuticals), high performance alloys for aircraft, carbon dioxide absorber in spacecrafts, nuclear applications
Manganese	Steelmaking, alloys, batteries, colourants and pigments, ferrites, welding fluxes, agriculture, water treatment, hydrometallurgy, fuel additives, oxidizing agents; odour control, catalysts, sealants, metal coating, circuit boards
Magnesite	Agricultural fertilizer, refractory bricks, filler in plastics & paints, nuclear reactors &

Table 2–5. Common Uses of Mined Products (continued)	
	rocket engine nozzles, manufacture of Epsom salts, magnesia, cosmetics, insulating material & disinfectant, fire retardant
Magnesium	Alloys used for aircraft, car engine casings, and missile construction, refractory material, agriculture (feed & fertilizer), filler in paper, paints & plastics, automobile & machinery, ceramics, fire retardant, catalyst, medicine, computers, pyrotechnics & flares, reducing agent for the production of uranium and other metals from their salts
Mercury	Thermometers, barometers, diffusion pumps, electrical apparatus, electrode, batteries, chlorine and sodium hydroxide manufacture, plant treatments, lighting, pesticides, dentistry
Molybdenum	Alloys, catalyst in petroleum refining, heating elements, lubricants, nuclear energy applications, missile and aircraft parts, electrical applications
Nickel	Stainless steel, corrosion-resistant alloys, gas turbines, rocket engines, plating, coins, catalysts, burglar-proof vaults, batteries
Niobium	Alloys, stainless steels, advanced engineering systems (space programs), nuclear industry, electrical products, jewellery
Palladium	Jewellery, watches, surgical instruments, catalysts, dentistry (crown), electrical contacts, hydrogen gas purification
Phosphate rock	Fertilizers, detergents, flame retardants, food and beverages, animal feeds, metal treatment, water treatment, pulp and paper, glass and ceramics, textiles and synthetic fibres, plastics, rubber, pharmaceuticals, cosmetics, petroleum production and products, construction, pesticides, toothpaste, mining, leather, paints, fuel cells
Phosphorus	Safety matches, pyrotechnics, incendiary shells, smoke bombs, tracer bullets, glass, calcium phosphate (used to produce fine chinaware), steelmaking, cleaning agent, water softener, pesticides
Platinum	Jewellery, coins, autocatalysts, electronics, glass, dentistry, chemical and electrochemical, catalysts, petroleum, laboratory equipment, antipollution devices in cars, investment, anti-cancer drugs, implants (pacemakers, replacement valves)
Plutonium	Nuclear fuel and weapons, pacemakers
Potash	Fertilizer, soap and detergents, glass and ceramics, chemical dyes and drugs, food and beverages
Pumice	Construction, stonewashing in textile industries, glass & metal polishing, dental supplies & paste, agriculture, sport & leisure facilities, cosmetics
Rhodium	Alloys (used for furnace windings, thermocouple elements, bushings for glass fibre production, electrodes for aircraft spark plugs, laboratory crucibles), electrical contact material, optical instruments, jewellery, industrial catalysts, car catalytic converter
Sand & Gravel	Concrete, bricks, roads, building materials
Selenium	Photoreceptors (used in the manufacture of plain paper photocopiers and laser printers), electronic applications, glass, pigments, alloys, biological applications, rubber, lubricants, catalysts
Silica	Glass (bottles and jars)
Silver	Photography (X-ray film for medical, dental, industrial uses), jewellery, electrical applications, batteries, solder and brazing alloys, tableware, mirrors and glass, coins
Soda Ash	Glass, detergents, chemicals, water treatment, flue gas desulphurization, pulp and paper
Sulphur	Sulphuric acid, ammunition, fungicide, vulcanization of natural rubber
Talc	Paper, plastics, paints, ceramics, refractories, roofing, rubber, cosmetics, pharmaceuticals, agrochemical, animal feed, cement, glass fibre
Tantalum	Electrolytic capacitors, alloys (use in aircraft and missile manufacture), lining for

