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Mining, Minerals and Sustainable Development

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Part II: Current Trends and Actors

Chapter 5
Case Studies on Minerals

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Chapter 5: Case Studies on Minerals

A true assessment of the need for minerals must start with the premise that every mineral has to be looked at individually. This chapter demonstrates this by describing the use of, and need for, five metals (aluminium, copper, lead, steel and gold) together with two non-metals (coal and potash) in light of the discussion in Chapter 4.[1]

Metals Overview

Steel is by far the most important industrial metal in terms of volume produced and used. (See Table 5–1.) World consumption reached 837 million tonnes in 2000, which exceeds the consumption of primary and secondary aluminium, the next most widely used industrial metal, by a factor of 25.[2]

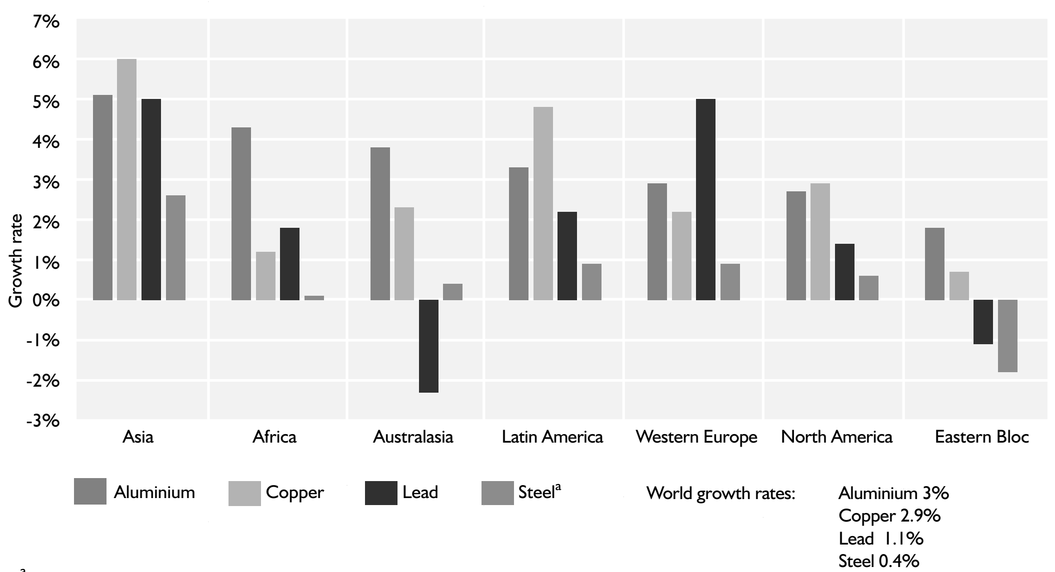
Table 5–1. Production, Consumption, and Recycling of Metals					
	Aluminium	**Copper**	**Lead**	**Steel**	**Gold**
Cumulative total world production	573 million tonnes	409 million tonnes[a]	204 million tonnes[a]	32 billion tonnes of crude steel	128,000 – 140,000 tonnes
Recent annual world consumption	24.9 million tonnes	15.1 million tonnes	6.2 million tonnes	837 million tonnes	3,948 tonnes
Consensus forecast for growth in consumption over next 10 years	3%	2.9%	1.1%	0.8%	4.3%
Share of total metal consumption derived from recycled material	North America 35%, Western Europe 31%, Asia 25%, world 29%	Western world 35%	US 70%, rest of western world 55%	US 79%, Western Europe 55%, East and SE Asia 52%, rest of western world 46%	Western world 35%

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

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. 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.[3] World-wide, the future of scrap recycling certainly looks promising, particularly with the growth of packaging expected in South America, Europe, and Asia, and especially China. In the case of lead, 60–62% of refined lead production in the western world comes 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.

