CHAPTER 5

CASE STUDIES ON MINERALS

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The purpose of this chapter is to apply the general analysis developed in Chapter 4 to a range of individual minerals to see what conclusions can be drawn about need and availability. While it would be interesting and valuable to apply these methods to any mineral commodity, space and availability of data require a selection of a limited number from among the over 90 products commonly sold. While materials such as sand and gravel represent a high fraction of total mining activity, they tend to be sold in local markets, each with its own set of issues and concerns. It seemed appropriate therefore to select minerals of major economic importance that are traded in world markets.

Other minerals, such as zinc, limestone, or gemstones, would also have been very interesting. And a study of industrial clays had to be excluded for space reasons.[1] It was impossible to cover everything. The length of each section should not be taken as an indication of anything other than what is needed to express the issues and is not intended to favour or disfavour any commodity.

This includes most metals. The first section of this chapter therefore focuses on several metals, starting with an overview and then turning to specific studies of steel, aluminium, copper, lead, and gold. The second section treats a fuel mineral (coal) and an industrial mineral (potash).[2] Most of what can be said about physical availability was set out in Chapter 4, but environmental, social, and other constraints on availability will be touched on for each of these minerals.

The Metals

An Overview

By sheer volume, steel is by far the most important industrial metal. (See Table 5–1.) Steel consumption in 2000 was well over 30 times the consumption of aluminium, the second most widely used metal.[3]

Over the last 25 years, growth in demand for metals has been fastest in regions undergoing rapid development – the transition countries – which have a substantial demand for use in infrastructure, such as housing, water, and electricity supply. (See Figures 5–1 and 5–2.) The rapid growth of demand for lead in these regions reflects the growing demand for lead batteries, many of them for cars. Transition countries, in general, have a moderate level of industrialization and infrastructure, and are at the stage

Table 5–1. Production, Consumption, and Recycling of Metals

	Steel	Aluminium	Copper	Lead	Gold
Cumulative total world production	32 billion tonnes of crude steel	573 million tonnes	409 million tonnes[a]	204 million tonnes[a]	128,000–140,000 tonnes
Recent annual world consumption	837 million tonnes	24.9 million tonnes	15.1 million tonnes	6.2 million tonnes	3948 tonnes
Consensus forecast for growth in consumption over next 10 years	0.8%	3%	2.9%	1.1%	4.3%
Share of total metal consumption derived from recycled material	US 79%, Western Europe 55%, East and SE Asia 52%, rest of western world 46%	North America 35%, Western Europe 31%, Asia 25%, world 29%	Western world 35%	US 70%, rest of western world 55%	Western world 35%

[a]World production from 1900–2000.
Source: CRU International; copper and lead production from USGS.

Figure 5–1. Metals Consumption: Regional Growth Rates, 1975–2000
Source: CRU International

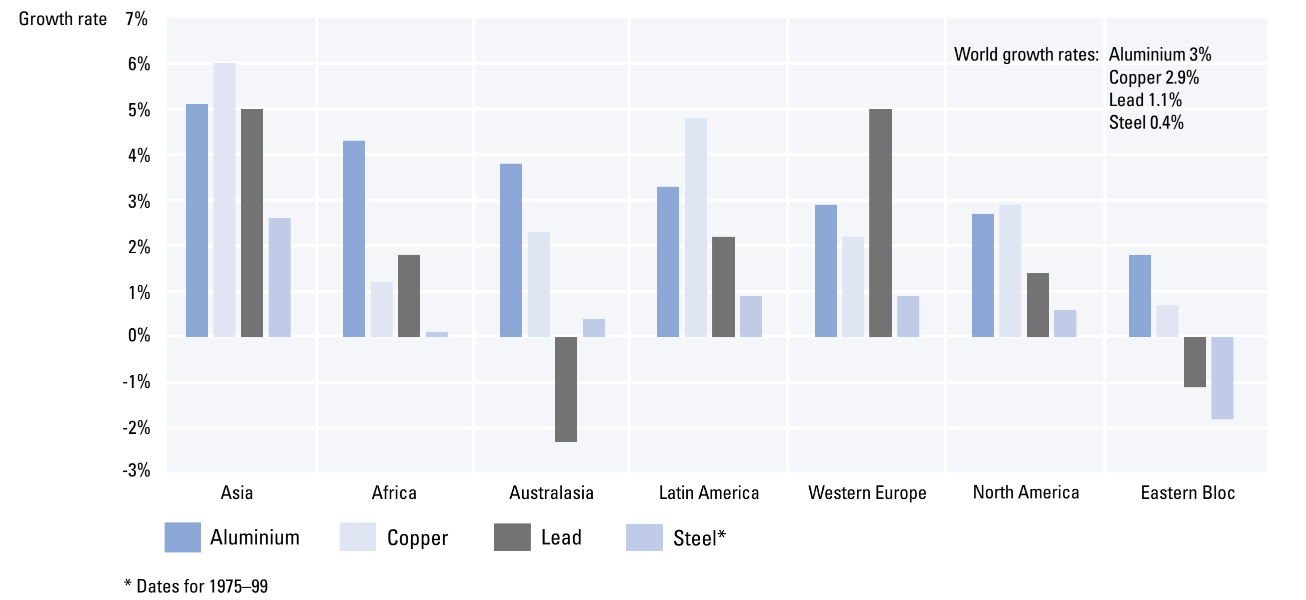
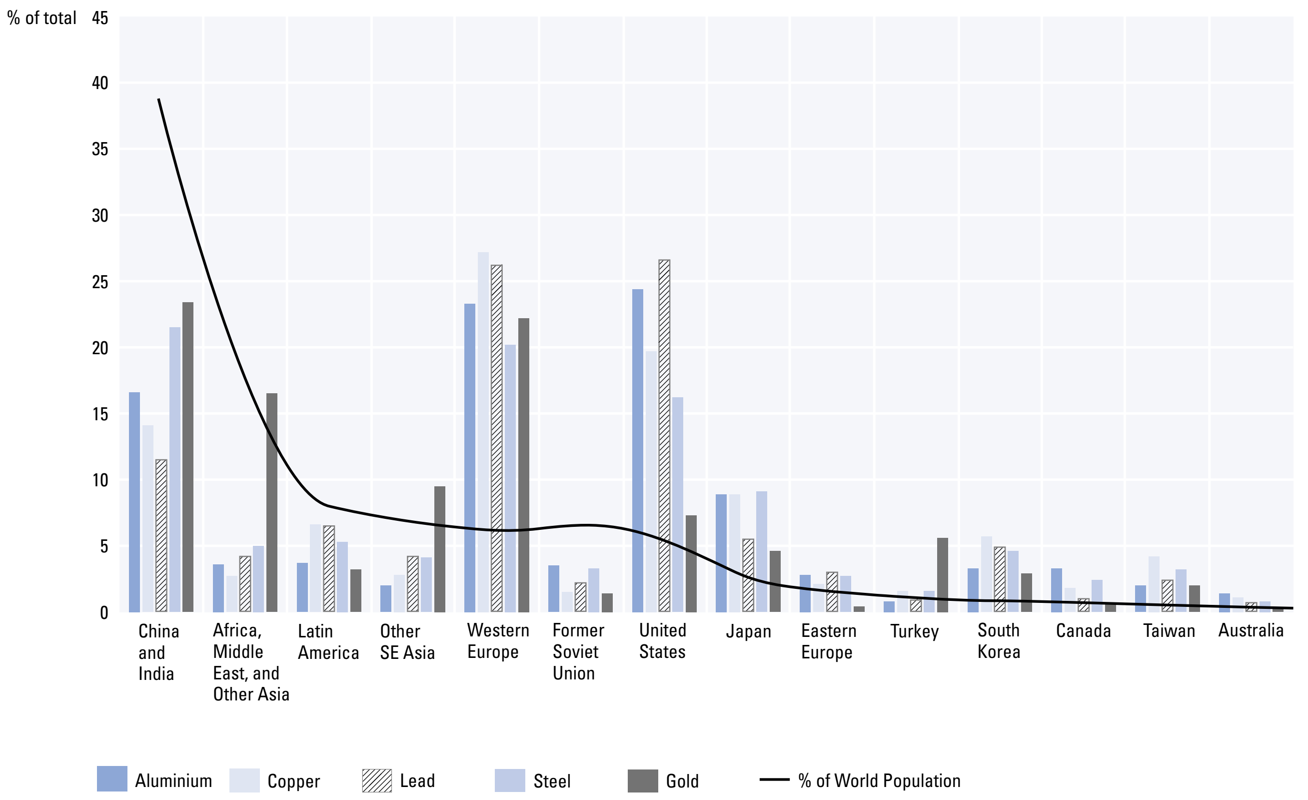


Figure 5–2. Consumption of Metals Compared with Population, by Region and for Selected Countries, 2000
Source: CRU International



when faster growth in metal consumption can be expected. In industrial economies, demand for metals grew at rates below the world average over the last 25 years, since demand for infrastructure spending was lower.

The distribution of steel demand between the industrial and transition countries shows less disparity than in the case of the non-ferrous metals, reflecting the fact that steel is a basic industrial raw material that is essential even in the least developed countries.

Not surprisingly, given the use of metals in a wide variety of industrial and consumer applications (see Table 5–2 and Figure 5–3), there is a reasonably strong positive relationship between consumption per capita and gross domestic product (GDP) per capita. (See Chapter 2.) A significant distinction emerges between countries with per capita GDP above and below US$10,000. A large number of countries are clustered below this level, and almost all of them use less than 6 kilograms (kg) of aluminium, 5kg of copper, and 200kg of steel per capita. (See Table 5–3.) Above this cut-off point, consumption per capita rises quite rapidly because this appears to be the level at which substantial semi-fabricating industries develop to serve domestic demand as well as export markets.

It should be noted that statistics on metals use can be misleading. As consumption is measured by the amount of metal produced and imported, it does not take account of whether products made from the metal are sold domestically or exported. Thus South Korea and Taiwan appear to have extraordinarily high metal consumption levels because they are heavily involved in metal manufacturing and are major exporters of metal products and lead batteries. Measured at the point of end-use, the real consumption of metals in these two countries would be much lower. At the same time, countries at the early stages of development do not use enough of the final product to justify local manufacture, so they import metal-intensive goods, which are not recorded in metal consumption statistics.

Recycling has an important role to play in the transitions towards sustainable development. In 2000, 15.6 million tonnes of aluminium scrap were recycled world-wide. The recycling rate is the percentage of

Table 5–2. Competing Metals or Materials in Some Large End-Use Applications

Industries	Competing metals/material
Transport:	
Motor vehicles	*Cast iron* and *steel* are used in the construction of motor vehicles. The need to reduce the weight of automobiles has led to the introduction of *aluminium* in engine parts and increasingly in body parts. Aluminium offers the same or better strength with lighter weight compared with steel, although the cost of aluminium per tonne (four or five times more than steel) is prohibitive. The steel industry has responded by demonstrating that cars can be built of steel and still achieve much of the weight savings associated with cars containing high proportions of aluminium. Other materials, such as *magnesium* and *engineering plastics,* are also competing for use in automotive components.
Aircraft frames	*Aluminium* won its first mass market when it was used as an alternative to *balsa-wood* in the manufacture of airframes.
Telecommunication:	
Cables	*Copper* lost part of this market to *optic fibres*, which are now used for new installations between major centres. Optic fibres are increasingly used in the branch connections, but copper remains the favoured material for the final connection to the end-user. *Mobile telephones* pose a new challenge, since no cabling is required.
Electrical transmission	*Aluminium* competes with *copper*, having won the market for overhead conductors. The lower resistivity of *copper*, however, makes it more effective as a conductor where space is restricted, hence its virtually unchallenged market for house wiring and power cables that are laid under ground.
Packaging	*Tinplate* was the first material to be used to make beer cans. *Aluminium* gradually made great inroads into this market, to the extent that tinplate was eliminated from this end-use in the US and to a large extent in Europe. This was a marketing triumph for the aluminium industry, which sold the concept that aluminium is recyclable (which is equally true of tinplate) and that aluminium cans are lighter and more convenient to the user. Recently, tinplate has recovered some market share, particularly in Europe. *PET* (a type of plastic) has gained market share for large containers because of convenience in use, but it cannot be conveniently recycled. *Glass* bottles can be re-used, and have traditional appeal in some countries. *Paper*, *plastic*, and *laminates* compete with aluminium foil in its packaging applications.