Table 2–5. Common Uses of Mined Products (continued)	
	chemical and nuclear reactors, wires, surgery (used in sutures and as cranial repair plates), cameras
Tin	Tinplates, alloys, solder, pewter, chemicals, panel lighting, frost-free windshields
Titanium	Production of light weight alloys, aircraft components (jet engines, aircraft frames), automotive components, joint replacement (hip ball and sockets), paints, watches, chemical processing equipment, marine equipment (rigging & other parts exposed to sea water), pulp and paper processing equipment, pipes, jewellery
Tungsten	Alloys (used in filaments for electric lamps, electron and television tube, metal evaporation work, etc), ammunition, chemical and tanning industry, paints, X-ray targets
Uranium	Nuclear fuel, nuclear weapons, X-ray targets, photographic toner
Vanadium	Alloys (especially in steel), catalysts, pigments for ceramics and glass, batteries, medical, pharmaceutical, electronics
Zinc	Galvanizing, alloys, brass, batteries, roofing, water purification, coins, zinc oxide (used in manufacture of paints, rubber products, cosmetics, pharmaceuticals, floor coverings, plastics, printing inks, soap, textiles, electrical equipment, ointments, etc), zinc sulphide (used in making luminous dials, X-ray and TV screens, paints, fluorescent lights)
Zirconium	Ceramics, refractories, foundry sands, glass, chemical piping in corrosive environments, nuclear power reactors, hardening agent in alloys, heat exchangers, photographic flashbulbs, surgical instruments

Source: ICMM, MERN, CRU International (2001), Industry Association websites.

There are 31 metals in the standard personal computer.[65] A modern jet engine is composed of 41% titanium, 34% nickel, 11% chromium, 7% cobalt, and lesser amounts of aluminium, niobium, and tantalum.[66] Nickel-based super alloys are used in jet engines because of high temperature stability and strength. These super alloys may contain more than 15 elements, including iron, vanadium, tungsten, cobalt, carbon, molybdenum, aluminium, titanium, and niobium. A car contains about 10 different types of steel alloys that constitute about 70% of all the materials used in it.[67] Minerals are used in a large number of non-mechanical uses, such as kaolin in paper, zinc in agriculture, and copper sulphate as a chemical raw material.

By end-use, metals are used in all sectors of manufacturing, although some are particularly large-volume consumers, such as transportation and appliances. Construction is also important. Some high-value metals are used in very small volumes in specialized uses. Non-metallic minerals are also used in manufacturing, but some minerals have other distinct uses, including agriculture (phosphates and borates, for example) and power generation (coal).

The future demand for metals is not, however, determined solely by the development of new applications for these materials or changes in existing ones. Metals may be substituted for alternative materials and vice versa, and this may occur at various levels, although the availability of the substitute materials must also be considered.

At the level of national and regional economies, the relative contribution of different materials towards economic output may change. These 'compositional shifts in economic activity' are most commonly measured by intensity of use.[68] Steel and copper consumption in the US, for example, was relatively stable between 1960 and 1985, while that of aluminium and plastics increased significantly. Similar trends may be identified in the construction materials sector.[69] Substitution may also occur with strategic uses of metals, which do not involve incorporation into products. In recent years, there has been a trend among central banks to exchange gold reserves for currency reserves. (See Chapter 5.)

Substitution also occurs within individual product applications. (See Box 2–3.) For instance, copper is now used in brake linings (together with plastics) instead of asbestos. Several important factors must be considered when choosing materials in product design. The market for fuel-efficient vehicles has been fundamental to materials choice in the motor industry, for example. A key limiting factor in the substitution of metals for other materials is not just the technology to produce the materials but also the infrastructure to incorporate them into finished products.[70] Some metals have unique physical characteristics that, based on current knowledge, make them essentially non-substitutable. An example is copper, which is fundamental in many electrical applications. While aluminium is a good electrical conductor and has considerable application in high-voltage transmission lines, it is not an economic alternative to copper for the distribution of electricity in most manufactured products and local electricity networks.

Box 2–3. Choosing Between Metals and Other Materials

The motor industry is a key metal user. Vehicle manufacturers in the US account for approximately 20% of aluminium, 14% of steel, and 10% of the copper used in the economy. The composition of cars world-wide has, however, changed considerably. For instance, 5% of the mass of Japanese cars in 1973 was composed of plastics, whereas in 1997 this increased to 7.5%. Plastics and composites have been used instead of steel in instrument panels, bumpers, and outer body panels. Cast aluminium has increasingly replaced cast iron in engine blocks. The bodies of several models of mass-produced cars have been made from fibre-reinforced polymers. Even though these are a small percentage of the market, it is still suggested that plastic may be the material choice for car bodies of the future. A key factor in this is the desire of manufacturers to reduce the weight of cars in order to achieve fuel efficiency.

