PART II

CURRENT TRENDS AND ACTORS

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CHAPTER 2

PRODUCING AND SELLING MINERALS

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The minerals industry is enormously diverse, which means that no easy generalizations can be made about mineral production or use.[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.

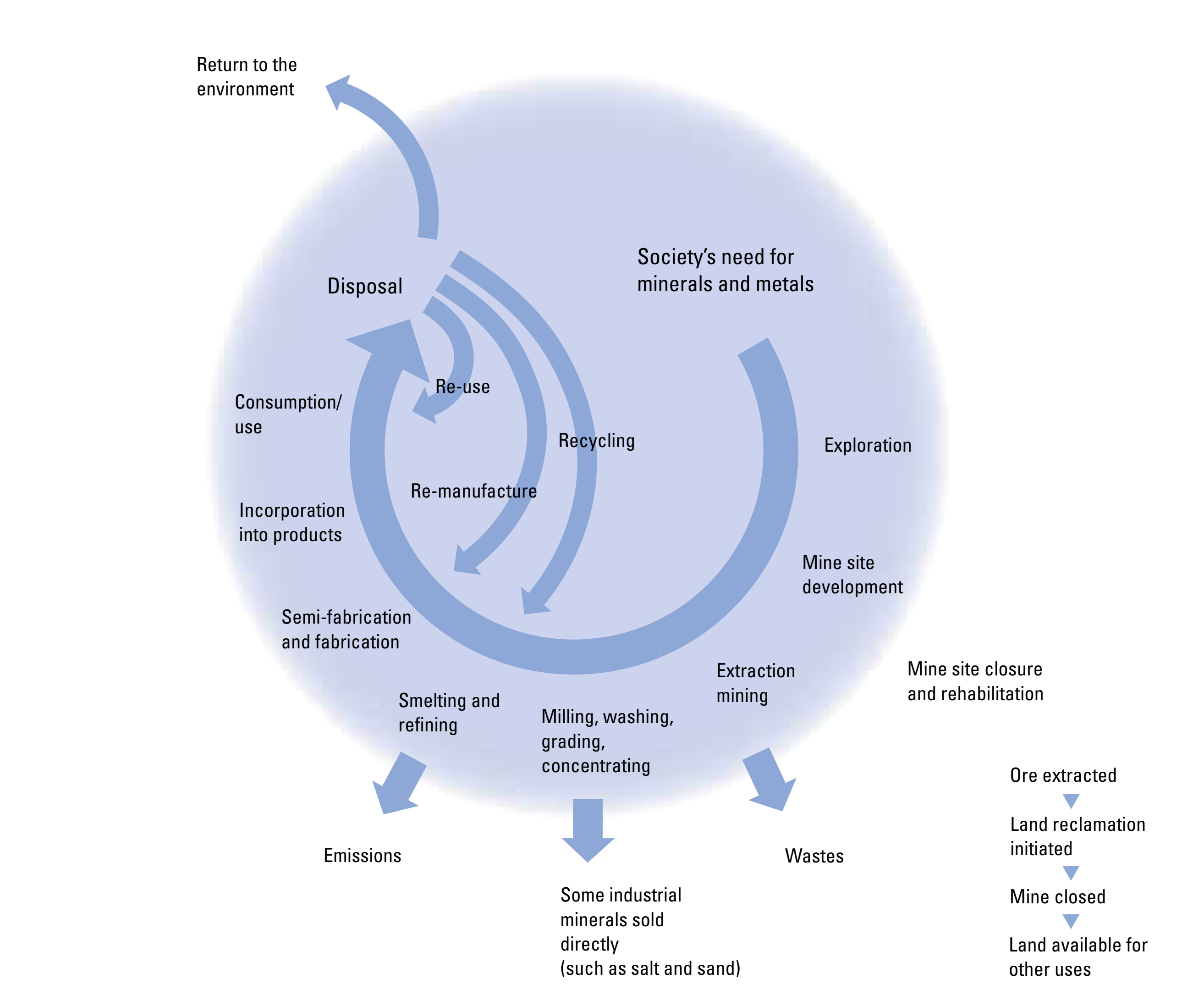
This chapter provides a summary overview of the minerals cycle (see Figure 2–1) from the location of minerals and exploration to the different types of end-uses of mineral commodities. It also considers employment levels, economic dependency on mineral production, and trends in mineral prices.

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.

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. The most commonly used definition is that a mineral resource is an *in-situ* concentration or occurrence of a material of

Figure 2–1. The Minerals Cycle
Source: Adapted from a diagram produced by Natural Resources Canada



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.[3] 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.

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.[4] 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 principal classes of mineral commodities are:

- metalliferous minerals (including base metals, ferrous metals, precious metals, and minor metals);
- energy minerals;
- industrial and construction minerals; and
- diamonds and precious gems.

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

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

Traditionally, minerals were most commonly produced in deposits in or near the regions where they were used. 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 because low-cost mineral deposits in these countries have in many cases been mined out. The difficulties and longer lead times in getting environmental permits and the higher labour costs for projects in the most industrialized countries have also contributed to this change. The extent of the migration varies widely with different minerals. It has gone further for many metals than for industrial minerals and construction materials.

However, the fact that some minerals are sold in global markets does not mean they are not also sold regionally or domestically. Domestic output to satisfy domestic demand accounts for a substantial share of global mining (for example in China, India, Brazil, and the US). This is true for metallic minerals as well as construction materials and industrial minerals.

This report focuses largely on globally traded mineral commodities. It is worth noting, however, that locally and regionally traded mine products often dominate in volume terms within regions.

Mineral commodities are supplied in different quantities, reflecting their scarcity and their value in use. Common mineral commodities can be produced cheaply, as they can be extracted from large deposits with economies of scale. Rare mineral commodities are expensive to produce because they tend to occur as trace elements in only a few deposits. They are also supplied in different forms. 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.

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)

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.[5] 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.[6] 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.

Location of Exploration and Production

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 the Asian financial crisis, recent mergers among the major companies, lower expenditures on exploration by the large multinationals, reduced access to finance for smaller companies, and a downswing in commodity prices. 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 Figure 2–2.)

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 mineral commodities, such as coal.