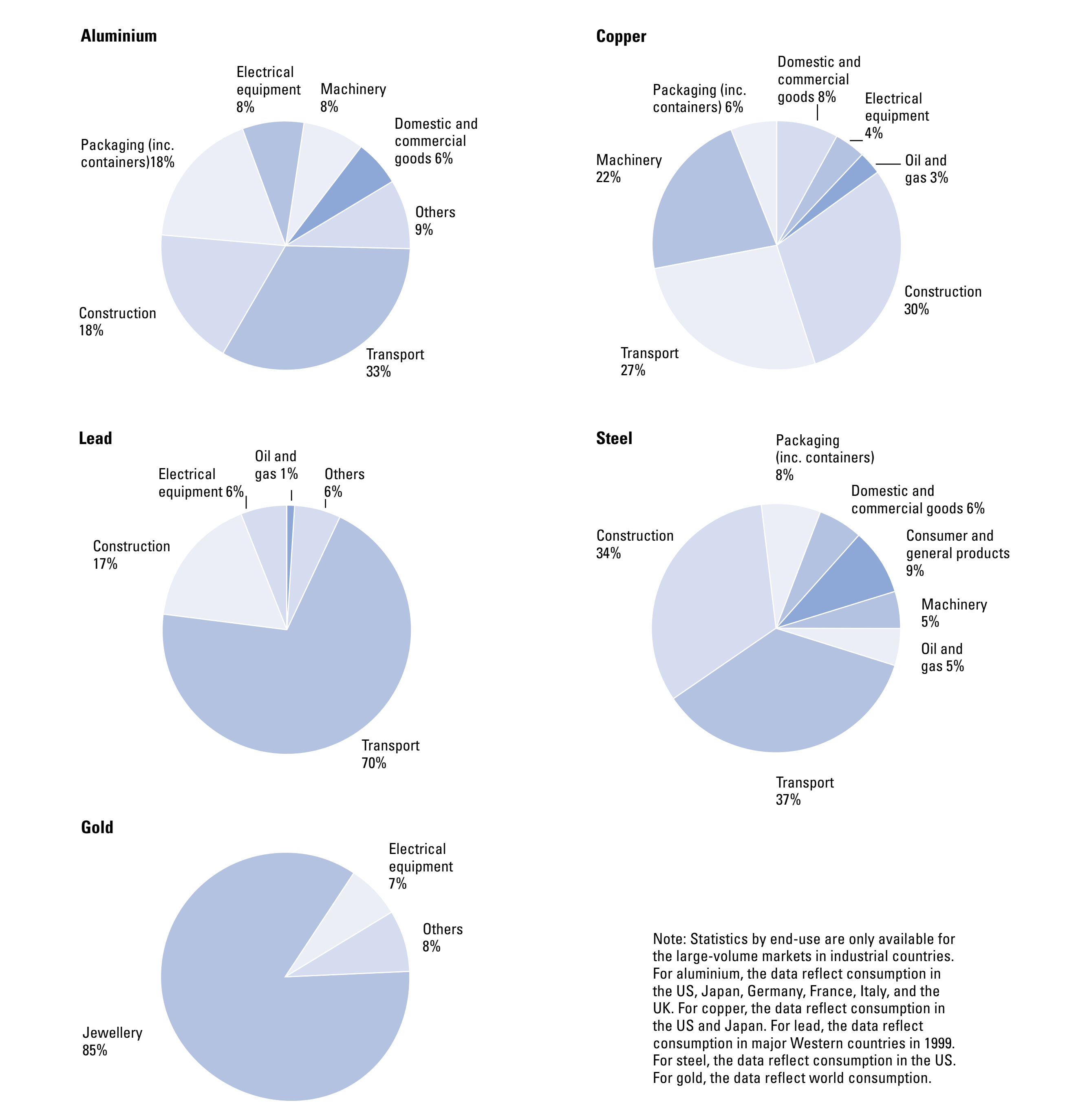
Table 5–2. Competing Metals or Materials in Some Large End-Use Applications (continued)

Industries	Competing metals/material
Construction:	
Roofing	Galvanized *steel* has always been seen as the simplest and cheapest form of metallic roofing or panelling for buildings. It tends to be replaced with better-looking or more technically efficient products as incomes rise. This market is heavily influenced by climate, tradition, and the skills of the local building trade. The selection of material depends in part on the willingness of the consumer to pay a higher price for a longer-lasting material. It also depends on the training and skill of the local building trade with each material. *Copper* is widely used in Germany and Central Europe, where snowfall is heavy. *Zinc* is traditionally favoured in France and Belgium, while the UK market prefers *lead*. Alternatives include *slate*, *tiles*, and *roofing felt*.
Window/door frames	*Aluminium* displaced *steel* and *wood* in window and door frames, but has more recently lost some market share to *plastic* window frames. The deciding factors are product design and the performance of the product when exposed to variations in temperature and climate.
Residential housing	Structural *steel* competes with *timber* in the construction of residential housing. There has been a campaign to promote steel-framed houses, especially in the US, but so far without any great success.
Heat transfer	*Aluminium* competes with copper in this sector and particularly in car radiators, where *aluminium* has been successfully promoted. Plastic plumbing tube has also taken some market share from *copper* and *brass*, chiefly on the basis of price.
Coins	*Copper alloy* coinage is threatened in some countries by *aluminium* and *zinc*, and more widely by the use of notes rather than coins. The use of *credit cards* in place of cash is also a form of substitution.
Batteries	*Lead* competes with other materials in the development of batteries for electrically powered automobiles. The lead-acid battery is bulky, has a limited capacity (and therefore range), and needs time to be recharged. Many alternative battery technologies for the motive force in electric cars are being considered, including: • solid oxide fuels cells, • hybrid fuel cell-battery combinations, • metal hydride batteries, • zinc-air batteries, and • lithium ion/polymer batteries. Fuel cells probably offer the most promising prospects, but none has yet achieved commercial acceptance compared with lead on any wide scale. Lead still dominates the market for conventional starting, lighting, and ignition batteries, the major market for lead.
Engineering	In engineering applications, the choice of materials is determined partly by tradition and familiarity, but also very much by production engineers who work on the selection of the most cost-effective and technically suitable material for components.

material becoming available for recycling each year that is recycled.

Recycling rates for building and transport applications range from 60% to 90% in various countries. The aluminium industry is working with automobile manufacturers to enable easier dismantling of aluminium components from cars in order to improve the sorting and recovery of aluminium. In 1997, over 4.4 million tonnes of scrap were used in the transport sector, and the use of aluminium in automobiles is increasing yearly.[4] The growth of packaging expected in South America, Europe, and Asia (especially China) may allow for growth in some parts of the scrap recycling industry. In the case of lead, 60–62% of refined lead production in the western world comes

Figure 5–3. Metal Consumption by End-Use, 2000
Source: CRU International



from recycled material. In the US, 90% of spent batteries are recycled. More than 50% of steel production in industrial nations comes from recycled materials.

Despite the rapid growth rates and large volumes consumed in Asia, especially China, on a per capita basis, most consumption still occurs in the most industrialized countries.[5] In 2000, these nations accounted for the majority of metals consumption, but only 14.6% of the world's population. Even for gold, where it is often claimed that developing countries play a pivotal role as consumers of jewellery, per capita consumption in India is still far below that in the US or the UK. Jewellery consumption of gold ranged from 31.5 grams per capita in Dubai to 4.0 in Hong Kong, 1.5 in the US, 1.2 in the UK, 0.6 in India, and 0.1 in China. Total national consumption was 600 tonnes for India, the highest of any country reported, and 409 tonnes for the US, as against 26 for Hong Kong or 41 for Dubai.[6]

Table 5–3. Population and Consumption of Metals in Industrial and Transition Countries, Per Capita and as Share of Total Consumption, 2000

	% of World Population	Aluminium		Copper		Lead		Steel (1999)		Gold[a]	
		kg/head	% consumption	kg/head	% consumption	kg/head	% consumption	kg/head	% consumption	grams/head	% consumption
Industrial Countries											
United States	4.6	22.3	24.4	10.9	19.7	6.1	26.6	458.2	16.2	1.0	7.3
Canada	0.5	26.6	3.3	8.9	1.8	2.1	1.0	606.4	2.4	0.8	0.7
Western Europe	6.9	14.2	23.3	10	27.2	4	26.2	381.1	20.2	2.0	22.2
Japan	2.1	17.7	8.9	10.8	8.9	2.7	5.5	562.8	9.1	1.4	4.6
Australia	0.3	18.3	1.4	8.9	1.1	2.4	0.7	340.7	0.8	0.6	0.3
Average/Total	*14.6*	*17.8*	*61.5*	*10.3*	*58.8*	*4.4*	*60.1*	*438.4*	*48.8*	*1.5*	*35.2*
Transition Countries											
South Korea	0.8	17.6	3.3	18.4	5.7	6.6	4.9	756.8	4.6	2.3	2.9
Taiwan	0.4	22.8	2.0	28.6	4.2	6.7	2.4	1,112.30	3.2	3.5	2.0
Other S.E. Asia	7.8	1.1	2.0	0.9	2.8	0.6	4.2	68.4	4.1	0.8	9.5
Former Soviet Union	4.8	3.1	3.5	0.8	1.5	0.5	2.2	90	3.3	0.2	1.4
Turkey	1.1	3.3	0.8	3.7	1.6	0.9	0.9	188.8	1.6	3.3	5.6
Eastern Europe	1.8	6.5	2.8	3	2.1	1.8	3.0	193.5	2.7	0.1	0.4
Latin America	8.6	1.8	3.7	2	6.6	0.8	6.5	81.8	5.3	0.2	3.2
Average/Total	*25.2*	*3.1*	*18.3*	*2.5*	*24.6*	*1*	*24.2*	*128.4*	*24.7*	*0.6*	*24.9*
China and India	38.8	1.9	16.6	1	14.1	0.3	11.5	74.4	21.5	0.4	23.4
Africa, Middle East, and Other Asia	22.4	0.7	3.6	0.3	2.7	0.2	4.2	9.3	5	0.5	16.5

[a]Gold consumption refers to fabrication of gold only, and excludes any investment or hoarding demand.
Sources: United Nations, WBMS, IISI, CRU International.

There is a consensus among forecasters that consumption of aluminium and copper will continue to grow at the historical rates of around 3%, at least over the next 5–10 years. The demand for lead is forecast to grow 1.1% annually in the next 5 years. Crude steel demand is expected to grow at between 1.8% and 2.1% per year.

Consensus forecasts are invariably based on history and a 'business as usual' approach to the future; they are often wrong. If transition and developing countries succeed in achieving a higher standard of living, barring some rather dramatic change such as development of alternatives to lead-based batteries, world consumption of lead could increase considerably. If 6 billion people in the world each consumed the 4.4kg per capita that is today typical in industrial economies, world demand would be 26.4 million tonnes – over four times current world consumption. Renewable energy advocates have long suggested that countries without established power grids can electrify more effectively with decentralized generation based on wind or photovoltaics. This could create increased demand for batteries, which today are principally lead.

The appetite for steel in China has been driven by sustained investment in construction and infrastructure over the past decade. There remains an extremely large potential demand for cars and consumer goods among China's huge population. Increasing personal incomes and continuing investment in infrastructure could keep the total demand for steel on the rise in China for some time.