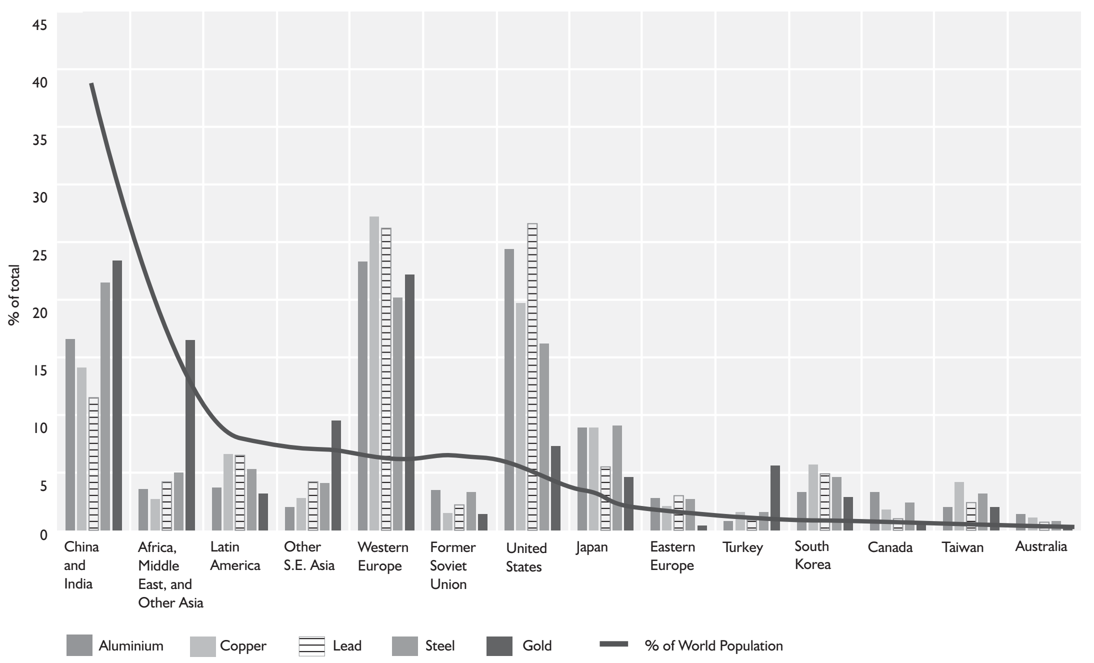
Over the last 25 years, growth in demand for metals has been fastest in regions undergoing rapid development – the transition countries – which have a substantial demand for use in infrastructure, such as housing, water, and electricity supply. (See Figures 5–1 and 5–2.) The rapid growth of demand for lead in these regions reflects the growing number of cars being used and the demand for lead batteries for the storage of power. Transition countries, in general, have a moderate level of industrialization and infrastructure, and are at the stage when faster growth in metal consumption can be expected as they enter, or move through, a new phase of economic development. Within industrial economies, demand for metals grew at rates below the world average over the last 25 years, since demand for use in infrastructure spending is lower.

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



[a] The figures for steel are for 1975–1999.

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



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.