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

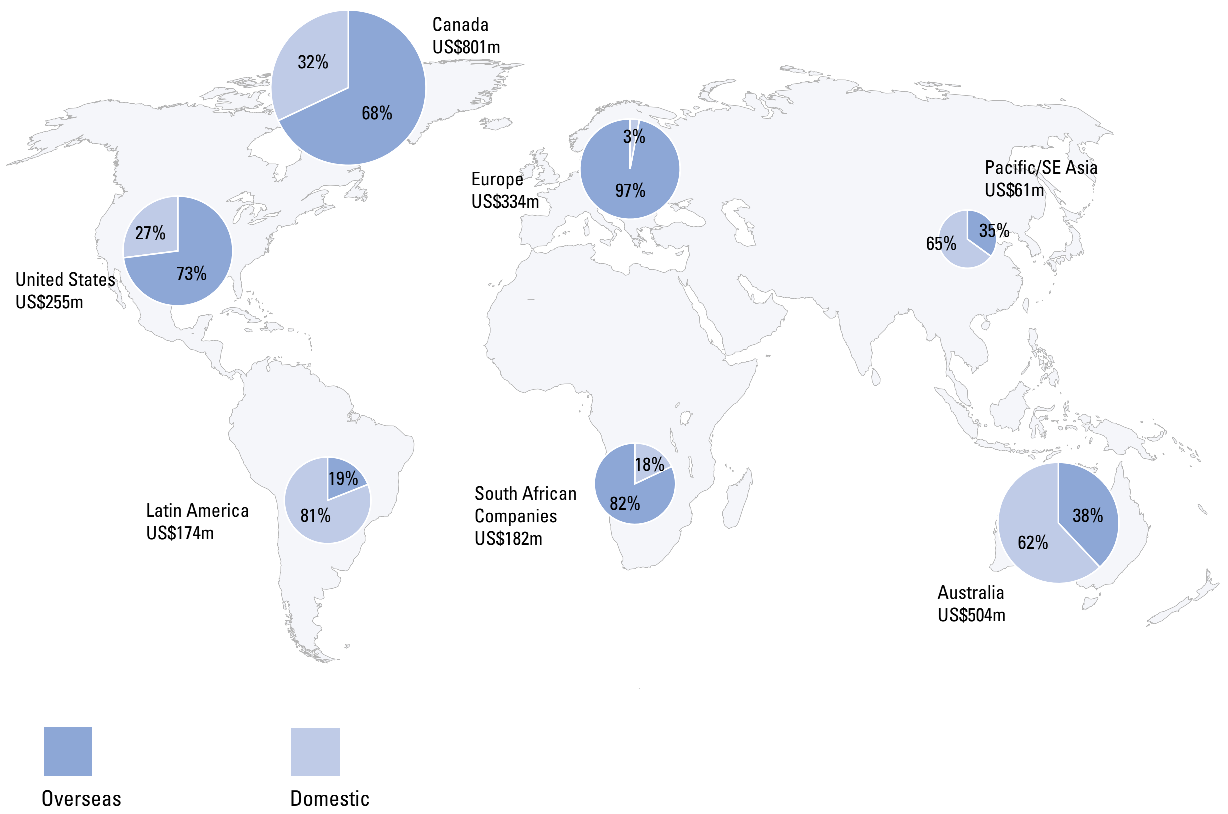
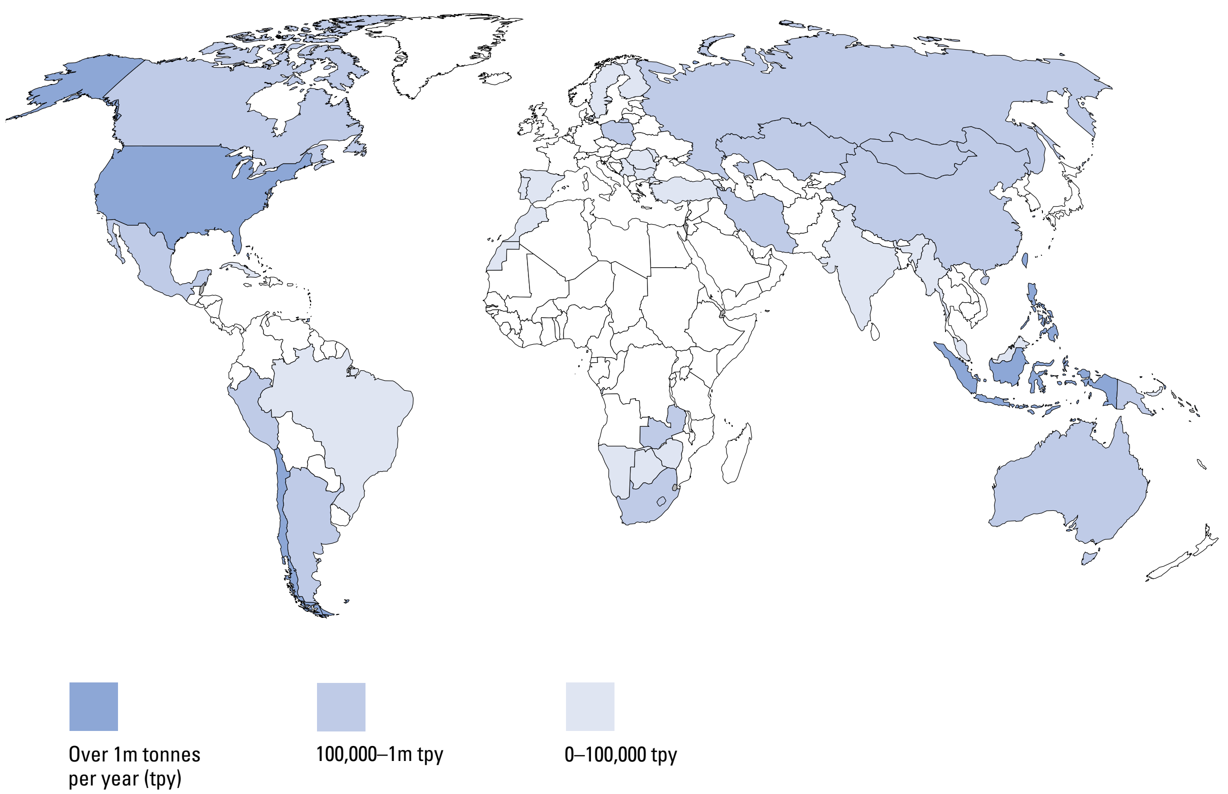


Figure 2–3. Producers of Copper by Size Group and Location
Source: CRU International



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 where they are found, but there is significant international trade in copper concentrates from sulphide ores. Important countries with refining but no mining are Germany, Italy, 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 users (such as Germany) and countries that are both (the US).

Aluminium

Bauxite, the main raw material for aluminium, is produced in large countries such as Brazil and Australia and in smaller countries such as Jamaica and Guinea. (See Figure 2–4.) There is little production, by contrast, in North America, Europe, or Africa (apart from Guinea).