In food and beverage packaging, there is intense competition between aluminium, steel, plastics, and glass as materials choices. The rivalry between suppliers of these materials has been a driver of significant technological advances that have, in turn, lead to a reduction in the amount of material used per unit of product. The weight of a steel food can fell by 60% between 1960 and 1990. Simple materials choice decisions are also influenced by market distortions (including bans) and inertia (preferences based on familiarity).

There are significant regional variations in choices between materials. Soft drinks in North America come in aluminium cans, whereas glass dominates in South America. Where metals are used, consumer lifestyle and pressures have had an overwhelming influence on the demand. In the case of long-term food packaging, metals remain the dominant material in use because of the need for strength during vacuum processing. Free market competition between materials has often been strongly influenced by regulation. In Denmark, aluminium cans were banned on the basis of a government analysis of the environmental impacts of this and other forms of packaging. Biodegradable plastics may increasingly competitive form of packaging in the future.

Source: Metal use by vehicle manufacturers in US from Rocky Mountain Institute http://www.rmi.org/sitepages/pid422.php; metal use in Japanese cars from Samel (2001); general trends in materials use in cars from Eggert (1990); weight of steel can from Nappi (1990).

Pricing and Price Trends

The London Metal Exchange (LME) is a market in which copper, aluminium, nickel, lead, zinc, tin and silver may be brought and sold, for delivery either immediately or at fixed dates in the future. LME prices refer to refined metals and are used as the basis price for transactions in these metals (apart from silver) worldwide. LME prices are also used as the basis for products upstream from refined metals (such as ores and concentrates) and for downstream products, such as some semi-fabricated products. They are even used as the basis for scrap prices.

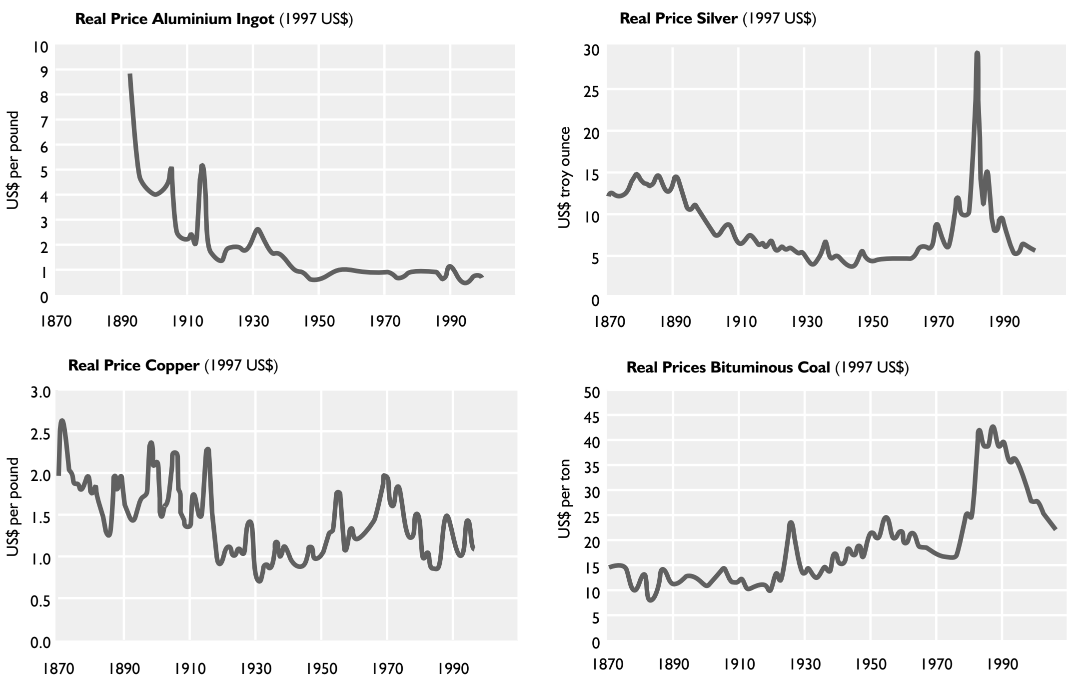
Only an estimated 5% of the metals produced annually are physically traded through the LME. Companies with physical metal to sell will normally deal directly with their customers or through merchants. The vast majority of LME contracts are hedging transactions where the buyer or seller of the metal can enter into forward contracts on the LME to secure a fixed price, even though the counterparty will quote a price based on the unknown future price of the metals.