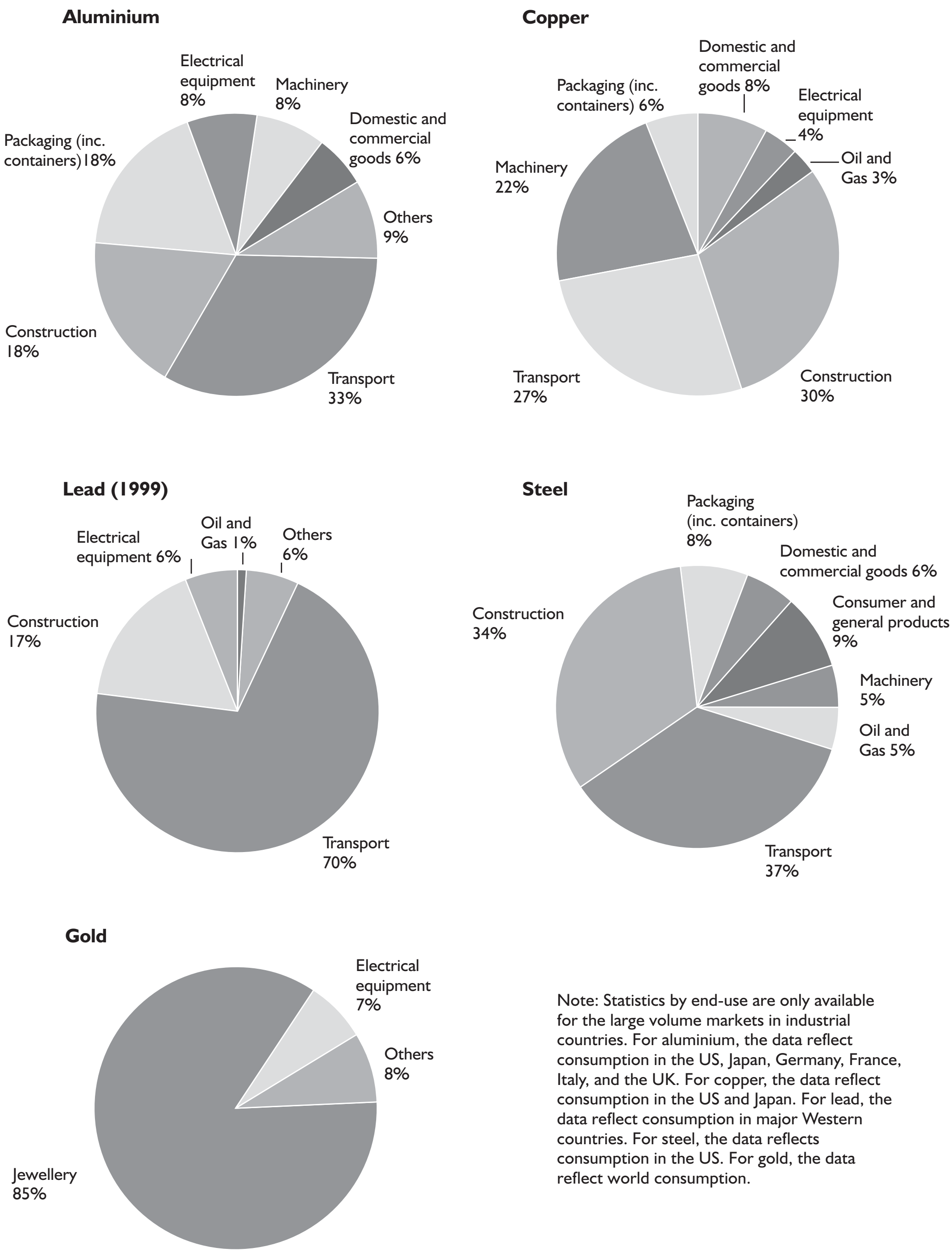
Not surprisingly, given the use of metals in a wide variety of industrial and consumer applications (see Table 5–2 and Figure 5–3), there is a reasonably strong positive relationship between consumption per capita and gross domestic product (GDP) per capita. (See Table 5–3.) A significant distinction 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. Above this cut-off point, consumption per capita rises quite rapidly because this appears to be the level at which substantial semi-fabricating industries develop, partly to serve domestic demand and partly to serve export markets.

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

Industries	Competing metals/materials
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.
Airframes	*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 greater density 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 End-Use Applications (continued)	
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 to power 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 beingconsidered, 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.
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.

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



Note: Statistics by end-use are only available for the large volume markets in industrial countries. For aluminium, the data reflect consumption in the US, Japan, Germany, France, Italy, and the UK. For copper, the data reflect consumption in the US and Japan. For lead, the data reflect consumption in major Western countries. For steel, the data reflects consumption in the US. For gold, the data reflect world consumption.

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**
Industrialized Countries											
USA	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 & Other Asia	22.4	0.7	3.6	0.3	2.7	0.2	4.2	29.3	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.

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.[4] In 2000, these nations accounted for the majority of metals consumption, but for only 14.6% of the world's population. Even for gold, about which it is often claimed that developing countries play a pivotal role as consumers of jewellery, per capita consumption in India is still less than half of that of the US or the UK.

It should be noted that the statistics on the use of metals can be misleading. As consumption is measured by the amount of metal produced and imported, it does not take account of whether the products made from the metal are sold domestically or exported. Thus South Korea and Taiwan appear to have extraordinarily high metal consumption levels, when in fact they are heavily involved in metal manufacturing and are major exporters of metal products and lead batteries. If 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 and so they import metal-intensive goods, which would not be recorded in the metal consumption statistics.