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

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

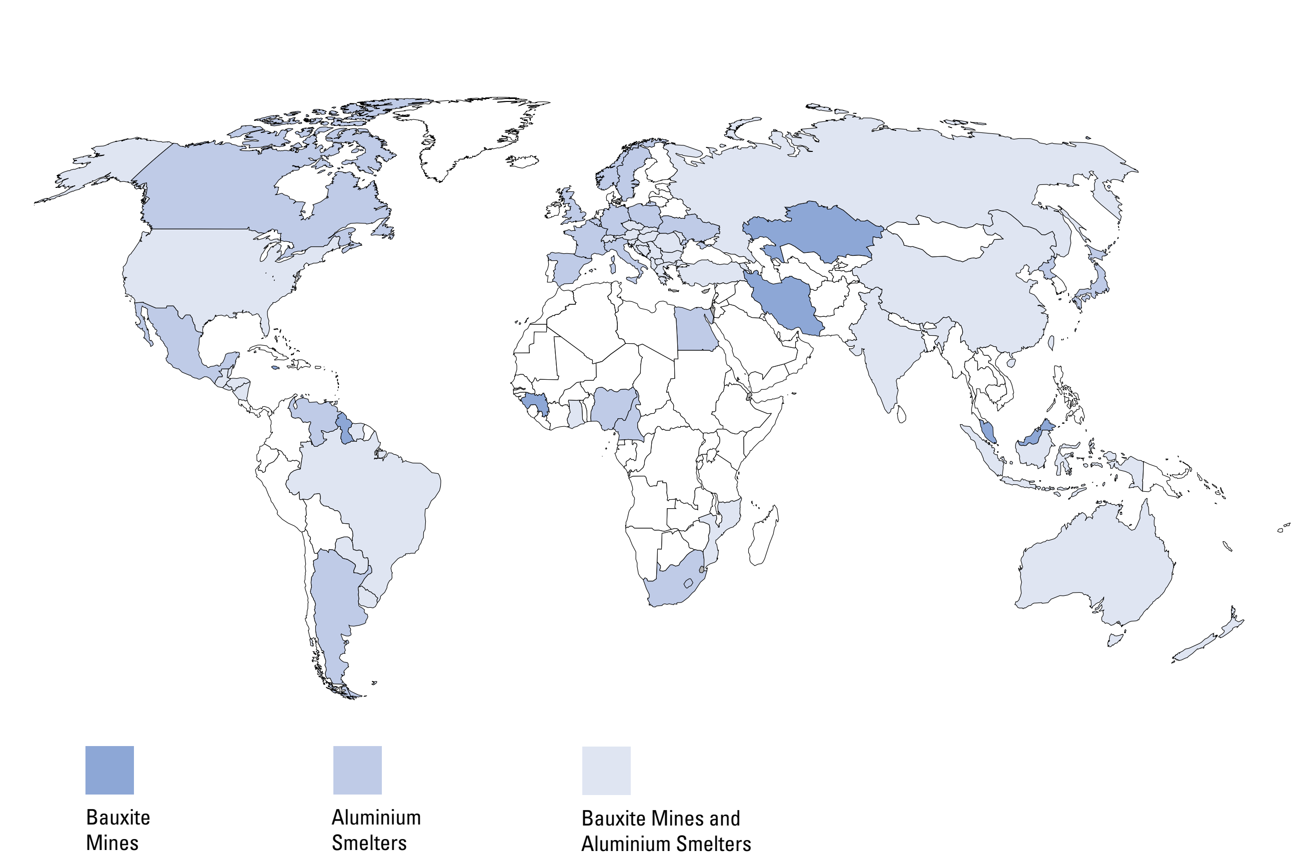
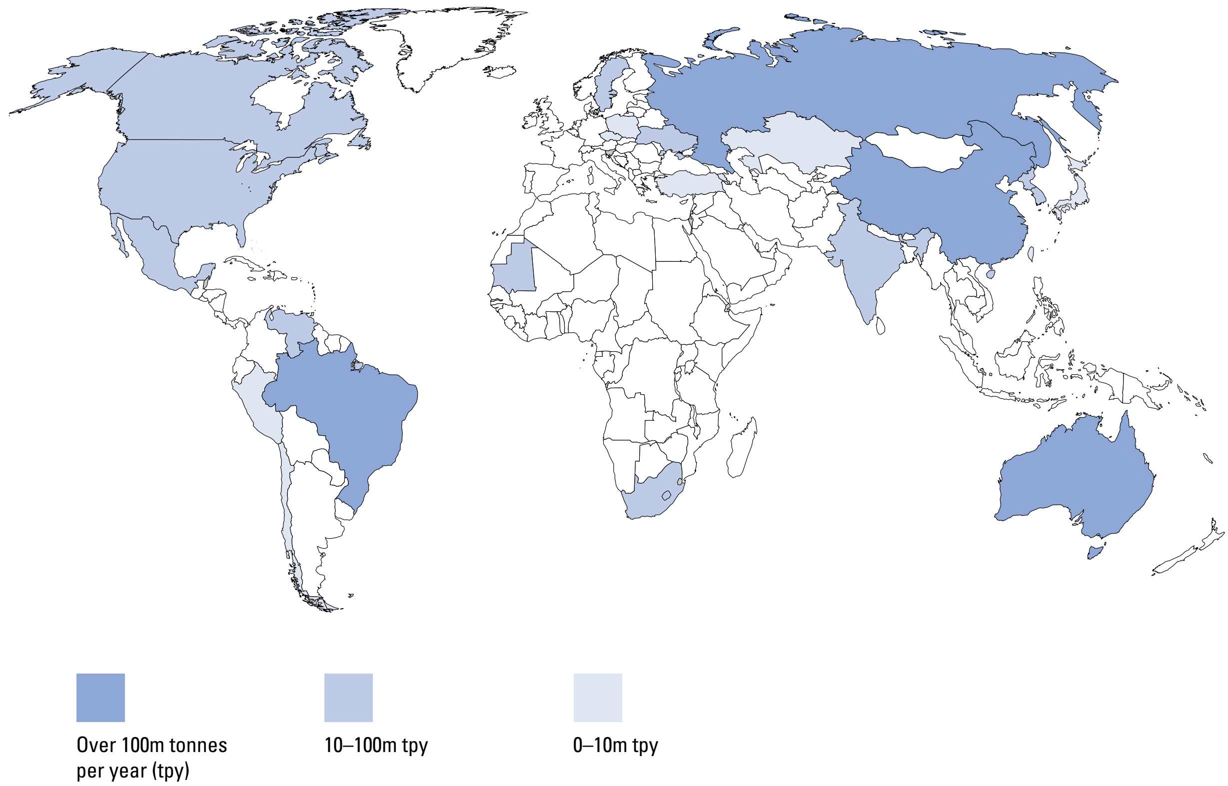


Figure 2–5. Producers of Iron Ore by Size Group and Location
Source: CRU International



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 use. Production in Africa is generally 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.

Most iron ore–producing countries also smelt iron ore (in blast furnaces or in direct reduction plants) and produce steel. Iron ore production and use are seldom in balance within any single country. Many countries that use iron ore do not produce it – 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 users 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

Most metallic minerals go through many processing steps in the transformation to a saleable metal or metallic-based product. The steps from the material in the ground to the processing plants also varies widely. In a classical 'concentrator', ore is crushed, ground down to very fine particles (which is quite energy-intensive), and then put through a range of processes to optimize the separation of valuable minerals from waste (or gangue). These processes include gravity separation, flotation, magnetic separation, electrostatic separation, and a range of other pre-treatments, involving an array of chemical processes or reagents.

In the aluminium sector, there is one generic process to commercial aluminium. Bauxite is mined and digested (or dissolved) in caustic soda at high temperature and pressure. From this liquor, pure hydrated alumina is precipitated. It is shipped globally as pure alumina powder. At smelter sites, the alumina and fluxes are fed to a 'pot line', where electricity is applied to reduce the alumina to aluminium metal. The metal is removed from the pots as a liquid and cast directly as ingots for shipping or future alloying, reheating, rolling, and shaping. Auxiliary plants for power, anode production, gas cleaning, and utilities mean that aluminium smelters are complex facilities.

Base metals occur normally as either sulphide or oxide minerals. The major processing routes are dictated by the specific valuable minerals, by the mix of minerals, and by the minor commercially interesting elements such as silver, gold, or platinum group metals that can be present. The minor components that present significant environmental or occupational health and safety risks, such as arsenic, bismuth, selenium, cadmium, and so on, may also dictate the processing route.