Understanding variations in the price of mineral commodities is critical to evaluating the future of the mining and minerals industry. This is principally because prices simultaneously reflect and affect both demand and supply. They are also influenced by artificial price-setting interventions by industry and governments. With a proper understanding of price setting, prices can be an important tool in analysing long-term trends in the minerals sector. For example, they can signal changes in the availability of minerals for extraction, as well as technological and organizational changes in mining and minerals processing.

Long-term descriptions of price depend on the methods used to account for inflation, all of which have relative merits.[71] Attempts have been made to use labour costs, the price of goods that do not result from resource extraction, and general national price indexes. Potter and Christy made one of the first attempts at a systematic description of price trends for mineral commodities, using the US Producer Price Index as a means of adjusting for inflation.[72] They showed that when the prices of all the mineral commodities were amalgamated, prices had declined by 40% between 1870 and 1957. This illustrates the potential for misinterpretation of data, for when the first 10 years of the data they used are excluded, the long-term trend is quite stable. Potter and Christy's work has been updated several times – most recently by Howie, who reported on real prices for selected commodities between 1870 and 1997.[73] (See Figure 2–13.)

Howie's analysis illustrates several points. First, the long-term trend for mineral commodities depends entirely on the product in question. Prices shift according to technology. Aluminium is perhaps the example of greatest price reduction associated with technological change. There have been major reductions in both the cost of energy and the amount of energy required to convert bauxite to alumina and then to aluminium ingot. Other mineral commodities such as copper have remained relatively stable, which may reflect the balance between technological change, physical availability, and demand.

Figure 2–13. Real Prices for Selected Mineral Commodities, 1870–1997
Source: Tilton (2002)



Second, there is considerable volatility. The appearance of this can be even more exaggerated if price fluctuations are quoted for frequencies less than a year. Some of the year-by-year price changes can be attributed to global events such as economic crises and wars. Price volatility is a key issue in mineral markets. This can significantly affect the revenues of mining and minerals processing companies and host governments as well as the costs to consumers, such as the fabricators of metal products.

The value of long-term historic price trends in predicting future patterns is debatable. Although numerous models for price are available, the complexity of issues relating to the availability of minerals and technology to extract them means that the past is no sure guide to the future.