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 at the same level in the next 5 years as observed over the past 25 – 1.1%. Crude steel demand is expected to grow at between 1.8% and 2.1% per year.

Analysts' forecasts are invariably based on history and a 'business as usual' approach to the future. If transition and developing countries succeed in achieving a higher standard of living, however, and absent some rather dramatic change such as the 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.

The appetite for steel in China has been driven by the gradual liberalization of the economy and 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 in the form of construction, transportation, power generation and distribution can therefore keep the total demand for steel on a rising trend in China for some time to come.

More work is required to examine the likely impacts for metals consumption if substantial income transfer is made from North to South as a consequence of the imperative to move towards more sustainable development.

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. 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. There is comparatively little focus on the over-consumption of aluminium, other than consumer reaction to excessive packaging of products, which is not being recovered and re-used.

Aluminium's popularity is due to several specific characteristics:

- Aluminium 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 huge range of shapes.

Even so, in only a few cases is aluminium the only material that can provide the required properties. Generally, the designer of the final product assesses the properties, performance, and price of the metal in comparison with the alternative materials, and selects what is judged to be the best solution for the market.

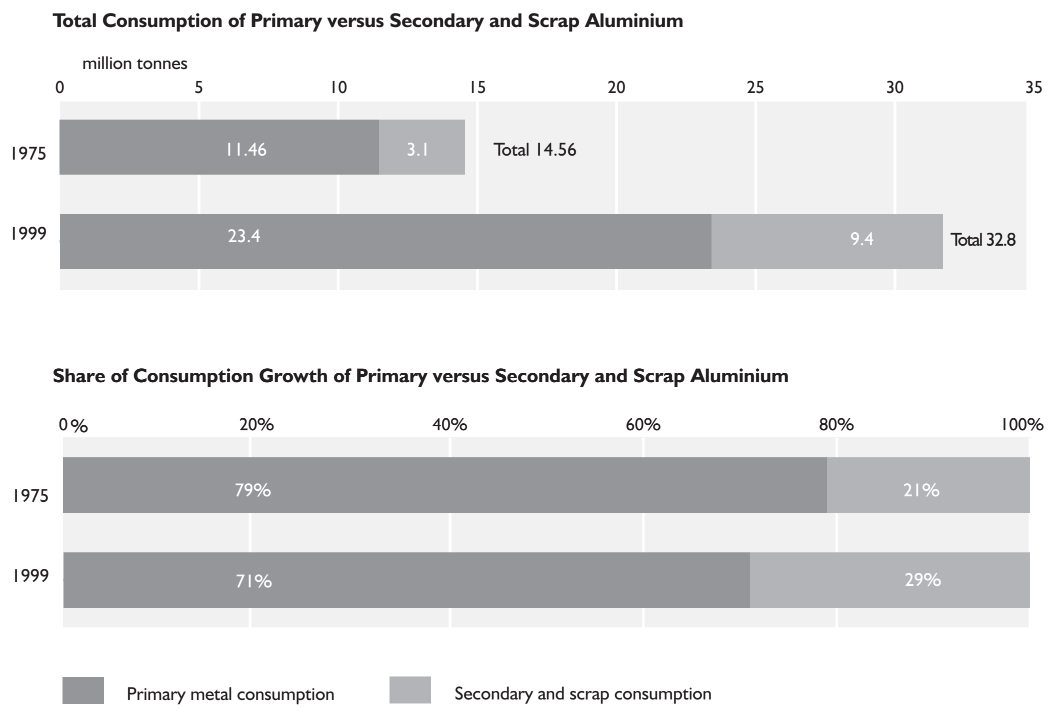
The Recycling of Aluminium

The recycling of aluminium 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 growing, and most of this can potentially be recycled. (See Figure 5–4.)