The economics of recycling is mentioned in many of the metals case studies. From a social perspective, the costs include the cost to society of acquiring landfill sites, operating them properly, and collecting and transporting material to them. In some cases this includes the costs of remediating environmental problems where disposal practices have proved inadequate. These costs are often not internalized in product prices or reflected adequately in the price of scrap materials. This has been an argument for government initiatives to encourage higher levels of recycling.

It should also be kept in mind that much recycling is done by individuals and small enterprises, or in countries where data are not well reported, and the data on their activities are often incomplete, making it very hard to define the precise rate of recycling.

Research has focused on the habits and preferences of consumers in the richest countries because that is where the biggest markets are. Little is known about what poor people use metals for – although in general terms it is clear that they have few metal products in comparison to other people. If their incomes rise, as sustainable development requires, it is hard to say what their priorities for spending those additional incomes might be, or what additional uses of metals or other minerals they would find most useful in improving their quality of life. This should be a high research priority.

Steel

The inherent qualities of steel are its strength and the ease with which it can be 'formed' or rolled into a wide variety of shapes and forms. The ability to protect steel against corrosion by zinc or tin coating has also extended the applications for steel extensively.

The mining of iron ore and the various other metals that are alloyed with steel, and the coal that is used in steel-making, together with transportation of these materials in enormous quantity and the fabrication of steel into final products, clearly makes steel the greatest direct and indirect employer of all the metals. It has been seen as a linchpin of industrialization of economies. Because modern techniques at many stages of the value chain are less labour-intensive, declining employment in this industry in some regions is a major political issue, and steel has become a major focus of world trade concerns.

Steel consumption is intimately linked with overall economic development. It is, however, interesting to note that there is nothing to show that steel consumption would start to decline in industrial countries that are increasingly dependent on services rather than manufacturing. So far, it appears that steel is consumed at a marginal rate that does not decline very much with income.

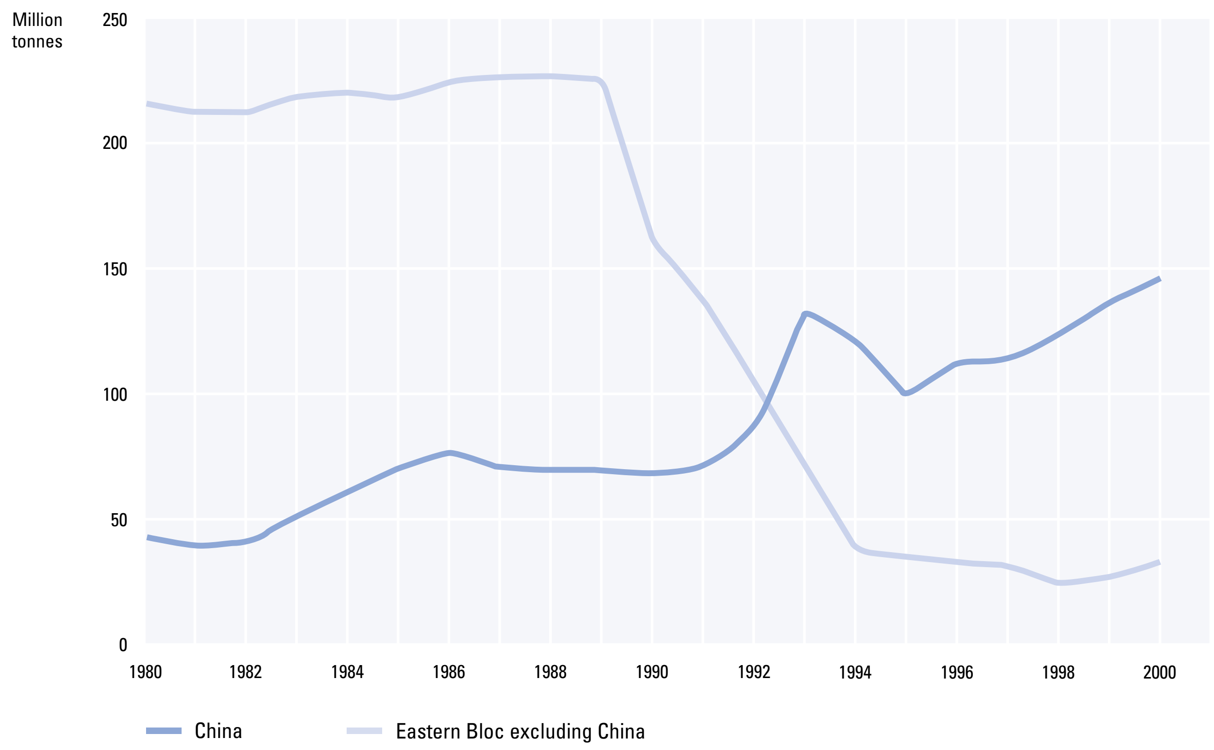
In 1985 the Eastern bloc consumed 40% of the world steel total. (See Figure 5–4.) By 1995 this figure had fallen to 18%, a mark of the contrasting results achieved by the Communist and capitalist economic systems. Another major development in the world steel markets is the growth in Chinese steel consumption. This is a striking illustration of the relationship between economic development and the consumption of steel; China has become the world's largest steel-maker, something hard to imagine just a few decades ago.

Steel can be recycled easily in the same production facilities that are used to produce it from primary raw materials. The more complex steel alloys (such as stainless steel) are recycled within those alloy industries. The recycling of steel scrap plays a large and growing role in the production of steel. All steel scrap is potentially recyclable, and the main production processes depend heavily on the availability of scrap as a raw material.

In electric arc furnace (EAF) steel-making, scrap is the principal source of iron. Additional raw materials used in the EAF process are direct reduced iron/hot-briquetted iron (DRI/HBI) and pig iron. EAF steel-making has been growing as a percentage of total steel-making capacity and this is expected to continue. In many countries it has the advantages of lower capital and operating costs than blast furnaces and basic oxygen converters. The EAF process is also more environmentally acceptable.

The volume of scrap used per tonne of steel production varies from region to region, according to the penetration of the EAF process and the availability of DRI/HBI. Recent data show that in North America, 792kg of scrap were consumed per tonne of steel produced; in Western Europe, the figure was 554kg per tonne of crude steel; in East and Southeast Asia 523kg; and in other western countries 457kg. In other words, well over half the total raw material used in the production of crude steel in the western

Figure 5–4. Consumption of Crude Steel in the Eastern Bloc and China, 1980–2000
Source: CRU International



world derives from scrap, and the share of scrap in total production is increasing. In Russia, China, and Eastern Europe, the figure is much lower because EAF production has so far made little progress.

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

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

Aluminium

Aluminium has only been produced commercially for 146 years and is still a young metal. Yet today more aluminium is produced than all other non-ferrous metals combined. There is comparatively little focus on the overconsumption of aluminium, other than consumer reaction to excessive packaging of products that is not being recovered and re-used. Relatively little is known about how people with very low incomes use aluminium, or which of their most pressing wants are unfulfilled.

Most aluminium is produced by a relatively small number of large companies; direct employment in the industry is fairly easy to determine simply by examining the payrolls of these companies. As with all minerals, the number of livelihoods that depend on this product indirectly is much harder to determine.

Production of aluminium and its ores is important to a number of national economies, such as India and Jamaica.

Aluminium's popularity is due to several specific characteristics:

- It has a high strength-to-weight ratio (which can be improved by alloying), which accounts for its use in aircraft and other forms of transport.
- Aluminium is an effective conductor of electricity.
- Aluminium can be formed by rolling down to sheet or foil with thickness of as little as 7 thousandths of a millimetre, so it can be extruded, cast, or drawn into a wide range of shapes.

Even so, there is no end-use for which aluminium is indispensable, though it is difficult to imagine another material making considerable inroads into aircraft frames. Aluminium has strong potential to be recycled in virtually all of its end-use applications, and its recycling networks and collection systems could provide a model for other large-volume metals. The volume that goes into dispersive uses – such as laminated lids of yoghurt cartons or fireworks displays – is comparatively small.

The big question surrounding the use and need for aluminium is a supply-side issue – the energy required to produce a tonne of primary aluminium (13,000–14,000 kWh). The energy requirement to recycle aluminium scrap is 5% of this. Clearly, from an energy efficiency perspective, it is best to meet growing demand with recycled material.

Community concerns at the mine site level certainly have occurred in the aluminium industry. A recent example is the Kashipur region of Orissa, India. But the most highly publicized areas of conflict over sustainable development values relate to energy use and the development of new smelters and the electrical capacity to run them, often through proposed hydroelectric development. Recent examples include the Karahnukar Hydro proposal in Iceland, a project in Orissa state in India, and a proposed project in the south of Chile.[7]

While this report is not intended to enter in depth into the climate debate, it is essential simply to note that the current concern about climate has and will focus attention on all forms of energy use, and primary aluminium smelting is a major energy user. Hydropower, especially in warm climates, may not be a carbon-neutral energy source, as found by the World Commission on Dams.[8]

The energy issue and the difference in energy consumption between primary and secondary sources drive much of the debate about aluminium to a focus on recycling.

The Recycling of Aluminium

Almost every aluminium product can be profitably recycled at the end of its useful life, without loss of metal quality or properties. In several countries, organizations have been set up specifically to promote aluminium recycling, particularly aluminium cans and foil. Many countries also have laws controlling packaging materials and recycling.

Aluminium recycling involves collecting scrap, separating it from other materials such as plastics or other metals, melting it, and casting it into a form that can be supplied as feed to a semi-fabricating process. There are two sources of aluminium scrap:

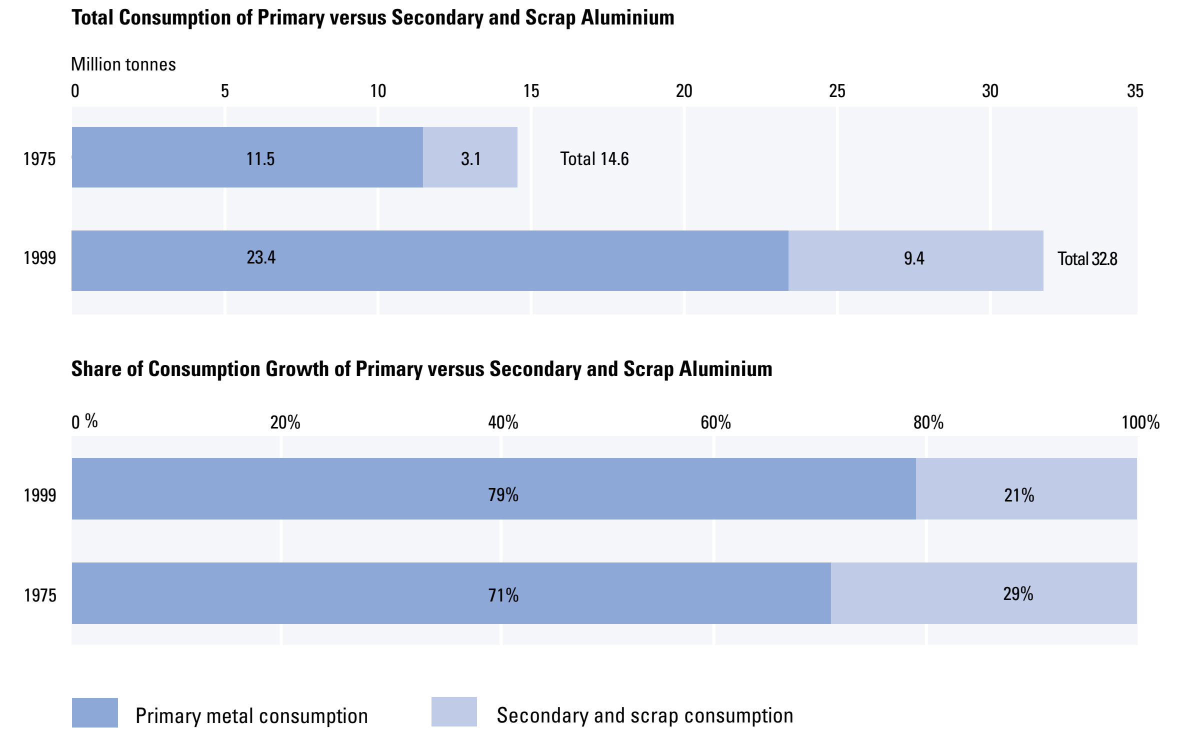
- New scrap is generated in the form of off-cuts, turnings, and saw chips in manufacturing processes. It is usually returned quickly to the supplier for reprocessing or is reprocessed by the company that generates the scrap.
- Post-consumer scrap arises when a product containing aluminium comes to the end of its life and is discarded or dismantled. This may take a few weeks (a beverage can), 10–15 years (a car), or 30–50 years (a building). Some products, notably foil and powder, are hard to recover once used.