Base metal extraction plants are generally all different, but fall in two major process groupings: pyrometallurgical, working with very-high-temperature molten materials, and hydrometallurgical, working with normally aqueous solutions. Pyrometallurgical plants will typically contain separate or combined steps for melting, crude metal production, primary refining, casting, re-refining, alloying, and product casting. There will be additional steps for minor and by-product treatment and production. For hydrometallurgical processing, there is a primary ore dissolution step. This can be in acid or alkali at high or low temperature and pressure, or can be bacterially assisted (bioleach), depending on the ore and economically desirable products. The solution is then typically purified by selective precipitation of products, by-products, or impurities. Depending on the metal and the desired product, electrodeposition of product from solution is often used (electrowon copper, electrolytic nickel or cobalt, and commercial zinc).

In the iron and steel sector there are three main routes to production of finished steel. Integrated steel mills use iron ore as a feed. Iron ore is mined and may be upgraded prior to shipping to the steel works by a range of techniques. A major percentage of iron ore is shipped as hardened pellets, which involves crushing and grinding the ore, upgrading, forming into pellets, and heating to give the pellets strength for shipping and for proper operation of the blast furnaces where they are used. The heart of an integrated mill is the blast furnace where iron ore (typically as a pellet) is mixed with coke in a high-temperature reduction process to produce liquid iron. The coke is produced by heating coal in an oxygen-free atmosphere. Fuel gas is simultaneously produced and used in other parts of the steel works. The liquid iron is then typically 'blown' to steel by injecting oxygen, again producing a usable fuel gas. The steel is then refined and cast into slabs or shapes for downstream rolling to commercial product for shipping.

In electric arc steel making, scrap steel is remelted, refined, and cast into intermediate shapes. These shapes typically, with reheating, are passed through a variety of rolling mills that reduce the size and finalize the shape to specific commercial tolerances. Historically, scrap-based steel was used in low-value products. In the last decade technology has allowed casting of sheet and plate of commercial quality to challenge 'integrated' mills. Over the last 20 years a substantial portion of electric arc furnaces feed has switched to Direct Reduced Iron in place of scrap. In this, high-quality iron ore pellets are typically reduced to iron with natural gas products or other carbon-reducing agents. The Direct Reduced Iron is substituted for scrap (up to 100%) and typically results in higher quality steels. There is a wide range of emerging processes.

By far the largest tonnage of materials mined are coal, sand, and gravel. All of these have basic processing steps involving sizing, screening, washing and other waste separation steps prior to shipping.

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. The process of adding value to minerals is often known as 'minerals beneficiation'. (See Figure 2–6.)

Recycling, Re-use, and Re-manufacture

Mineral commodities vary in the extent to which they can be re-used, 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 industrial 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 mineral commodity. The key determinant is that the commodity 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 used in stainless steel and other non-ferrous alloys but the stainless steel and the alloys are themselves largely recycled.

If a metal is converted into a new chemical form, as in the production of chemicals, recycling is usually impossible. It is also often 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.

There are basically three different kinds of scrap: home or revert scrap is generated at the metal refining or processing stage and is usually reintroduced into the melting furnaces; new or prompt industrial scrap is produced by manufacturing processes, such as car production, and can be collected and recycled relatively quickly; and old or obsolete scrap is recovered post-use, which may be many tens of years in the case of much infrastructure and other capital goods. It is important to understand the differences among these three types in order to discuss the recyclability of various metals.

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).

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

Figure 2–6. Minerals Benefication Process
Source: Chamber of Mines of South Africa

Stage	Mineral benefication process category	Process flow-chart		Labour intensity	Capital intensity
1	Mining and producing an ore or concentrate (primary product)	Run-of-mine ores →	Washed and sized concentrates	High	High
2	Converting a concentrate into a bulk tonnage intermediate product (such as metal or alloy)	Mattes/slags/ bulk chemicals →	Ferro alloys/ pure metals	Low	High
3	Converting the intermediate goods into a refined product suitable for purchase by both small and sophisticated industries (semis)	Steel/alloys →	Worked shapes and forms	Low	High
4	Manufacturing a final product for sale	Worked shapes and forms →	Worked shapes and forms	Medium to high	Medium to high

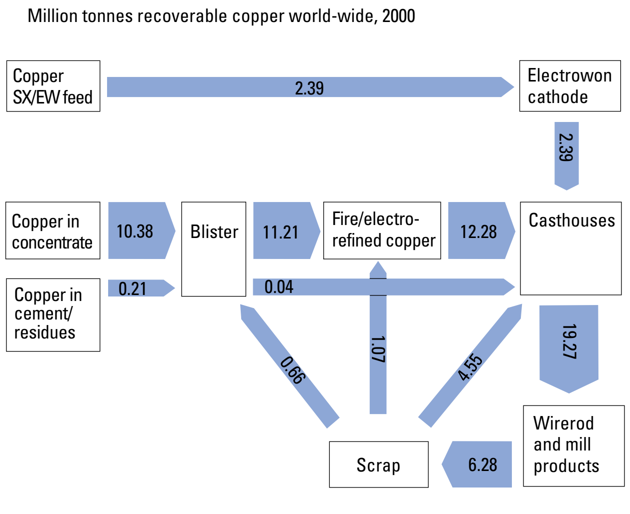
use. Steel food and beverage cans are often returned relatively soon after use. Other steel products have a longer life and some are eventually collected and returned. Most old motor vehicles are eventually shredded, and the scrap returns to the steel industry. Demolition scrap, including obsolete building elements, plant and equipment, rails, and so forth, is heavily recycled. In recent years, more than 50% of total steel use has been derived from recycled material.

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. Beverage cans are a major source of post-consumer scrap. Old post-consumer scrap is also recovered from buildings, other construction, and motor vehicles.

Estimates of the residence time for metals in use by society depend principally on assumptions regarding the life span 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 masks considerable variation between applications. In Sweden, 80–90% of the copper that has been produced and used 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 use 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 2–7.)

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. Overall recovery of lead is about 55% of use.[12] A high proportion of spent lead-acid 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 lead-acid batteries is over 90%. Secondary lead now accounts for 66% of total lead use in the US (59% if only old scrap is considered). 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.

Figure 2–7. Copper Processing Routes
Source: CRU International



On the other hand, 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, in contrast to 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.

It is important to remember that while recycling will be an ever-important component in the supply of metals, new virgin metal will be required in order to meet the demands of the world's growing population.

Employment in the Minerals Industry

No one knows how many jobs the minerals industry provides world-wide. The uncertainty becomes 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 provide this type of information.

Explorationists, 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] Since country-specific data include employment for both mining and oil and gas exploration, however, 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. 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]

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.[17] Employment numbers vary considerably among regions. The ILO data also indicate that the largest concentration of mining employment (60%) is in Asia.[18] This is concentrated in China, which has about half the world's mining employees.

Employment statistics for the minerals industry in a selection of the most important mineral-producing countries are given in Figure 2–8.[19] Many of these data relate to mining, while others include smelting and refining. The regional distribution of employment 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.[20] This is despite the fact that these regions produce just over 10% of the world's output.[21] In contrast, South America employs 10% of the labour force to mine over 40% of global copper supply.