Figure 5–4. Total and Share of Consumption of Primary versus Secondary Aluminium, 1975 and 1999
Source: CRU International



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 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. When aluminium is used in locations where scrap collection is inefficient or non-existent, secondary consumption remains low. Where metal consumption has been relatively high for many years, as in Western Europe or North America, and where centres of consumption are more concentrated, the collection system is usually better developed, and the proportion of old scrap returning to the market is higher. 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%.[5]

The analysis of the economics of recycling indicates that there is a substantial (though variable) margin available to remunerate the scrap collecting chain. For companies that generate new aluminium scrap, there should be an economic incentive to obtain cash for what would otherwise be a waste product, especially since the collection costs will be small. For old scrap, the economics of collection is less compelling. There may be a chain of four or five parties, each incurring collection, storage, transport, and finance costs, until the scrap is sold to a secondary smelter. The value of the scrap therefore diminishes towards the beginning of the chain.

A persistent obstacle to the efficient recycling of aluminium is the way metal is used in many different alloys. Ideally, scrap should be sorted into specific alloys to be recycled. It is not difficult to keep scrap of the 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 is currently no commercial process for separating the scrap by alloy. This means that even though some scrap contains several different alloys, it can be recycled only as lowest grade of foundry alloy, the lowest value category. A recent development by Alcan Aluminium promises to make it possible to segregate shredded scrap by alloy.[6]

Major Policy Issues in the Future of Aluminium Use

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 help to provide a model for other large-volume metals. The volume that goes into dispersive uses – such as the laminated lids of yoghurt cartons or in 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, the more recycled material that can be made available to meet the growing demand, the better.

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 recover 50–60% of their used packaging, material recycling rates should be 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. If these regulations are not fully and uniformly enforced, however, non-compliant recyclers will remain in business and compete on an unfair basis with those that have incurred the costs of compliance, driving the compliant smelters out of business.

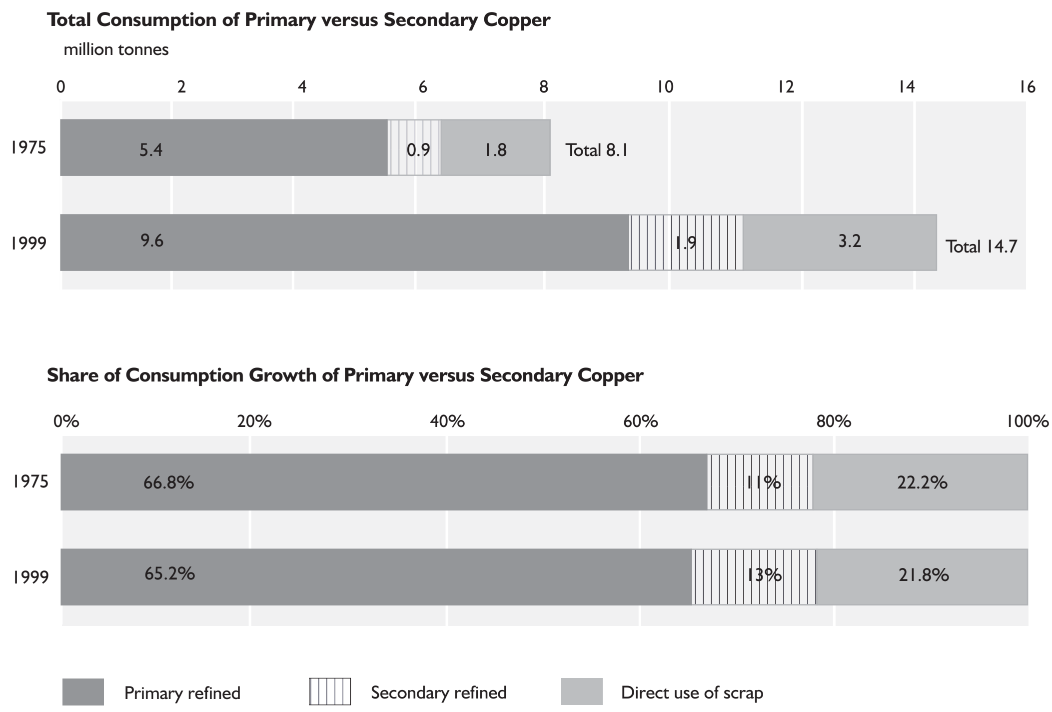
Government intervention designed to improve and encourage the recycling of aluminium should focus on the types of scrap that do not have sufficient value to ensure that the existing system gathers them. One option is to add a deposit to the price of an aluminium can that is refundable when the can is recycled, though the costs of operation may outweigh its value. Another option is for municipal authorities to provide recycling centres for the general public where they may return used cans from their household waste.