To recycle aluminium, a collection system and reprocessing facilities are required. These will only be set up when there is a sufficient concentration of metal in use to generate scrap in large enough quantities to justify the investment. The rate of recycling for aluminium is therefore determined by the rate at which it is fabricated (in the case of new scrap) or products are discarded (in the case of old scrap). Since the use of the metal is growing, the pool of metal in use is constantly increasing, and most of this can potentially be recycled. (See Figure 5–5.)

There are major regional differences in the rate of recycling. In North America, as much as 35% of total aluminium consumption comes from secondary sources (mainly from beverage cans); in Western Europe, the figure is 31%, but in Asia it is only 25%.

In general, secondary consumption is lower in regions

Figure 5–5. Total and Share of Consumption of Primary versus Secondary Aluminium, 1975 and 1999
Source: CRU International



where aluminium consumption has grown rapidly in recent years. Furthermore, when used to build power lines and buildings, aluminium is unlikely to return as scrap for many years. Where scrap collection is inefficient or non-existent, collection for secondary consumption remains low. Where metal consumption has been relatively high for many years, as in Western Europe or North America, and centres of consumption are more concentrated, the collection system is usually better developed. In the US, as much as 80% of the raw material used to produce can body stock consists of scrap; in Western Europe, the figure is 50%.[9]

The analysis of the economics of recycling indicates that there is a substantial (though variable) margin available to remunerate the scrap collecting chain. Companies that generate new aluminium scrap have an economic incentive to obtain cash for what would otherwise be a waste product, especially if the collection costs are small. For old scrap, the economics of collection is much more complex.

A key issue in the efficient recycling of aluminium is the way metal is used in many different alloys. Aluminium can be recycled into a more valuable product if it is sorted by alloy. It is not difficult to keep various alloys separate when it is new scrap that arises in an industrial process. With old scrap, particularly that collected from the shredding of cars or household goods, separating the scrap by alloy is harder. While it is possible to separate the different metals contained in a car (steel, zinc, copper, and aluminium, for example), there has been no commercial process for separating the scrap by alloy. In the absence of such a process, scrap containing several different alloys can be recycled only as a foundry-grade alloy, a relatively low value product. A recent development by Alcan Aluminium promises to make it possible to segregate shredded scrap by alloy and that others may also have developed such processes.[10]

Major Policy Issues in the Future of Aluminium Recycling

Many countries have legislation controlling packaging materials and recycling. Recycling rates are set in several states in the US for all drinks containers, while others require packaging materials to contain minimum proportions of recycled raw materials. Japan aims to recycle 70% of aluminium cans by 2000 and 80% by 2002.

The European Union Directive on Packaging and Waste requires that by 2001 member countries should have been recovering 50–60% of their used packaging, material recycling rates should have been 24–25%, and no material should be recycled at less than 15%. In practice, the aluminium can industry far exceeds these targets, though aluminium foil is recycled at generally very low rates.

Poor enforcement of regulation hinders the collection and recycling of scrap. Environmental controls are rightly imposed on the secondary smelting industry, which can cause serious pollution. But these are not effectively enforced everywhere, so the playing field is not level for those who comply. Where waste regulations do not adequately distinguish between material due for final disposal and raw material of the recycling industry, this can impose significant administrative costs.

Government intervention to increase recycling is often most effective if focused on the margin, where revenues are not quite an adequate incentive for commercial recycling. They can take different forms, from internalizing the cost of waste to producers and sellers, to instituting refundable deposits on products, and providing citizens with cheaper and more convenient collection centres.

Because of its vertical integration, and market incentives to recover material, aluminium is a fertile industry for development of more advanced concepts of product stewardship, and these do seem to be emerging.

Copper

Copper is one of the metals that has been in use longest. It has been an important material in the development of civilization because of its high ductility, malleability, thermal and electrical conductivity, and resistance to corrosion. Copper has become a major industrial metal, ranking third in quantity after steel and aluminium. Copper is very useful for power transmission and generation, building wiring, and telecommunications. It has a virtually unchallenged market for house wiring and underground power cables. The copper uses hardest to substitute may be motors and electronics. Investment in power generation and distribution and telephone systems has been a key driver of copper consumption.

As is the case with all minerals, little is known about the current uses made of copper by those in extreme poverty, or what needs they would meet with copper products if their incomes allowed them to do so. It seems quite plausible to believe that their immediate demands might include electrification and use of more electronic products. Widespread electrification for the world's poor would undoubtedly result in increased demand for copper.

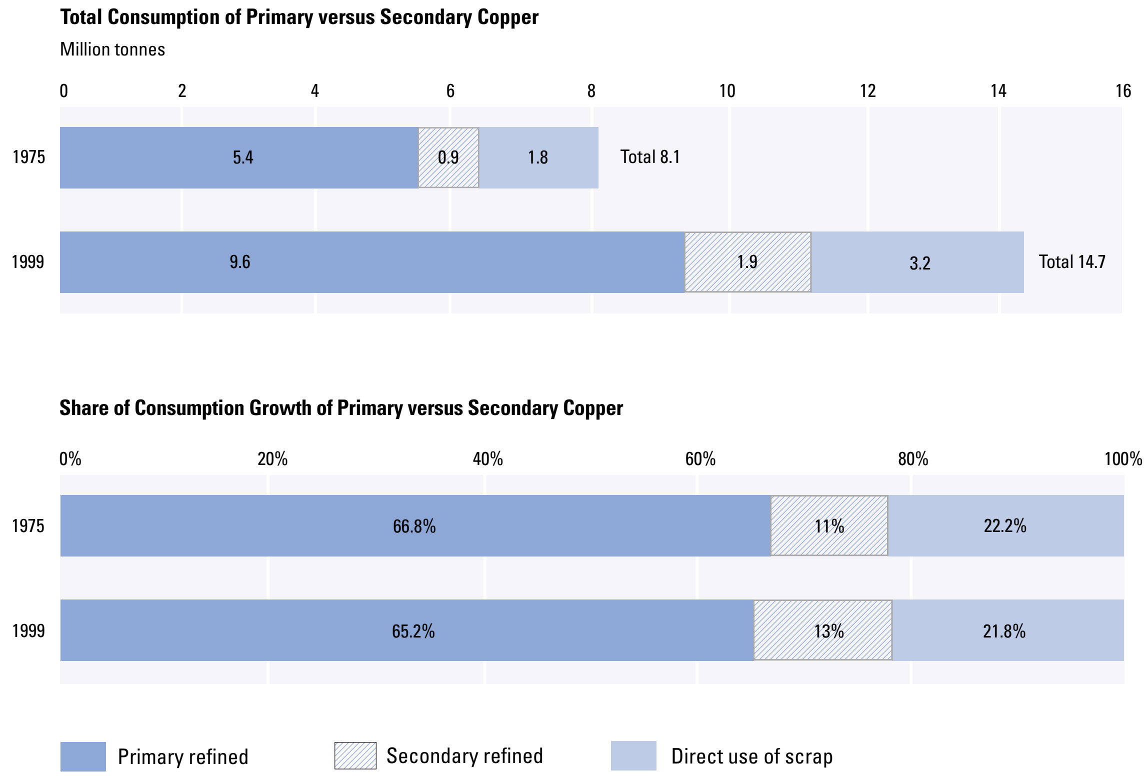
Whereas aluminium smelters often rely on hydropower, copper smelting is mostly done with pyrometallurgical techniques that can produce significant air emissions of sulphur oxides, arsenic, or other pollutants. This has long been a source of concern for local communities and other stakeholders, and increasingly stringent air quality regulations have been among the factors reducing copper smelting in places such as the US.[11] It has been an issue at smelters from Peru to Zambia.[12] Although much of the industry has made significant improvements in pollution control, and there are alternative extraction technologies gaining market share, this is still an area in which the copper industry faces a challenge to its operations worldwide.

There are two principal routes by which copper is recycled. Copper scrap free of alloying materials (including 'dirty' or contaminated alloy scrap) is refined in secondary smelters to produce pure refined copper (effectively equivalent to refined copper produced from ores and concentrates). Clean alloy scrap (of which brass scrap is a large component) is recycled by semi-fabricators into the same alloy. (See Figure 5–6.)

The supply of secondary copper is sensitive to the price of copper in the short term. Low metal prices lead to stockpiling of old scrap in the collection chain. New scrap is recycled regardless of the price. The collapse of the former Soviet Union has also had a major influence on scrap supply in Western Europe in the past decade, as large volumes of scrap were exported from Russia to Germany and other West European countries. In 2000, the Russian government took steps to restrict and finally stop this in order to retain the valuable raw material for Russian industry. The switch in Russian policy has made it harder to determine the total volume of copper recycled, since the direct use of scrap is not recorded or published in these.

While some secondary copper can be processed using some primary smelting technologies, the two are not always completely compatible. It is not always necessary to submit scrap to the full primary process.

Figure 5–6. Total and Share of Consumption of Primary versus Secondary Copper, 1975 and 1999
Source: CRU International



Note: These numbers do not include statistics for the former Soviet Union, Eastern Europe, or China, where data are not collected.

Secondary smelting costs vary according to the type of scrap purchased. High grade and pure scrap can be processed in an anode furnace and then electrolytically refined, whereas low-grade complex scrap must be smelted to produce blister copper first. In contrast to secondary smelting, the costs of the next step – refining – are less variable and directly comparable to the cost of refining primary copper.

The profitability of a secondary smelter depends largely on its ability to acquire scrap at attractive prices. Those that are able to extract other metals as well as copper (such as tin, zinc, or precious metals) may have an advantage.

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

In general, copper and its alloys are easily recognized and therefore unlikely to be wasted when they become available for recycling. Very little copper is used in the form of powder or sulphate, which is dispersed and can never be recovered.

Legislation directing manufacturers to take responsibility for recycling their products at the end of their lives could increase the rate of recycling, particularly if it leads to changes in product design. Trade in some types of copper scrap may be affected by national regulations introduced as part of the Basel Convention. (See Chapter 11.)

Lead

Lead is a very corrosion-resistant, dense, ductile, and malleable blue-grey metal that has been used for at least 5000 years. In some countries, however, environmental and health issues have reduced or eliminated its use in cable sheathing, petrol additives, solder, shot, and pigments.

Lead has been used, for example, in the manufacture of water pipes since Roman times, but new piping is no longer made of this metal. In the 1960s and 1970s, there was also a market for lead in covering electric cables for insulation and for general protective purposes. Technological factors, together with the cost of lead, have caused this market to disappear except where cabling requires special protection (such as underwater). Lead shot used for sporting purposes is now less popular since it has been recognized that it can accumulate on marsh lands and seashores, and can poison wildfowl and other birds that live alongside water. Lead solder has lost a market in the manufacture of food cans, because of the danger of contaminating the contents of the can. Lead was also widely used in paints, but this application has virtually ceased, at least in Europe and North America, where it is specifically banned for use in indoor applications.