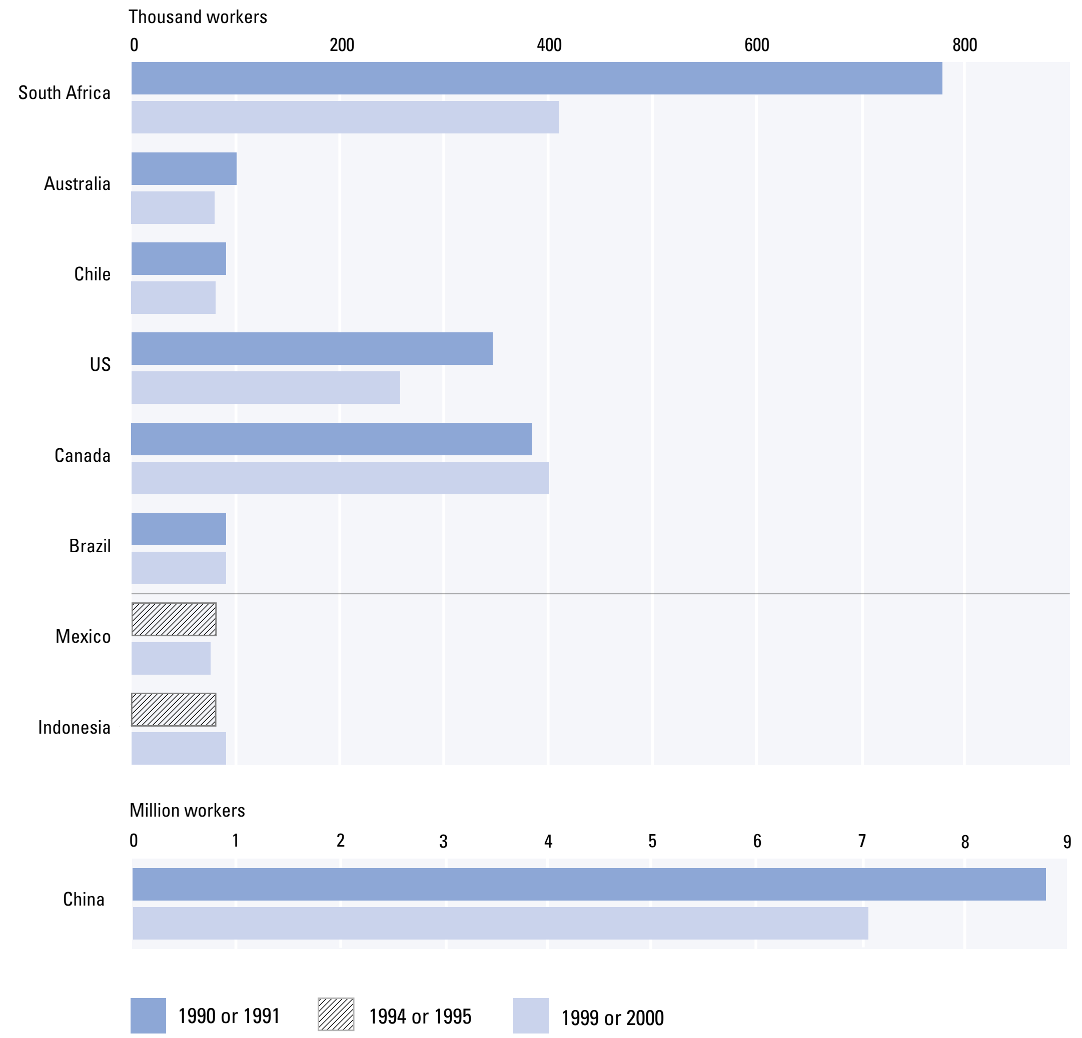
The relative importance of the minerals industry as a source of employment can be demonstrated by comparison with the total work force. In both Australia and Chile, employment in the mining industry for the period 1999-2000 represented almost 0.9% of the total work force.[22] In South Africa, the mining industry represented 2.7% of the economically active population or some 9% of workers in the non-agricultural formal sectors of the economy in 1999.[23]

The number of people employed in mining and minerals processing has been in decline. In some countries, such as the UK and Germany, employment has fallen as mines have closed or production has fallen and the sector became less important. More generally, most of the industry has become more capital-intensive due to technological change. In some parts of the world, such as Eastern Europe and the former Soviet Union, a decrease in employment is due to the changing structures of mining enterprises. 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.[24]

In many countries, employment is concentrated in certain parts of the industry. In Australia, the black coal industry is the largest minerals sector employer, accounting for approximately 25% of the work force in the minerals sector in 1999.[25] In India, the coal industry is estimated to have accounted for 70% of the 700,000 formally employed in mining in 1999.[26] In Chile, the copper industry accounts for over 30% of the mine labour force.[27]

Changes in employment levels have varied within countries, depending on the mineral being produced. For instance, in Chile between 1995 and 1999, employment in the copper sector dropped by 21%, compared with 60% in the gold/silver sector.[28] However, the non-metal mining industry in the same period increased employment by 61%.[29] Although employment in the US mining industry decreased by 31% between 1985 and 2000, within this sector the coal industry is the biggest employer and showed the largest decrease – almost 60%.[30] In Canada, employment in the minerals industry experienced a modest increase of about 3% in the 1990s.[31] Despite

Figure 2–8. Changes in Employment in Mining and Minerals Processing, Selected Countries, 1990s
Source: Government databases and websites



this, the chain of production that includes metal, non-metal, quarrying, and coal mining registered a decrease of 26%, while the structural materials sector showed an important recovery, with the number of employees increasing by about 60%.[32]

The impact on employment of the introduction of more capital-intensive technologies is demonstrated by the steel industry. Global steel production has risen by approximately 30% in the past 25 years.[33] Over the same period, estimated employment in the major steel-producing countries (excluding China) has fallen from around 2.5 million to fewer 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 steel-making processes and technologies.[34]

Employment figures are greater if downstream activities are included. The greatest employment in the minerals industry is often not at the mining stage. For example, the zinc industry is estimated to provide direct employment to about 210,000 people worldwide.[35] Zinc mining, excluding that occurring in China, employs about 55,400 people, or 26% of the total.[36] Zinc refining and smelting employs an estimated 65,000 people and the zinc oxide industry a further 6000 people.[37] 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.[38]

Mineral-Dependent Economies

Mineral production and processing are important economic activities in many parts of the world. Classifying mineral dependence is difficult because of

Table 2–2. Steel Industry Employment in Selected Countries, 1974 and 2000

Country	1974	2000	Decline
	(thousand)		(per cent)
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.

the number of ways in which this can be measured. Common measures record mineral output as a percentage of gross domestic product (GDP) or the value of minerals in relation 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 2–9), 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.)

The importance of mineral production to regional and national economies is demonstrated by the findings of MMSD's regional processes. Australia relies substantially on mineral commodities for export income – 45% of its merchandise export income, accounting for 9% of GDP, comes from basic mineral commodities.[39]

In the Southern African Development Community region, mining output constitutes about 8% of GDP. In South Africa, which is responsible for more than 70% of the region's mining output, the figure is 6.5%.[40] The range within Southern Africa is considerable – from 34% of GDP in Botswana to less than 1% in Mozambique.[41] 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.[42]

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.[43] In Brazil, mining activities (including oil and gas extraction) account for 8.5% of the GDP and 32% of national exports.[44] Chile obtains 10.3% of its GDP and 44% of the value of its nationals exports from mining.[45] And mining in Peru contributes almost 50% of the exports and 5.5% of the GDP.[46]

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

Figure 2–9. Countries Dependent on Ore and Metal Exports, 1999

Source: Based on data arranged by Eggert (2001). Data source: World Bank (2001b) and (for data on ore and metal exports in DR Congo, Mauritania, Mongolia, Tajikistan, and Zambia) UNCTAD (2001).