Endnotes

[1] Unless otherwise indicated, statistical information in this chapter is from CRU International (2001).
[2] Wedepohl (1995).
[3] US Geological Survey, at http://minerals.usgs.gov/minerals/pubs/mcs
[4] Regueiro et al. (2000).
[5] 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. Moreover, because transport costs are high relative to costs of production, 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.
[6] For more detail on these definitions, see Canadian Institute of Mining, Metallurgy and Petroleum (1998).
[7] Metals Economics Group, Canada quoted in Financial Times, 1 November 2001.
[8] Ayres et al. (2001).
[9] US EPA (1983).
[10] Ayres et al. (2001).
[11] Jolly (2000).
[12] Henstock (1996).
[13] The diverse statistical sources that are available include international organizations, regional associations, national governments, labour unions, and industry information. The most important problem in reporting employment data is the lack of a common methodology, which would allow reliable comparisons between nations. This problem of aggregation occurs because of different proportional shares of direct and indirect employment and different stages of the chain of production that are included (some figures include mining only, while others do not discriminate between extraction, smelting, refining, and fabrication workers). Finally, both reliability and quality of the data are often related to the state of development of the country. The industrial countries generally have better estimates of employment levels.
[14] ILO (2001), *Labour Statistics Database* (LABORSTA). The data referred to the ILO is the total number of people employed by economic activity according to the International Standard Classification of all Economic Activities; these statistics cover mining, quarrying, and extraction of oil and natural gas activities.
[15] http://www.ilo.org/public/english/dialogue/sector/sectors/mining.htm
[16] Ibid.
[17] ILO (2001), *Labour Statistics Database* (LABORSTA).
[18] Bureau of International Recycling, at http://www.bir.org/biruk/index.asp.
[19] *South Africa:* Government of South Africa, Department of Minerals & Energy (2001) South Africa's Mineral Industry Yearbook for 1999/2000, page 9. *Australia:* Data exclude metal ore extraction, smelting, refining, and basic metal fabrication. Source: Hancock (2001). *Chile:* Includes both direct employment and contractors. Includes coal but excludes oil. Source: Chilean Copper Commission (2001). *US:* Includes all mining, processing, independent shops and yards, and office workers. Source: Mine Safety and Health Administration, US Department of Labor. *Canada:* Includes all mining, smelting, refining, and fabrication. Source: Mining Association of Canada (2001). *Brazil:* Mining, smelting, and refining. Source: Brazilian Bureau of Mines (2001). *Mexico:* Earliest available data are for 1994–95. Source: Secretaria de Trabajo y Prevision Social (2001) http://www.stps.gob.mx. *Indonesia:* Earliest available data are for 1994–95. Excluding mining services. Source: Wiriosudarmo (2001). *China:* Source: Chinese Statistical Information Network (2000).
[20] Hancock, Peter (2001), *Baseline Assessment Australia Final Report*, MMSD
[21] SADC (2001) *Review of the Performance of the Mining Industry in the SADC region*, Southern African Development Community, Rep. SADMIN/TC/1/2001/3. 10 June, 55 pp.
[22] Dreschler, B (2001) Small Scale Mining and Sustainable Development in the SADC Region. Report prepared for MMSD-Southern Africa.
[23] Data sources as per Figure 2–7

[24] South African Minerals Bureau (2000) South Africa's Mineral Industry 1999/2000, p8..
[25] Government of South Africa, Department of Minerals & Energy (2001) South Africa's Mineral Industry Yearbook for 1999/2000, page 9.
[26] Hancock, Peter (2001), *Baseline Assessment Australia Final Report*, MMSD
[27] Tata Energy Research Institute (2002) Overview of Mining and Mineral Industry in India. Prepared for MMSD.
[28] COCHILCO (2001) *Estadisticas del Cobre y otros Minerales 1991-2000*, Cochilco, Santiago de Chile.
[29] Ibid.
[30] Ibid.
[31] National Mining Association (2001).
[32] Ibid.
[33] Mining Association of Canada (2001), Facts and Figures 2000.
[34] Ibid.
[35] Ibid.
[36] IISI (2001), http://www.worldsteel.org.
[37] IISI (2001), http://www.worldsteel.org.
[38] CRU International (2001) MMSD Background Report.
[39] Of the 60%, 160,000 are in China and 60,000 in the former Soviet Union.
[40] International Zinc Association (2001) web page. http://www.iza.com
[41] Ibid.
[42] Ibid.
[43] Ibid.
[44] Government of South Africa, Department of Minerals and Energy (2001) p.8.
[45] Hancock (2001).
[46] Government of South Africa, Department of Minerals and Energy (2001), p.5.
[47] MMSD Southern Africa (2001).
[48] Ibid.
[49] Enriquez (2001).
[50] Barreto (2001).
[51] Lagos et al. (2001).
[52] Glave and Kuramoto (2001).
[53] MacDonald (2001).
[54] Ibid.
[55] Regueiro et al. (2000).
[56] United Nations (2000).
[57] Ibid.
[58] Ostensson (1997).
[59] United Nations (2000).
[60] Jeffrey (2001).
[61] BGR Hannover (1995), cited in Regueiro et al. (2000).
[62] Regueiro et al. (2000).
[63] See Radetzki and Tilton (1990).
[64] See Tilton (2002).
[65] Jeffrey (2001).
[66] Ibid.
[67] Ibid.
[68] Considine (1991).
[69] Moore and Tilton (1996).
[70] Considine (1991).
[71] Tilton (2002) Chapter 4.
[72] The Producer Price Index is a group of indexes that measures the average change over time in selling prices as supplied by domestic producers of goods and services. This contrasts with the Consumer Price Index, which measures price change from the purchaser's perspective. Potter and Christy (1962).
[73] Howie (2001).