The addition of tetraethyl lead to gasoline was standard in the 1960s and 1970s to improve the operation of combustion engines. This end-use has also been lost. The dispersal of lead particles in exhaust fumes is hazardous. And exhaust fumes are now cleaned to prevent other harmful emissions, through the use of catalysts containing platinum or palladium. Lead in petrol contaminates such catalysts, and was eliminated to enable them to work (see Chapter 10).

The result is that lead-acid batteries – the largest application in which there are to date no competitive substitutes – have become the most important end-use for this metal, accounting for about 75% of the consumption (in countries where this is measured and recorded). There are some other uses where lead may be a preferable alternative, such as radiation shielding.

Manufacturers of batteries buy refined lead and fabricate it directly into batteries for sale to car manufacturers (in the case of original equipment batteries) or the retail trade (replacement batteries). While there is some international trade in batteries and new cars containing batteries, there is less discrepancy between the location of reported consumption and the location of final consumption of the products containing lead than for other non-ferrous metals.

Demand for lead is closely linked to the demand for motor vehicles, which continues to grow world-wide. The use of lead in new and replacement batteries therefore continues to grow, and accounts for almost all the growth in the use of lead. It was offset in the 1960s and 1970s by a gradual reduction in the size and weight of batteries required to provide starting, lighting, and ignition power for automobiles. But in the last two decades the average weight of a car battery has stabilized at about 10.5kg.[13]

The question of whether there is 'overconsumption' of lead by high-income consumers is tightly tied to the question of whether these same consumers are wastefully or excessively using motor vehicles, since lead for vehicle batteries is the dominant use of the product. It is beyond the scope of this study to consider any perverse subsidies for auto use, better and less damaging transportation alternatives, or the consequences of eventual widespread ownership of motorcars in densely populated countries like China and India.[14]

Whether there is 'underconsumption' of lead is also relatively straightforward, given its dominant role in electrical storage batteries. The question is the extent to which the ability to store electricity is a priority for people with very low incomes. (See Box 5–1.)

Box 5–1. Batteries for Decentralized Electrical Systems

In July 1997, the International Lead Zinc Research Organization, the Solar Energy Industries Association, and the Ministry of Energy and Mines of Peru signed a Memorandum of Understanding for the design and installation of pilot remote-area power supply hybrid systems to supply 24-hour electricity to remote communities. The systems incorporate solar energy, existing diesel gensets, advanced batteries to store and supply energy, and state-of-the-art power electronics.

The project, which is funded by industry and a variety of national and international governmental bodies, is due to be completed in June 2002. Its objective is to support sustainable development of rural communities in poor areas along the Amazon River in Peru, which now have little or no electricity, by providing electricity necessary to increase income-generating activities. The desired benefits include reduction in diesel fuel costs, reduction in environmental damage from exhaust and fuel spills in this environmentally sensitive area, availability of 24-hour electricity, and the enhancement of the quality of life and economic activities.

Source: ILZRO.

While lead is hardly immune from the mine site, smelter, and refinery issues that are encountered in most mineral commodity chains, the most critical issues that will determine the future of this commodity have to do with lead in use, and concerns over whether it can be managed safely where it is used. The result of trends previously identified has been to limit the use of lead to applications where it can be collected and re-used or recycled without appreciable loss into the environment and where it cannot be reasonably replaced. Batteries have the advantage of being easily recycled, and provide a major source of raw materials for the lead smelting and refining industry. Dispersive uses of lead will over time be identified and prohibited. Use of the metal will be limited to applications where high and efficient rates of recovery, re-use, and recycling can be achieved.

Lead has the highest recycling rate of all industrial metals. Recycling and recovery rates for most materials in developing countries tend to be high. If dispersive uses are eliminated, as most countries are doing with leaded gasoline, most lead in use could be recovered and recycled.

Lead recycling has become an efficient but not highly profitable operation in most industrial countries. Lead is a co-product of a number of other metals, such as zinc. It is therefore inevitably produced as these minerals are mined and processed, and this availability of lead from primary production at low cost is likely to continue to limit the price of recovered or secondary lead.

Since batteries account for a high proportion of total lead use, they constitute an easily identifiable source of scrap. However, they arise not in large volumes but one by one, in the hands of individual motorists. In many countries, there is now legislation (in some form) requiring or encouraging spent batteries to be collected and re-processed. In the US, for example, people who buy a replacement battery either receive a discount for returning spent batteries or pay an extra deposit. The inherent value of lead in battery scrap is not great, however, and in the absence of other incentives, spent batteries may just be thrown away. There is a good case for creating or strengthening incentives for the individual motorist to return spent batteries, both to avoid land disposal of a potentially hazardous material and to reduce the need for primary lead production.

Many battery producers organize their own collection systems for spent batteries through garages and other retail outlets. They then have the batteries smelted back into lead by a secondary smelter. Thus battery producers are in a sense competing with the scrap collecting industry. The result is that a high proportion of spent batteries are collected and reprocessed.

Battery scrap is a valuable resource to the battery manufacturer since it arises locally and can be converted into refined metal easily. Some battery companies operate their own secondary smelting plants for this purpose.

Secondary smelting is carried out principally in dedicated secondary smelters, but some smelters, mainly in Europe, take a mixture of primary and secondary feed. There is no shortage of secondary smelting capacity, and none is expected to arise in the medium term. Some lead products, such as old lead sheet, are recycled without being smelted. They can be remelted and re-used directly.

Basel Convention regulations are a potential obstacle to the recycling of lead. (See Chapter 11.) Its objective is to prevent the movement of hazardous waste across national borders in order to prevent dumping in countries where environmental controls are weak or poorly enforced. However, it can prevent the movement of scrap, such as used batteries, that is potentially hazardous but is also a valuable resource for the recycling industry.

Gold

Gold is notable for its versatility. It is malleable and ductile, an excellent conductor of heat and electricity, immune to tarnish, and resistant to all but the strongest acids. These properties make gold very useful in a variety of industrial applications, though it is used sparingly because of its cost. It also has a role that none of the other minerals studied in this chapter performs: it is the most important mineral to be used as a store of value. Until recently, it backed most of the world's principal currencies, and it is still held as a reserve asset by many central banks. It remains the preferred store of individual wealth in many parts of the world. It is highly prized for ornament, and by far its largest current use is for jewellery, some of which has the dual purpose of ornamentation and a form of savings.

In recent years the annual demand for gold has been around 4000 tonnes per year. Jewellery is the main driver, constituting 80% of total demand in 2000.[15] Gold has a variety of other applications, including electronics, dentistry, decorating materials such as glassware and ceramics, medals, and coins. Taken as a whole, non-jewellery use of gold has been relatively stagnant over the last 10 years, though some individual uses such as electronics have shown considerable growth. Given the cost of gold, this indicates these uses have no easy substitutes. But gold faces intense competition in almost all markets.

Use of gold for jewellery has been volatile for two main reasons – income sensitivity in industrial markets and price sensitivity in developing countries. Developing countries now constitute about two-thirds of world demand for jewellery, with about a fifth of this in the Indian subcontinent alone, where gold jewellery is of great cultural significance.[16] In a considerable part of South Asia and the Middle East, gold jewellery (and to a lesser extent bars and coins) serve as bridal dowries and a store of value.

Gold is scarce, with a very low abundance in Earth's crust.[17] In physical terms, annual production is only a fraction of most other metals. In 2000, mine production amounted to 2574 tonnes, which represented 65% of total gold consumption. Its value is sufficient that other incentives are not needed for recycling. It is certainly more highly recycled than any of the other metals considered in this study. (See Box 5–2.) Gold production has been increasing slowly over the last few decades. In the last 6000 years, over 140,000 tonnes of above ground stocks have been accumulated.[18]

Box 5–2. Why Gold Is So Interesting

MMSD received many comments on gold during the preparation of this report. There are objective reasons for this level of attention – gold issues are somewhat different than those of other metals:

- Many livelihoods depend on gold production – Gold often occurs in forms that can readily be identified and produced. It therefore supports many of the world's 12–15 million artisanal miners and their dependents. It also supports a disproportionate share of the employment-intensive small and medium-scale industry. Even at the large end of industry, the top 15 gold companies directly employed some 200,000 people in 1999–2000.
- Exploration activity is concentrated heavily on gold – In the recent peak of 1997, US$5.1 billion was spent on gold exploration, compared with base metal exploration of well under US$2 billion. To the extent communities are disturbed by exploration, the chances are good that it may be for gold.
- There are public NGO campaigns directed specifically at gold – Some NGOs are actively campaigning on gold-related concerns: Goldbusters, for instance, 'aims to depress the price of gold by asking governments and individuals to divest of gold investments and consumers to no longer purchase gold jewelry'. There is little parallel in the case of other commodities. There are also major public campaigns, sometimes successful, for legislation to prohibit the use of cyanide in gold mining.
- Gold is a store of value with a continued role in the monetary system – The US dollar is the world's principal reserve currency. The US, the world's largest gold owner, holds about 60% of its foreign reserves in gold. Many others hold substantial reserves in gold. It also is important for individual savings in many countries. Other metals do not have these functions or the controversies that go with it. Some eminent authorities expect its reserve role to continue.
- Several highly publicized negative incidents have occurred in the gold industry – Gold mining has had a significant share of the bad publicity received by industry in recent years.

In Tanzania, where gold exports rose from US $200,000 in 1982 to $120 million in 2000, President Mkapa noted that they 'made a deliberate and a conscious decision to make mining an engine of growth. Tanzania today is where South Africa was at the beginning of the last century.' But not all have the same view: the draft MMSD Report was criticized by Professor Philip Crowson of the University of Dundee because it 'implies that the present price of gold is somehow "right" and that development of new gold mines in developing countries should not be prejudiced. Is that really the view? To keep minerals of any type in above-ground stocks when there is no further use for them is perverse and certainly not sustainable.'

This report is not intended to be 'pro' or 'anti' gold but an attempt to reflect in as balanced a way as possible what was an exceedingly complex and passionate debate long before the MMSD Project came on the scene.

Source: Exploration expenditures from Otto (2002); Mkapa quote from Mkapa (2001); campaign quote from http://csf.colorado.edu/bioregional/apr99/0015.html.

The metal is readily identifiable and rarely found in forms other than its elemental state. In some cases it occurs as free gold in veins, nuggets, or visible flakes. Since these can be used without complex recovery techniques or metallurgical processes, gold is one of the minerals that has been in use the longest.

This susceptibility to simple techniques of recovery means that production can be considerably simpler than the other minerals studied, with the possible exception of coal. While there are large gold mines, gold is mined in more individual locations and often at a much smaller scale of enterprise than is the case with iron ore or most of the base metals. As the mining industry has concentrated into a smaller number of larger enterprises, gold and coal remained among the bastions of the small and medium producer.

Gold Production as a Source of Livelihoods

After steel, aluminium, and copper, gold has the fourth highest value in terms of world metals production. It may well, however, be responsible for far more than its relative share of total mining employment. An estimated 12–15 million artisanal miners in the world support several times that number of family members. Though it is difficult to estimate the fraction of these millions of people engaged in gold mining, it is clearly very significant. It is estimated that perhaps 20% of total world gold production comes from artisanal and small-scale mining. In many countries where this is an important source of employment, the sector accounts for the majority of gold production.

Even in the formal sector, gold supports a large number of small companies. A high proportion of the well-known Canadian and Australian junior companies are in gold, which collectively employ a considerable number of people; small and medium-sized companies are frequently found in almost all gold mining regions. Even in the large end of the industry, gold is a major employer. The top 15 gold-producing companies in 1999 and 2000 employed approximately 250,000 people. (See Table 5–4.)