Copper

Copper is one of the metals that has been in longest use by society and has been one of the important materials in the development of civilization. Because of its properties of high ductility, malleability, thermal and electrical conductivity, and resistance to corrosion, copper has become a major industrial metal, ranking third after iron and aluminium in terms of quantities consumed. Copper is essential for power transmission and generation, building wiring, and telecommunications. It has a virtually unchallenged market for house wiring and underground power cables. Investment in power generation and distribution and in telephone systems has been a key driver of copper consumption.

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 5–5.)

Figure 5–5. Total and Share of Consumption of Primary and 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.

The supply of secondary copper is sensitive to the price of copper in the short term. Low metal prices lead to hoarding 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 into 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 the export of scrap, in order to retain this 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 this country.

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

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

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

In general, copper and its alloys are easily 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. A greater threat of loss arises from copper used in small quantities in wire, for example, coated in insulating material. This may be too small in volume to justify recycling.

Legislation directing producers to take responsibility for recycling their products at the end of their lives could increase the rate of recycling, though there is concern as to whether such legislation can ever be enforced effectively in practice. Some low-grade or complex copper scrap could be prevented from reaching a suitable smelter by the Basel Convention regulations. (See Chapter 11.)

Lead

Lead is a very corrosion-resistant, dense, ductile, and malleable blue-grey metal that has been used for at least 5,000 years. But in some countries 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 because of the danger of transmission into the water supply. In the 1960s and 1970s there was also a market for lead in covering electric cables for insulation and for general protective purposes, and this use has also largely disappeared, because it has been replaced by plastic insulating materials. 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, for environmental reasons. First, the dispersal of lead particles in exhaust fumes is hazardous. Second, exhaust fumes are now cleaned to prevent other harmful emissions, through the use of catalysts containing platinum or palladium. Lead in petrol poisons such catalysts, and therefore was eliminated to enable them to work.

The result is that lead-acid batteries – the one end-use where lead cannot at this stage be replaced – 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). 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 (in the case of replacement batteries). While there is some international trade in batteries and in 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 is the case with the 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 a battery required to provide starting, lighting, and ignition power for automobiles. However, in the last two decades the average weight of a car battery has stabilized at about 10.5kg.[7]

The question of whether there is 'over-consumption' 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.

While it is beyond the scope of this study to address transportation and mobility alternatives, there are certainly powerful arguments that countries such as the US and Canada have subsidized the use of automobiles and are excessively dependent on a form of transportation that consumes a diminishing resource (petroleum), while adding to air pollution problems, including climate change. But a motorcar is still a symbol of economic advancement and success in developing economies. In industrial countries, where the environmental damage done by motor vehicles and all the infrastructure that they require is a more prominent concern, there is still not enough investment in public transport to persuade many people to abandon car ownership in favour of alternative means of travel.

Attempting to limit access to lead for batteries does not seem a likely policy tool to address this concern. If automobile use is reduced, it will reduce demand for lead, but that reduction will occur for reasons other than a shortage of the metal.

The result of all these trends 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 in the world. 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 in automobile batteries 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 materials 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 the recycling process does not rely totally on the scrap collecting industry, though some are collected by scrap merchants. Consequently, 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. Their alternative is to buy refined metal at the London Metals Exchange price plus premium.

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.

The Basel Convention is a major 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 also prevent the movement of scrap, such as used batteries, that is potentially hazardous but is also a valuable resource for the recycling industry.

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.

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 an indispensable commodity required in very large quantities even in the richest countries of the world.

Steel can be recycled very 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. Carbon steels and coated steel are recycled in carbon steel facilities.

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

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

EAF steel-making has been growing as a percentage of total steel-making capacity and is expected to continue, as it has the advantages of lower capital costs and operating costs, compared with the blast furnace and basic oxygen converter route. 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 (or its alternative, hot briquetted iron). Recent data show that in North America 792kg of scrap was consumed per tonne of steel produced; in Western Europe, the figure was 554kg per tonne of crude steel; in East and South East Asia, it was 523kg; and in other western countries, it was 457kg. In other words, well over half of the total raw material used in the production of crude steel in the western world derives from scrap, 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 funds 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.