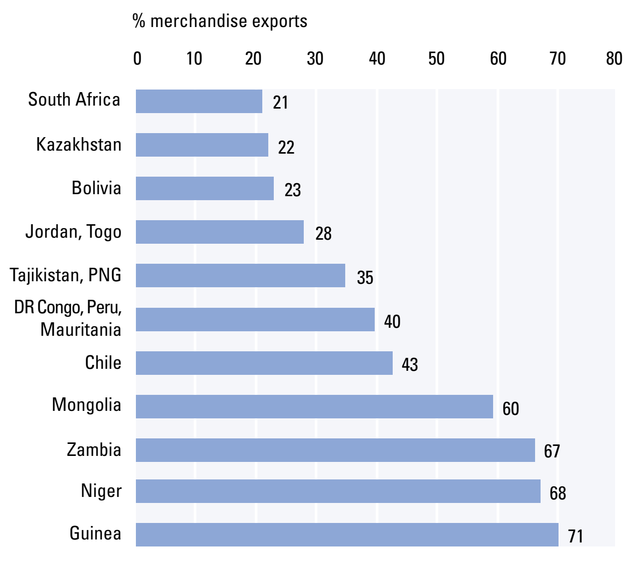


Table 2–3. Mineral Dependence in the Structure of Exports, 1999

Country	Ores and Metals	Fuels	Total
	(per cent of merchandise exports)		
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[a]	0	66
Kazakhstan	22	42	64
Mongolia	60[a]	0	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[a]	0	40
Mauritania	40[a]	0	40
Australia	17	19	36
Papua New Guinea	35	0	35
Tajikistan	35[a]	0	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

[a] Includes SITC 522.66 in addition to SITC Section 3.
Source: Eggert (2001), based on World Bank and UNCTAD data.

is from the metals sector).[47] In Canada, the mining industry contributes 3.7% of GDP and about 14% of exports.[48] Construction and industrial minerals form a significant percentage of total mineral production in the US and Canada. (See Figures 2–10 to 2–13.)

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.[49] Some of these are among the world's largest producers of natural stone, feldspar, and kaolin.

Mineral Markets

The quantity and type of mineral commodities used varies considerably between countries. Historically, Europe, Japan, and the US have been the largest mineral-using regions. But this is changing as markets mature, especially as use increases in Brazil, China (see Box 2–1), and other Asian countries, such as Malaysia and Thailand.

Europe and Asia are the two principal regions using most of nine metals and minerals: aluminium, lead, zinc, copper, nickel, steel, gold, coal, and phosphate rock. (See Table 2–4.) The European Union 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).[50] 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 use depends on the proximity of phosphoric acid and phosphate plants as well as on the location of final use; North America and Asia are the largest regions if use in this case. Africa is also an important user, largely because Morocco is the largest producer in the world. It should be noted that

Figure 2–10. Value of Non-fuel Mineral Products in Canada, by Type, 1999
Source: MacDonald (2002)

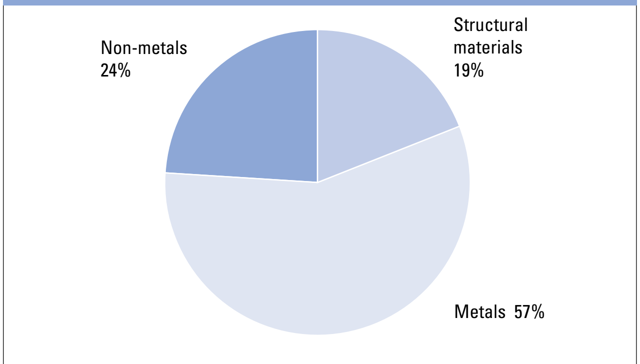


Figure 2–11. Top Five Mineral Products from Canada, by Value, 1999
Source: MacDonald (2002)

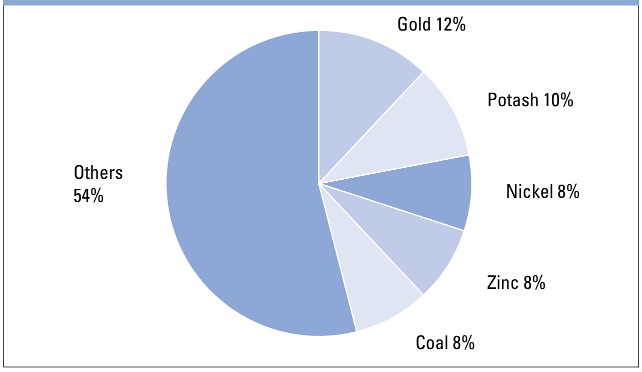


Figure 2–12. US Non-fuel Minerals Production Value, 1995 and 2000
Source: MacDonald (2002)

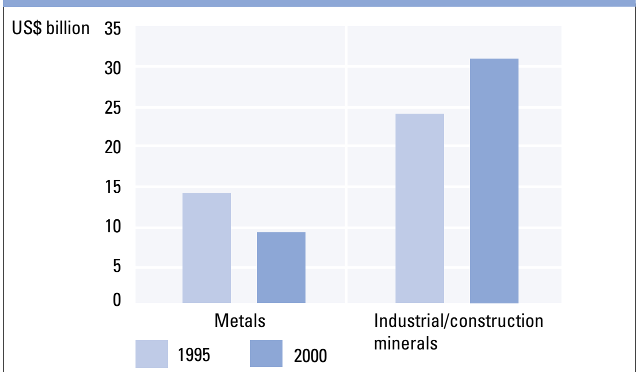
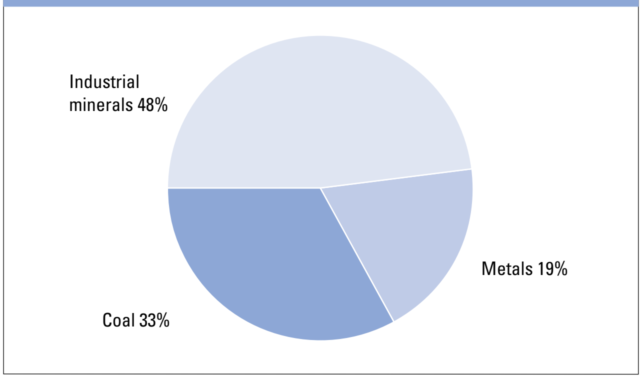


Figure 2–13. US Mineral Production Value, by Sector, 1998
Source: MacDonald (2002)



Box 2–1. 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 using, importing, and exporting during its rapid industrialization. Annual use grew at double-digit percentage rates through the 1990s. Chinese use 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 user. 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 (2001b).

data on use only record the countries of first use. There is considerable trade in semi-manufactured and mineral-containing products.