According to the World Gold Council, gold accounts for a significant proportion – ranging from 5% to nearly 40% – of the exports of many heavily indebted poor countries.

Gold has been central to the development of South Africa, though declines in gold employment in this industry in recent years have been a difficult problem to manage. (See Box 5–3.) In many countries where gold mining is currently important, there are at present limited options for alternative industrial activities to support economic development.

Table 5–4. Output of Top 15 Gold-Producing Companies, 1999 and 2000

	Company	Base	1999 (tonnes)	2000 (tonnes)	Employment (2000)
1	AngloGold	South Africa	215.2	225.3	77,600
2	Newmont	US	130.0	153.7	10,800
3	Gold Fields Ltd	South Africa	118.7	121.2	55,000
4	Barrick	Canada	113.8	116.4	5,500
5	Placer Dome	Canada	97.9	92.8	12,000
6	Rio Tinto	UK	92.9	84.9	5,100[a]
7	Homestake	US	74.3	68.6	na
8	Harmony	South Africa	41.4	66.8	42,600
9	Normandy	Australia	58.8	64.5	na
10	Freeport McMoran	US	74.0	59.1	7,800[b]
11	Ashanti Goldfields	Ghana	48.6	54.0	10,400
12	Durban Roodepoort	South Africa	27.7	35.7	19,111
13	Kinross	Canada	31.3	29.4	1,600
14	Buenaventura	Peru	23.6	28.5	1,800[c]
15	Newcrest	Australia	26.3	27.9	na

[a]Number of employees in Rio Tinto's gold mining interests in Kennecott Minerals (US), Kelian (Indonesia), Lihir (Papua New Guinea), Morro do Ouro (Brazil), Peak (Australia), and Rio Tinto (Zimbabwe). [b]Includes employees from the company's copper production. [c]Includes employees from the company's silver and other precious metals production.
Source: Gold Fields Mineral Services (2001); company annual reports.

Box 5–3. South African Gold Mining

South Africa is the world's leading gold producer, providing nearly 17% of all newly mined gold in 2000. Its share of the total has shrunk dramatically, however, from a peak of more than 70% in the 1960s and 1970s as other producers have grown in importance and its output has fallen.

In 2000, South African gold production fell for the seventh consecutive year, dropping by 21.2 tonnes, or 4.7% from its 1999 level, to reach 428.3 tonnes. Production levels have suffered as ore grades have fallen and lower gold prices have forced the closure of less payable or profitable areas. South Africa still has more than a third of known global reserves, but much of the more accessible gold has been mined, leaving reserves that are deeper, of lower grade, and more expensive to extract, though change in operations and the exchange rate have kept many South African producers competitive. The fall in the price of gold has had a severe impact on South Africa's gold mining industry. There has been substantial restructuring, involving both company mergers and massive cuts in employment.

Employment in the gold industry has fallen drastically over the past decade, and today the mines account for just 2% of the registered labour force. From more than a half-million in the late 1980s, the number employed fell to 257,000 (including 130,000 non-South Africans) in 1998. Gold exports fell from US$6.3 billion in 1994 to an estimated US$4.4 billion in 1998. Because of gold mining's links with other sectors, however, it is estimated that for every three people working in a mine, another person is employed by industries that serve mining. In addition, on average each worker in the gold industry supports 7–10 dependents.

Source: Gold Fields Mineral Services Ltd (2001); CRU International (2001); Chamber of Mines of South Africa, personal communication (2001).

Gold may also be disproportionately important at the exploration stage. Certainly, artisanal and small-scale prospectors have been over a good part of Earth's surface. So have junior exploration companies and others with more sophisticated techniques. The western world has been spending several billion dollars per year on gold exploration – substantially more than is spent looking for copper, zinc, and nickel combined.[19]

Overconsumption of Gold?

As with all minerals, there are arguments that current levels of consumption by some consumers are excessive. In part, this is the perception that jewellery – at least in industrial countries with effective savings alternatives to holding gold – is a nonutilitarian end, despite the seemingly universal human desire to be decorated and to decorate possessions. They argue this purpose could be served by other materials that have less environmental and social impact from production.[20] They believe that people have a duty to be responsible consumers in the interest of sustainable development, and that high levels of personal gold consumption are inconsistent with that objective.

Those who feel that consumers should prefer other materials have just as much right to make that argument as the World Gold Council has to convince consumers to use more gold, though they may have fewer resources at their disposal. In May 2001, the World Gold Council, an industry-sponsored organization, launched a US$55-million campaign to 'remind consumers that gold's intrinsic value extends beyond fashionability, leading it to be revered by almost every culture for its radiance, beauty and spiritual richness'.[21] Independent of the World Gold Council, the Gold Marketing Initiative is asking gold companies producing more than 100,000 ounces a year eventually to contribute US$4 per ounce of annual production to gold promotion.[22] Since no nation seems ready to adopt eco-efficiency policies to restrain gold consumption, the jury in this case will be the world's consumers.

The other argument, which has long raged among economists without any sign of abating, is whether gold should continue to be used to back world currencies or whether this role is outmoded, with gold now a 'barbarous relic.' It is not hard to see how some have agreed with British economist John Maynard Keynes, who said 'the form of digging holes in the ground known as gold mining…not only adds nothing to the real wealth of the world but involves the disutility of labour'.[23] (Even Keynes, however, acknowledged gold had 'played its part in progress' and was an effective means of generating employment.) For Keynes, it is intuitively odd that so much human labour and capital goes into producing a product that is then often kept underground in vaults where no one does anything with it. Yet eminent economists argue that gold will have a continued role as a reserve asset 'for a long time to come'.[24]

Underconsumption of Gold?

How, besides providing livelihoods, can gold help meet the needs of the world's poor? As in the case of lead, there is a single dominant use. Although there may be other ways in which the needs of the poor could be met by access to gold-containing products, there is one use that is most important simply in terms of quantity: gold in jewellery (and some other forms) is the store of value that in many societies has long been the principal hedge against currency depreciation for those without access to other reliable means of saving. Quite simply, if the poor had enough income enhancement to be able to save, they might very likely save in the form of gold.

This, however, can create problems for broader economic development. If these savings are not banked, they cannot back the expansion of credit and availability of capital. (See Box 5–4.) Other macroeconomic effects could also be considered undesirable: in 1998 alone, India imported more than 600 tonnes of gold, at a cost of almost US$7 billion – a big component in the soaring cost of non-oil imports.

The Future of Gold as a Reserve Asset and the Future Price of Gold

Taking into account variations since the 1960s, gold prices have been relatively stable in recent years despite their general decline. (See Figure 5–7.)

The future of gold as a reserve asset of central banks will be a major factor in the future of the market and price. But it is not the only factor. Others are the extent to which gold is still recognized and used by individuals as an inflation hedge or store of value, whether uses other than jewellery grow, and whether individual consumers decide to increase or decrease the amount of gold jewellery that they buy.

Central Bank Gold Policy

The extent to which gold still serves to stabilize the world monetary system is hotly debated, and the signs are mixed. Taken together, central banks have become net sellers of gold. The modest rise in gold prices after the events of 11 September 2001 was a clear sign – there was no flight to gold. It is also possible that gold played a role in limiting the economic crisis in Argentina in 2002.

Central banks together still hold a very substantial fraction of above ground stocks. Much depends on

Box 5–4. The Indian Experiment With Gold Banking

India's experiment with its gold bank is an attempt to get privately held gold into the banking system, where it could be an effective source of development capital. Through the Reserve Bank of India, the government itself holds just 400 tonnes, in contrast with 12,000–13,000 tonnes thought to be in private hands. In January 1999, the government more than doubled the customs duty to try to curb the outflow of funds for gold purchases. At the same time, the finance minister set out the blueprint for a new strategy, to be implemented through a Gold Deposit Scheme to bring gold back into circulation. The intention was to reduce the country's reliance on imports and provide owners of bullion with some additional income.

The scheme also freed owners from the problems of storage, transport, and security. The depositor earned interest on an otherwise unproductive asset by lodging it with approved banks, and was also able to collateralize that asset.

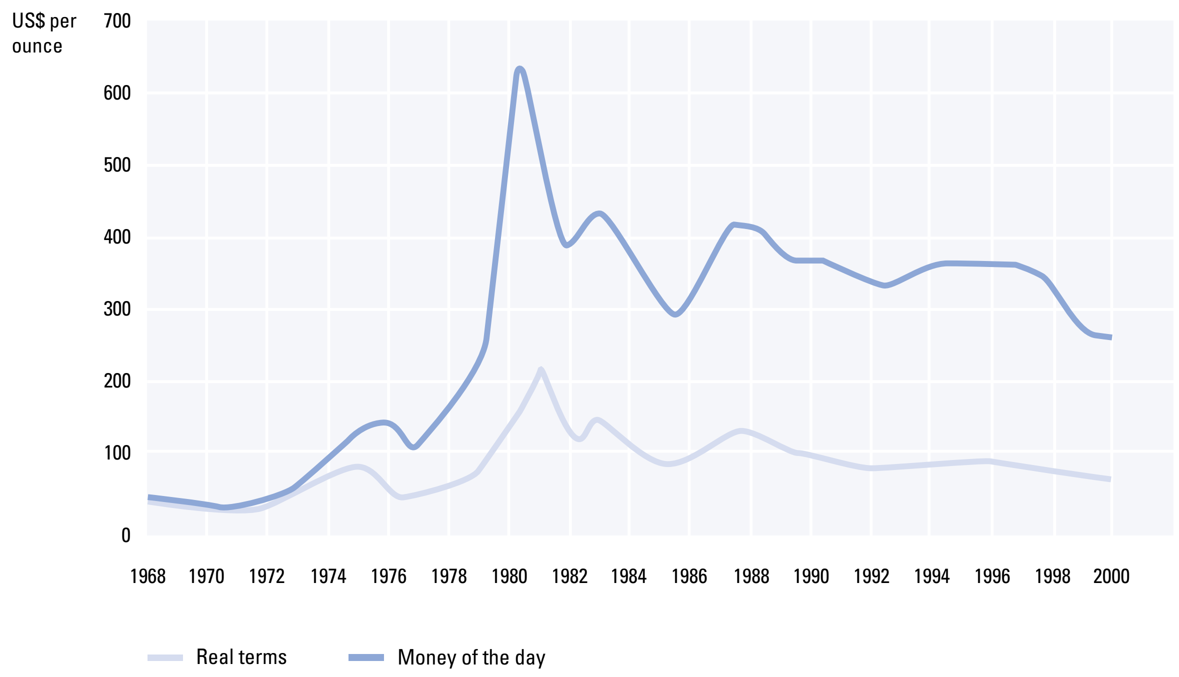
An example of a typical gold deposit scheme was that launched by The State Bank of India in November 1999. An individual, family, trust, or company could deposit as little as 200g of gold, for three to seven years, in return for a gold certificate that pays tax-free interest of 3–4%. At the end of the term the certificate can be exchanged for an equivalent amount of gold, or the market value of the gold, with no capital gains tax.

The certificates are transferable, and can be used as security for a loan. Gold deposited can be withdrawn early, but with an interest penalty. Banks offering deposit schemes lend the gold to local jewellers at an interest of 9–10%, less than the cash borrowing rate. The interest spread pays for assaying, refining, paying local tax, and hedging against the risk that the bank will not be able to lend out all its gold for periods to match the deposits. Initial targets for the scheme were ambitious. The State Bank announced a goal of 100 tonnes in the first year, which would mean a saving of about US$1.2 billion in foreign exchange.