Gold

The production of gold presents some of the most difficult issues in any discussion of the need for and availability of minerals. It is notable for its versatility – being malleable and ductile, an excellent conductor of heat and electricity, immune to tarnish, and resistant to all but the strongest acids. 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. The fact that these can be used without complex recovery techniques or metallurgical processes has meant that it is one of the minerals that has been in use the longest.

Despite its exceptional properties, gold is seldom used for industrial purposes because of its cost. It is highly prized for ornamental use. Historically, 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 remains a preferred store of wealth in many parts of the world.

Availability and Demand

Gold is rather scarce, with a very low abundance in the Earth's crust.[8] In terms of weight, annual production is only a fraction of most other metals. (see Chapter 2.) In 2000, mine production amounted to 2,574 tonnes,[9] which represented 78% of total gold consumption.[10] Gold production has been increasing slowly over the last few decades. In the last 6,000 years well over 100,000 tonnes of gold have been mined.[11]

Total world geological resources of gold are estimated to be about 100,000 tonnes, including 15–20% in the form of by-product resources. [12] South Africa has half of the total, and Brazil and the US have about 9% each. (See Table 5–4.)[13] Some of the 9,000 tonnes in US resources would be recovered as by-product gold. At the current production rate, these resources would last about 25 years. Exploration activities for gold are currently at a relatively low level, given the stagnant price and abundance of identified resources.

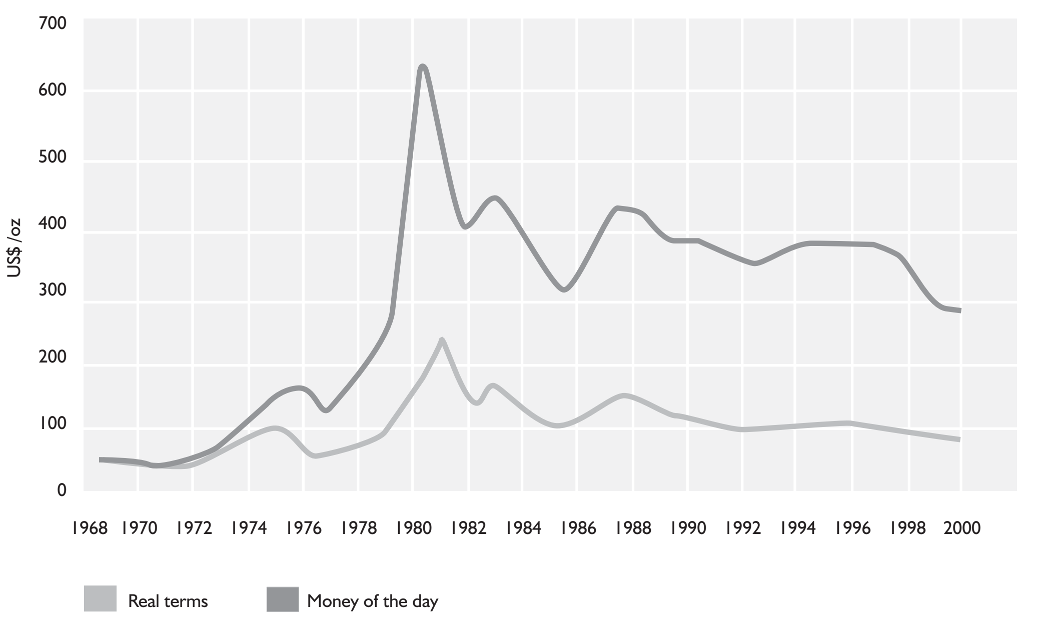
Table 5–4. Estimated Gold Reserves and Resources
(excluding some by-product reserves)

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
China	NA	NA
Other Countries	9,300	11,800
World Total[a]	**49,000**	**77,000**

[a]May be rounded. NA: Estimate not available in 2000.
Source: US Geological Survey, http://minerals.usgs.gov/minerals/pubs/commodity/gold/300300.pdf (11 December 2000).