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. Americans use about 600 kilograms of metals per person a year.[51] 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.[52] Several studies have proposed that intensity of use of a mineral (the use of a mineral commodity 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.[53] (See Figures 2–14 and 2–15.) 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 mineral commodities. As economies mature, all other things being equal, they move to a less materials-intensive phase, spending 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 mineral commodities is falling over the long run.[54] But it remains difficult to forecast future demand given all the factors that can affect intensity, some of which,

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)

Figure 2–14. Copper per Capita Intensity of Use, 1999
Source: World Bureau of Metal Statistics and World Bank

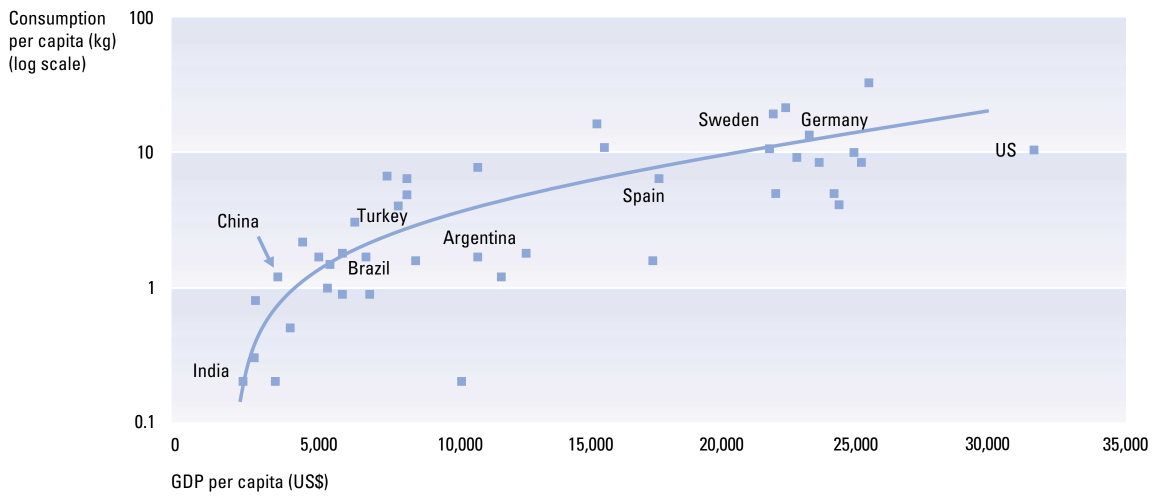
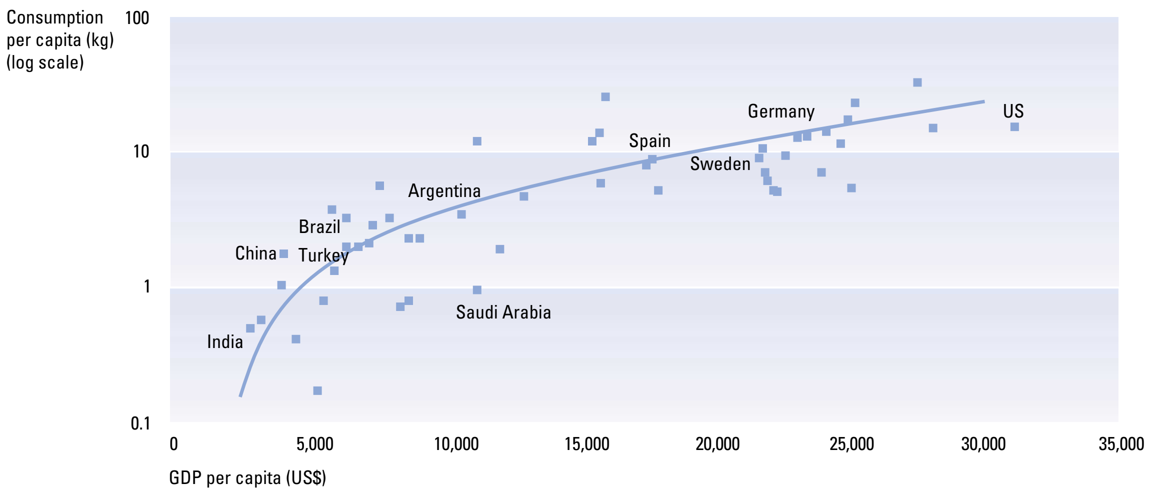


Figure 2–15. Aluminium per Capita Intensity of Use, 1999
Source: World Bureau of Metal Statistics and World Bank



such as new technology, are impossible to predict.

End-Uses and Mineral Commodities

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.

There are 31 metals in the standard personal computer.[55] A modern jet engine is composed of 41% titanium, 34% nickel, 11% chromium, 7% cobalt, and lesser amounts of aluminium, niobium, and tantalum.[56] 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.[57] Mineral commodities have 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 found in all sectors of

Table 2–5. Common Uses of Mined Products

Aggregates	Concrete, building construction, roads, bridges, sewer and 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 and 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 and 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 and extinguishing systems, acrylic fibres, medicine, cosmetics
Borates	Fertilizers, disinfectant, detergent, water softener, corrosion inhibitor for antifreeze, 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	Bricks, ceramics, nutritional additives, concrete, mortar
Coal	Electricity generation; steel making; chemical manufacture; production of liquid fuels, plastics and polymers
Cobalt	Superalloy (used in jet engines and 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, and helicopter motor spindles), automotive parts (wire, starter motor, bearings, gears, valve guides), industrial applications and machinery (tools, gears, bearings, turbine blades), furniture, coins, crafts, clothing, jewellery, artwork, musical instruments, cookware

Table 2–5. Common Uses of Mined Products (continued)

Dolomite	Building stone, nutritional additives
Feldspar	Glass, ceramics, enamel, tile glazes, source of alkalies and alumina in glazes, paint, plastics, mild abrasives, welding electrodes
Fluorspar	Steel making, aluminium, fluorocarbons (used in refrigerants, blowing agents, solvents, aerosols, sterilants, fire extinguishers)
Gallium	Compound semiconductors in mobile phones, glass and mirror coatings, transistors
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 and friction linings, battery and fuel cells, pencil fillings, seals and gaskets, conducting linings on cables, antistatic plastics and rubbers, heat exchanger, electrodes, apparatuses and linings for the chemical industry
Gypsum	Building construction (plasterboard, plaster and cement), agriculture, glass, chemicals
Iron	Steel making, alloy
Kaolin	Filler for paper, rubber, plastic, paint and adhesives, refractories, ceramics, fibreglass, cement, catalyst for petroleum refining
Lead	Batteries, cable sheathing, lead crystal, solder and 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	Steel making, 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 and paints, nuclear reactors and rocket engine nozzles, manufacture of Epsom salts, magnesia, cosmetics, insulating material and disinfectant, fire retardant
Magnesium	Alloys used for aircraft, car engine casings, and missile construction; refractory material; agriculture (feed and fertilizer); filler in paper, paints, and plastics; automobile and machinery; ceramics; fire retardant; pyrotechnics and 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

Table 2–5. Common Uses of Mined Products (continued)

Phosphorus	Safety matches, pyrotechnics, incendiary shells, smoke bombs, tracer bullets, glass, calcium phosphate (used to produce fine chinaware), steel making, 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 and metal polishing, dental supplies and paste, agriculture, sport and 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 and 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 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 lightweight alloys, aircraft components (jet engines, aircraft frames), automotive components, joint replacement (hip ball and sockets), paints, watches, chemical processing equipment, marine equipment (rigging and 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), 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), 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.

manufacturing, although some are particularly large-volume users, such as transportation and appliances. Construction is also important. Some high-value metals are used in very small volumes in specialized uses. Non-metallic mineral commodities are also used in manufacturing, but some mineral commodities 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.[58] Steel and copper use 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.[59] 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 2–2.) 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.[60] 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 2–2. 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, led 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 be an 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).