The gold deposit scheme targets households in the hope that they will take advantage of the opportunity to earn interest on their gold. The scheme is not without its obstacles, however. Most of the gold in India is in the form of jewellery, which would have to be melted down to bullion on deposit, destroying the value of the work, which is usually about 10–15% of the retail value. A more serious difficulty is that much of the gold in private hands has been bought with non-declared income, which its owners are reluctant to declare for fear of investigation by tax officials. By January 2001, the designated banks had succeeded in raising only 6179kg of gold. The State Bank of India had raised the bulk – about 5800kg, which is nowhere near what it had originally projected.

Source: World Gold Council (2001) p.17; Economic Times of India, March 20, 2001.

Figure 5–7. The Gold Price, Average London Fixing, 1968–2000
Source: CRU International



whether these institutions as a group are net buyers or net sellers, and on what scale. Of the 170 countries reporting to the International Monetary Fund (IMF) in the late 1990s, 70% declared some gold as part of their reserve assets. Ten countries reported that they definitely did not hold any gold; another 41 did not declare either way.[25] The US holds around three-fifths of its foreign reserves in gold. The European Union has about 27% of its reserves in gold. At current market prices, the international average is about 16%.

In the 1990s it became clear that the commitment of some governments to maintaining gold as a store of value was declining. The drop in official purchases of gold and the increase in sales indicated that some bankers thought it time to change policy. This caused concern to the gold producers and other governments. The world's key financial organizations (official institutions and the IMF) hold the equivalent of 15 years of mine output.[26] As there was no coordinated approach to gold sales by either miners or central banks, there was growing fear of a collapse of the gold price. When prices fell, much of the loss affected countries in sub-Saharan Africa. Gold mining employment in South Africa alone is said to have declined by some 300,000, in what is known there as the Gold Crisis.[27]

On September 26, 1999, the Central Bank Gold Agreement (also known as the Washington Agreement or Washington Accord) was announced.[28] A group consisting of the members of the European Monetary Union, the European Central Bank, the UK, and Switzerland, with the tacit agreement of the US Federal Reserve, the Reserve Bank of Canada, and the Bank of Japan, agreed on a programme to stabilize the gold market. Together with the IMF, these participants control well over 20,000 tonnes of gold reserves.[29] The main provisions of the agreement were a freeze on any additional lending by the signatories and a limit on gold sales to 2000 tonnes over five years, with no more than 400 tonnes to be sold in any one year. What happens at the end of the initial five-year term of the agreement in 2004 is still uncertain. As a group, central banks have not returned to the market as buyers of gold in any significant quantities and they remain sizeable net sellers. The increasing reliance on the US dollar, notably in Latin America, has been accompanied by gold sales. The emergence of currency blocs, such as in the European Union, has meant the pooling of reserves.

Future agreements affecting the gold market will be of key concern. While central banks as owners have to decide what is in their interest, these decisions are fraught with consequences for others and should be made in an atmosphere of consultation and transparency.

Availability of Gold

Total world geological resources of gold are estimated to be about 100,000 tonnes, including 15–20% in the form of by-product resources. [30] (See Table 5–5.)[31] Some of the 9000 tonnes in US resources would be recovered as by-product gold. At the current production rate, these resources would last about 25 years.

As with the other metals studied, physical availability is in the short and intermediate term less of an issue than are environmental, social, and political challenges to producing these reserves. The gold industry faces challenges at the market level, as indicated. For aluminium, energy requirements for smelting are a key issue. For copper, smelter emissions are a major problem. For gold, there are somewhat different issues.

First, given the gold industry's focus on exploration and the multiplicity of the people and companies that explore for gold, the issues of land rights will be prominent. These include the important question of acceptability to indigenous and aboriginal communities and the continued debate over what areas are or should be 'off limits' to exploration and mining.

Table 5–5. Estimated Gold Reserves and Resources (excluding some by-product reserves)

Country	Gold Reserves (tonnes)	Gold Resources (tonnes)
South Africa	19,000	40,000
United States	5,600	6,000
Uzbekistan	5,300	6,300
Australia	4,000	4,700
Russia	3,000	3,500
Canada	1,500	3,500
Brazil	800	1,200
Other Countries	9,300	11,800
World Total[a]	**49,000**	**77,000**

[a]May be rounded.
Source: US Geological Survey, http://minerals.usgs.gov/minerals/pubs/commodity/gold/300300.pdf
(11 December 2000).

While these concerns are not unique to gold, they may be of particular importance for this commodity.

Second, the ratio of the volume of waste to the volume of product will continue to attract attention. Calculations can be done many ways, but all concur that for low-grade gold deposits, some number of tons of waste – and correspondingly high amounts of energy and water – may be needed to produce a relatively small and simple gold object. This will continue to strike some people as wasteful, and some of them will link this concern to the question of whether use as jewellery or bullion in bank vaults is somehow less utilitarian than the industrial uses more common for other metals.

Third, for whatever reason, a number of the highly publicized accidents and failures of recent years that have fuelled public concerns over safety and environmental protection have occurred at gold sites, from Baia Mare and Merrespruit to Summitville and Omai. Ensuring that all who are mining have the capacity for sound environmental management is a challenge for all of industry; clearly not all do.

Finally, using cyanide to extract gold is the technology of choice for larger gold companies; mercury is still the agent of choice for a large part of the artisanal sector. Both of these technologies have caused significant environmental concern. The extent to which the new cyanide code (see Chapter 10) or other steps will improve both management and perceptions, and continued progress in controlling mercury use, will both be important concerns.

Fuels and Industrial Minerals

Coal

Need and Availability

Coal has been an important energy source for centuries.[32] In 2000 it provided 24.9% of the world's primary energy requirements.[33] In addition to being used to generate electricity, coal is used directly for heating. This includes important industrial processes such as steel and cement manufacture. Coal, when processed into coke, is also important in production of iron and steel.

The types of coal may be ranked in order of increasing carbon content and decreasing moisture content:

lignite (brown coal), sub-bituminous, bituminous, and anthracite. The last three are known as 'black coal' and the last two as 'hard coal'. Most types of this mineral have specific uses. Among the hard coals, steam or energy coal is used for electricity generation or conversion into other forms of secondary energy. Although all categories of coal can be used for electricity generation, power plants have to be designed to handle specific types of this material. A plant designed to burn bituminous coal, for example, cannot burn brown coal. Coking coal is always bituminous.

Coking coal is used by the steel industry in the stage involving production of blast furnace iron. While all coking coals can be burnt in suitably designed power plants to generate electricity, the reverse is not true in that bituminous steam coals cannot all be converted into coke. An important feature of coals used by the steel industry is that they should have as low a level of ash and sulphur as possible. Coal is also used to produce liquid fuels, chemicals, polymers, and plastics.

Significant deposits of coal exist on all continents, meaning that availability at the global level is not currently a critical issue. Coal is produced in over 50 countries. Known total reserves of coal are shown in Table 5–6. In 2000, a total of 3639 million tonnes of hard coal were produced, along with 895 million tonnes of brown coal.[34] On this basis, the world has more than 200 years of coal reserves. It is important to remember that while coal production in Europe is declining rapidly, this is not true in all industrial countries. US production, for instance, increased from 710 million tonnes in 1980 to 899 million tonnes in 2000. Most important, not all types of coal are suitable for all purposes. Nor are all types found at comparable grades all over the world.

Table 5–6. Known Reserves of Coal

	Reserves (billion tonnes)	Share of total (per cent)
North America	256.5	26.1
Europe	122.0	12.4
Former Soviet Union	230.2	23.4
Asia Pacific	292.3	29.7
Rest of World	83.2	8.4

Source: BP Energy Statistics, June 2001

Like gold, coal is relatively easy to identify, and often fairly accessible to exploitation by basic technologies. This means that in many regions of the world production of coal by small and medium-scale enterprises is fairly common. For the same reasons, there is considerable small-scale and artisanal activity in several countries, notably China.

Some types of coal are traded internationally for specific uses, particularly the sub-bituminous and bituminous types. For instance, about 39% of coking coal (192 million tones) was traded internationally in 2000. In contrast, the 574 million tonnes of hard coal traded internationally represented only 16% of the total world production of this type. Due to the high moisture content of brown coal, it is uneconomic to transport this type over long distances. In the three largest coal-consuming and -producing economies (China, US, and India), over 95% of production is used domestically.

For coal that is traded by sea, the patterns of supply differ by region and by category of coal. The major suppliers of steam coal into the Pacific region are Australia, China, and Indonesia, whereas the major suppliers into the Atlantic region are South Africa, Colombia, and Russia. The major suppliers of coking coal into the Asian market are Australia and Canada, while in the Atlantic it is Australia, the US, and Canada.

Over 80% of the world's coal production is used in its country of origin. In some countries, coal is a particularly important energy source. Poland, South Africa, Australia, and China all rely on coal to produce over 75% of their electricity, since they have limited alternative fossil fuel energy sources. In many countries, coal is a key fuel for domestic heating and cooking.

Changes in the demand for coal are affected by global competition from other fossil fuels such as oil and gas. With the exception of Japan and the US, the demand for steam coal for electricity generation in many industrial countries is decreasing. In Europe, the availability of cheap natural gas has resulted in the output of coal-fired power stations being reduced and smaller, less efficient stations being closed. An additional factor affecting coal production in Europe has been the higher costs than new mines in countries such as Colombia, Australia, and Indonesia. Subsidies to support coal mining in Europe are being reduced and coal production is declining, even though imports into the major European nations are increasing.

A key area for growth in coal production is the Pacific region. Unlike in Europe, the ability to develop gas infrastructure is limited in many parts of the Pacific. As a result, coal-fired power stations are seen as being needed to meet the surge in electricity demand associated with industrial growth and rising living standards.

Factors Affecting Future Coal Use

A key factor affecting demand for coal is the technologies employed in its use. Despite an increase in the production of pig iron between 1990 and 2000, total world production of coking coal declined from 548 million tonnes to 497 million tonnes. This is partly due to an increase in the efficiency of blast furnaces, but also to more stringent environmental controls. Demand for coking coal is linked closely to pig iron output across the world.

Steel companies have introduced equipment that injects coal directly into the blast furnace as a substitute for coke. It is estimated that currently 32 million tonnes of coal are being injected into blast furnaces worldwide. Coal for injection purposes does not require coking properties. It does, however, need the same levels of chemical purity as coking coal. The technology of coke making has developed so that poorer coking coals can be used at increasing levels in the mix of coals being fed to coke ovens. Currently this technology is used mainly in Asia and South America. These coals are often the same as those used for injection and have resulted in a second category of coking coal being established. This category is often referred to as semi-soft coal in contrast to high-quality coking coals, referred to as hard coking coals.

As with other carbon fuels, policies set by governments and producers have always had significant implications for coal use. For instance, following the oil price shocks of the 1970s, electric utilities turned from oil to coal, and by 1983 the trade in steam coal exceeded that of coking coal. Energy policy is now increasingly influenced by environmental concerns, which may have significant implications for the way in which coal is used and overall demand.

There are numerous environmental concerns relating to coal use, including emissions of polluting gases associated with iron and steel production and direct combustion for electricity generation. Technologies have been developed to address these, many of which are relatively well established in industrial countries. An example is systems to remove sulphur from flu gases in power stations (although this requires limestone to be mined). The concept of clean (or cleaner) coal technology incorporates numerous innovations that reduce emissions and use coal more efficiently. One example is fluidized bed coal combustion, which reduces emissions of nitrous oxides and leads to the efficient capture of sulphurous gases.

Emissions of carbon dioxide are now widely acknowledged as one underlying cause of global climate change and may therefore have significant effects on future coal use.[35] Coal has the highest carbon-to-hydrogen ratio of any fossil fuel and therefore produces a higher proportion of carbon dioxide than fuels such as oil or natural gas. Conventional modern coal-fired power stations operate at efficiencies of approximately 38%, compared with advanced 'combined-cycle' gas-fired plants that operate at 55% or more. Older coal-fired plants operate at much lower efficiencies. Some modifications can raise efficiencies (the conversion of the chemical energy present in coal to electricity) up to 40%. The next step in coal-fired technology is to convert coal into gaseous form and then burn it in a combined-cycle gas plant. Overall efficiency levels in the region of 50% may be achieved. Clearly, a key area of concern to industry, governments, and other actors is the transfer of these technologies to countries where coal use for electricity generation is increasing rapidly.

Obviously the contribution of coal combustion to carbon dioxide emissions needs to be evaluated alongside other sources and other gases (such as methane from reservoirs for hydroelectric power plant).[36] The Kyoto Protocol (part of the 1992 Framework Convention on Climate Change) or subsequent agreements may cause many governments to change their policies in order to create incentives for alternative energy sources. Carbon taxes and emission permits both within and between countries may affect the price of energy and thus the demand for coal. This topic is already the subject of an established debate with regard to energy policy and sustainable development. The European Union is currently one of the most sensitive markets with regard to the regulation of coal usage.

Potash

Approximately 95% of the current global consumption of potassium is used for fertilizers; the remainder is used in various industrial applications, including the manufacture of caustic potassium and other intermediate chemicals important to industry. Potash is the trade term that refers to fertilizer materials containing potassium. Potassium is essential for plant and animal life. Many soils lack sufficient quantities of available potassium for the demands of crop yield and quality. As a result, available soil potassium levels are commonly supplemented by potash fertilization to improve the nutrition of plants, particularly for sustaining production of high-yielding crop species and varieties in modern agricultural systems.[37]

Photograph not shown

Potassium is present in all types of rocks, but mining of potash ores is mainly restricted to two types of sedimentary deposits: deposits of marine origin that are found at depths typically ranging from 400 to more than 1000 metres below the surface, and surface brine deposits associated with saline water bodies (such as the Dead Sea, the Great Salt Lake, and China's Qarhan Lake). World resources of potassium bearing sedimentary deposits are immense and are reported to total 17 billion tonnes.[38] Of this, 8.4 billion tonnes of reserves are categorized as commercially exploitable.[39] With current annual global consumption of about 25.8 million tonnes, both economic reserves and the resource base are sufficient to meet world demand for centuries.

Potash ores situated at depth are mined mainly by conventional mechanized methods. Solution mining is used when underground extraction is no longer technically feasible. Solar evaporation of brines that naturally contain potassium is the third method of obtaining potash ore.

The processing of potash ores normally results in large volumes of waste materials, including brines, slimes containing clay, and salt tailings. The disposal of saline wastes, including the rehabilitation of land after mining, has been a key issue in the environmental management of the potash industry.[40]

World production of potassium fertilizer salts has grown significantly in the last century to meet the growing requirements of intensive agriculture. From 1998 to 2001, potash production varied in the narrow range of 25.4–25.8 million tonnes yearly, compared with consumption of 21.9–22.8 million tonnes. In 1998 and 1999, potash usage of 11.1–11.4 million tonnes in industrial countries was only slightly higher than usage in developing countries of 10.5–10.9 million tonnes.

There are only 14 producers in the world potash market. Four countries account for three-quarters of global output: Canada, Russia, Germany, and Belarus. Canada has the largest known reserves of potassium. These extensive, consistent, and high-grade potash deposits represent more than 50% of estimated world reserves. The sizeable potash deposits in the former Soviet Union contain large amounts of ore, but these are of a type that has higher refining costs. Thailand has 10 billion tonnes of potash consisting of a mixture of ore types.

Major consuming regions, such as Asia and Latin America, will continue to depend substantially on imports, due to the resilient imbalance in the supply/demand situation and the sustained growth in demand. Exporting regions such as North America, East Europe/Central Asia, and the Near East will expand their capabilities to meet world requirements for potash in growing and emerging markets.

Four countries currently account for close to 53% of global potash usage. The US is the largest consumer, typically accounting for about 20% of the world total. China, Brazil, and India represent approximately 15%, 10%, and 7%, respectively, of world consumption. Western Europe is also an important consuming region, using about 17.5% of the total in recent years.

Potash demand is determined largely by the requirements for fertilizer production, which is forecast to reach 25 million tonnes by 2005. The most fundamental factors determining long-term demand for potash will be developments in agricultural techniques and patterns of food production to meet a growing world population. Future need for potassium fertilizers will also depend on a number of specific factors, including:

- the extent and severity of potassium deficiency in cropland,
- the introduction of new or improved crop varieties with greater potassium requirements,
- shifts in demand for agricultural products,
- the profitability of potassium fertilization to farmers,
- prices for agricultural products and other fertilizers,
- government crop production or restriction programmes, and
- weather conditions (including those associated with climate change).

The correct availability of potassium in the soil (of which fertilizer is one source) is important in plant resistance to drought, frost, and a number of diseases and pests. The element is essential for the development of the root system and fosters nitrogen fixation of leguminous crops, and it improves the size, colour, and sugar content of fruit crops. Natural reserves of soil potassium diminish with each successive crop. This withdrawal or 'soil mining' is greatly increased and accelerated by higher yields and more intensive cropping.

The decision to use potash in agriculture depends on the relationship between the cost of fertilizer and the return on yield. It also depends on the level of technology associated with the production system in question. The debate about the role of fertilizer in supplying plant nutrients is linked to concerns about the environmental and social impacts of modern agricultural production systems. In many industrial countries, there is an increasing focus on organic farming practices, which place greater emphasis on the recycling of organic matter. Even so, the International Guidelines covering organically produced foods do allow for potassium to be used where adequate crop nutrition and soil conditions cannot be achieved through the recycling of organic materials alone.[41] Potassium fertilizer (and therefore the requirement for potash mining) will continue so long as modern agricultural practices are the basis for meeting the world's food requirements.

Endnotes

[1] H. Murray, Indiana University, Industrial Clays. This study will be published with the MMSD working papers.

[2] Unless otherwise indicated, the data in this chapter are supplied by CRU International. Information is also provided by McCloskey Coal, Gold Fields Mineral Services, the International Iron and Steel Institute, the United Nations, the U.S. geological Survey, and the World Bureau of Metal Statistics.

[3] In Table 5–1, aluminium consumption refers only to primary metal produced from bauxite; all scrap-based aluminium consumption is separate and in addition to this figure. Copper consumption refers to refined copper, of which 86% in the western world is produced from ore and concentrate, while 14% is produced from scrap; in addition, a large amount of scrap is recycled as alloy (notably brass). Lead consumption refers to refined lead, of which 60–62% in the western world is now produced from scrap and the remainder from ores and concentrates. In addition, a small amount of lead is recycled in the form of alloys. Steel consumption refers to carbon steel, of which over 50% is produced from scrap in the western world. In addition, stainless steel scrap is recycled as stainless steel. Production statistics are for 2000.

[4] World Aluminium Institute at http://www.world-aluminium.org/production/recycling/index.html.

[5] Defined as the US, Canada, Western Europe, Japan, Australia, and New Zealand in the statistics shown in this chapter.

[6] Data from GFMS, IMF, CRU.

[7] For Iceland, see Norsk Hydro Ices Aluminum Smelter, Environment News Service, 4 April 2002, at http://www.corpwatch.org/news/PRT.jsp?articleid=2270; see 'World Bank in India, Car Culture Pushes Privatisation,' *AidWatch*, at http://www.aidwatch.org.au/news/15/10.htm; see 'Chile Green Groups Question Aluminum Plant Comment,' *Planet Ark*, 3 December 2001, at http://www.planetark.org/dailynewsstory.cfm/newsid/13528/story.htm.

[8] World Commission on Dams (2000).

[9] Data for secondary recovery of aluminium are much less complete than those for primary consumption. The major form of secondary production is the re-melting of scrap to produce alloy ingots. This is reasonably well recorded, but there are undoubtedly some small secondary smelters that do not report production. There are also producers of billet from scrap (with some primary additions). Production from these plants is much less well recorded in Europe. Then there is scrap that is directly re-used in semi-fabricating plants that have their own casting facilities. This scrap can arise within the plant or be bought in from scrap merchants. This recycled material is not fully recorded and in some countries is not recorded at all. Finally, some pure aluminium scrap is melted in the casthouses of primary smelters and cast into products that are sold as primary aluminium. How this metal is recorded, if at all, is uncertain. All that can be said with confidence is that the volume of aluminium recycled is greater than the volume recorded. This should be borne in mind when considering any calculations about the amount of aluminium scrap that is lost in landfills and could in theory have been recycled.

[10] The process uses laser induced optical spectroscopy. Each piece of scrap is sampled by means of a laser, identified, and then separated by alloy. If commercially proven, the process would enable much more of the value of aluminium scrap from shredded automobiles to be retained. The process is being tested by the Huron Valley Steel Corporation and is being promoted by the Auto Aluminium Alliance and the Aluminium Association; see US Department of Energy, Office of Industrial Technologies (2001); Comments of International Recycling on Draft Report.

[11] MacMillan (2000).

[12] See 'Zambian Copper Chokes Miners', *Electronic Mail & Guardian*, 29 January 1997, at http://www.mg.co.za/mg/news/97jan2/29jan-zamcopper.html. A list of smelters is available at

http://www.ame.com.au/smelters/cu/smelters.htm.

[13] A standard automotive SLI (Start, Light and Ignition) battery is composed largely of lead and sulfuric acid.

[14] The mobility study now being supported by the World Business Council for Sustainable Development may shed some light on these questions.

[15] Gold Fields Mineral Services Ltd. (2001). Total includes fabricated items as well as bar hoarding and net producing hedging and investment.

[16] World Gold Council (2001) p.17.

[17] Wedepohl (1995) estimates that there are 2.5 parts per billion of gold in Earth's continental crust.

[18] Gold Fields Mineral Services. Of this, some 70,000 tonnes are said to be held in the form of jewellery, and 30,000 tonnes in official institutions. Ibid.; ICMM comments on draft report.

[19] Otto (2002).

[20] See http://csf.colorado.edu/bioregional/apr99/ 0015.html and http://www.rainforestjukebox.org/ gold/platform.htm.

[21] World Gold Council, London, press release, 10 May 2001.

[22] This organization should not be confused with the Global Mining Initiative.

[23] Keynes (1936), p.129.

[24] Robert A. Mundell, quoted in Gold Institute comments on MMSD draft report.

[25] World Gold Council.

[26] Ibid.

[27] Total number of employees in South African Gold Mines fell from 474,851 in 1990 to 197,537 in 2000 (Chamber of Mines of South Africa).

[28] Orellana (2001).

[29] World Gold Council, at http://www.gold.org/finalgold/gold/Gra/Pr/Wr991006.htm.

[30] This refers to gold recovered as a by-product in the mining and extractive metallurgy of other metals. The gold (or any other saleable element) is classed as a by-product if it is not the main source of revenue for the facility producing the metals concerned. The main source of by-product gold is the copper industry. Other sources include platinum producers, silver mines, and, on a very small scale, lead and zinc mines.

[31] In Table 5–5, 'reserves' refers to that part of the reserve base that could be economically extracted or produced at the time of determination. The term need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials; thus terms such as 'extractable reserves' and 'recoverable reserves' are redundant and are not a part of this classification system. 'Resources' refers to that part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources). The term 'geologic reserve' has been applied by others generally to the reserve-base category, but it also may include the inferred-reserve-base category; it is not a part of this classification system.

[32] This section is based on information provided by McCloskey Group, supplemented by information available from the World Coal Institute at http://www.wci-coal.com.

[33] British Petroleum (2001).

[34] IEA Coal information (2001).

[35] Houghton et al. (2001).

[36] Ibid.; World Commission on Dams (2000).

[37] This section is based largely on data provided by the International Fertilizer Industry Association, Paris.

[38] US Geological Survey (2000a).

[39] Measured in terms of the mass of potassium oxide.

[40] UNEP (2001b).

[41] FAO/World Health Organization (1999).