Consideration of the social, economic, and environmental impacts of different mineral commodities is also key. For example, copper is 30% more efficient at transmitting electricity. Replacing copper with aluminium in electricity transmission would therefore lead to an increase in any global warming effects associated with the provision of electricity. Life-cycle assessment provides a useful tool for the comparative analysis of the various impacts. (See Chapter 11.)

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) world-wide. 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 metal.

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.

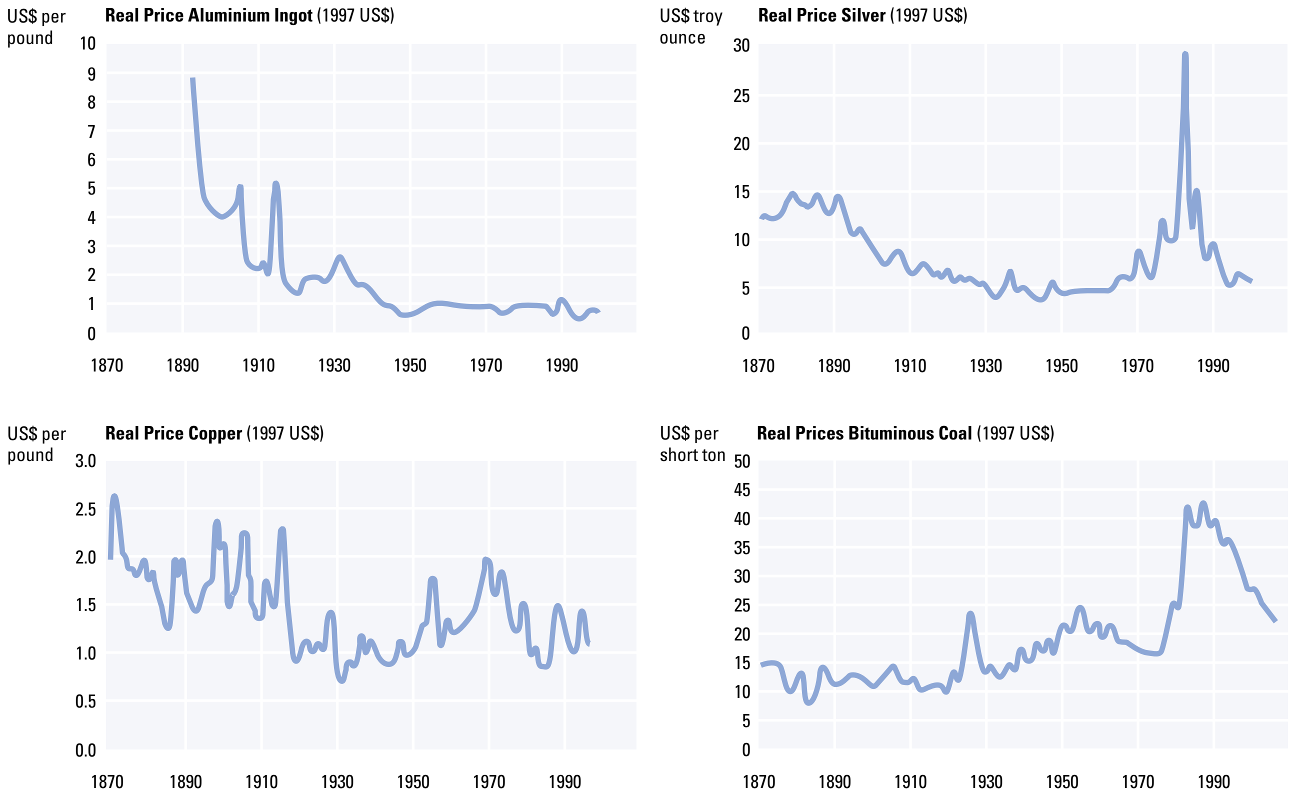
Long-term descriptions of price depend on the methods used to account for inflation, all of which have relative merits.[61] Attempts have been made to use labour costs, the price of goods that do not result from resource extraction, and general national price indexes. Potter and Christy made one of the 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.[62] 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.[63] (See Figure 2–16.)

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.

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 commodity 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.

Figure 2–16. Real Prices for Selected Mineral Commodities, 1870–1997
Source: Tilton (2002)



Endnotes

[1] Unless otherwise indicated, statistical information in this chapter is from CRU International (2001).

[2] Wedepohl (1995).

[3] For more detail on these definitions, see Canadian Institute of Mining, Metallurgy and Petroleum (1998).

[4] US Geological Survey, at http://minerals.usgs.gov/minerals/pubs/mcs

[5] Regueiro et al. (2000).

[6] 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 mineral commodities. 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 used.

[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 different proportional shares of direct and indirect employment and different stages of the chain of production 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 vary between countries.

[14] ILO (2001b). The data referred to from the ILO are 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] Bureau of International Recycling, at http://www.bir.org/biruk/index.asp.

[18] ILO (2001b).

[19] *South Africa:* Government of South Africa, Department of Minerals & Energy (2001) p.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] CRU International (2001).

[21] Of the 60%, 160,000 are in China and 60,000 in the former Soviet Union.

[22] Data sources as per Figure 2–7.

[23] South African Minerals Bureau (2000) p.8.

[24] Government of South Africa, Department of Minerals & Energy (2001) p.9.

[25] Hancock (2001).

[26] Tata Energy Research Institute (2001).

[27] Chilean Copper Commission (2001).

[28] Ibid.

[29] Ibid.

[30] National Mining Association (2001).

[31] Mining Association of Canada (2001).

[32] Ibid.

[33] IISI (2001), http://www.worldsteel.org.

[34] Ibid.

[35] International Zinc Association (2001) web page. http://www.iza.com.

[36] Ibid.

[37] Ibid.

[38] Ibid.

[39] Hancock (2001).

[40] Government of South Africa, Department of Minerals and Energy (2001) p.5.

[41] MMSD Southern Africa (2001).

[42] Ibid.

[43] Enriquez (2001).

[44] Barreto (2001).

[45] Lagos et al. (2001).

[46] Glave and Kuramoto (2001).

[47] MacDonald (2002).

[48] Ibid.

[49] Regueiro et al. (2000).

[50] Regueiro et al. (2000).

[51] Jeffrey (2001).

[52] BGR Hannover (1995), cited in Regueiro et al. (2000).

[53] See Radetzki and Tilton (1990).

[54] See Tilton (2002).

[55] Jeffrey (2001).

[56] Ibid.

[57] Ibid.

[58] Considine (1991).

[59] Moore and Tilton (1996).

[60] Considine (1991).

[61] Tilton (2002) Chapter 4.

[62] 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).

[63] Howie (2001).