In recent years annual demand for gold has been around 4,000 tonnes per year. Jewellery is the driver of current gold demand, constituting 80% of total demand in 2000.[14] It is important to recognize that gold has a variety of other applications, including electronics, dentistry, industrial and decorative materials (glassware and ceramics, for instance), medals and coins. Taken as a whole, non-jewellery use of gold has been relatively stagnant over the last 10 years. Gold faces increasingly intense competition in almost all markets. Taking into account variations since the 1960's, prices have been relatively stable in recent years despite their general decline. (See Figure 5–6.)

Figure 5–6. The Gold Price, Average London Fixing, 1968–2000
Source: CRU International



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 sub-continent alone, where gold jewellery is of great cultural significance.[15] 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.

Several important issues could affect gold demand dramatically. Among them, three stand out:

- the extent to which gold is still recognized and used by individuals as an inflation hedge or store of value;
- central bank policies towards their own gold holdings; and
- the success or failure of intensive efforts by industry to promote gold, particularly in jewellery, to individual consumers.

Gold as a Store of Value

Gold is the store of value that in many societies has long been the principal hedge against currency depreciation. The extent to which it still plays this role is the subject of debate.

The signs are mixed. For example, when taken together, central banks have become net sellers of gold. On the other hand, very modest rise in gold prices occurred after the events of 11 September 2001. It is possible that gold played a role in limiting the economic crisis in Argentina in 2002.

Individuals in many in developing countries save with gold. It is often not banked and from an economic point of view represents an asset that cannot back the expansion of credit and availability of capital. (See Box 5–1.) It can be significant in other ways as well: in 1998 alone India imported more than 600 tonnes of gold, at a cost of almost US$7 billion, a big factor in the soaring cost of non-oil imports.

Box 5–1. The Indian Experiment With Gold Banking

There are deliberate efforts in India and perhaps elsewhere to get the wealth represented by private gold stocks into circulation. 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 also be 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, 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 6,179kg of gold. The State Bank of India had raised the bulk – about 5,800kg, which is nowhere near what it had originally projected.

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

Central Bank Gold Policy

The dominant factor in the future demand for gold is the policy followed by central banks, which together hold close to a third of the gold still in use. Whether the future price of gold goes up or down depends very much on whether these institutions as a group are net buyers or net sellers, and on what scale.

The Bretton Woods agreement of 1944 replaced the previous gold standard with the gold exchange standard, under which countries undertook to maintain a fixed value for their currencies against the US dollar, while the dollar itself was pegged to gold at US$35 per ounce: the price at which most of the gold held by central banks was acquired. The link was effectively abandoned in 1968, and formally broken in 1971.

Most countries nevertheless still hold some of their reserves in the form of gold. 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. Only 10 countries reported that they definitely did not hold any gold, but another 41 did not declare either way.[16]

The US holds around 60% of its foreign reserves in gold, perhaps because with the world's main reserve currency it has little need for other currencies. The European Union (EU) has about 27% of its reserves in gold. In contrast, some countries hold only a small share of their reserves like this and others have none whatever. At current market prices, the international average is about 16%.

In the mid-1990s it became clear that the commitment of governments to maintaining gold as a store of value was declining. The decline 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.[17] This would be enough, together with scrap gold, to feed 13 years' manufacture of jewellery. 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 By mid-1999, the price of gold hit a 20-year low.

Net central bank gold sales rose from 311 tonnes in 1996, to 544 tonnes the following year and 656 tonnes in 2000.[18] Prominent among sellers in recent years have been the National Banks of Belgium and the Netherlands, the Bank of England (on behalf of the British Treasury), and the Swiss National Bank. Amidst declining prices, the IMF also proposed to sell some of its large gold store, although this was blocked by a US veto.

The central bank sales of gold have affected the interests of producers and producing countries, particularly smaller gold-dependent economies. Bank sales increase supplies to the market and are taken as a signal by investors to sell. When prices fell in 1996–97, most of the loss (around US$1.84 billion), affected countries in sub-Saharan Africa, with other heavily indebted poor countries suffering a loss of around US$400 million. Gold mining employment in South Africa alone is said to have declined by some 300,000 in what is called in that country the Gold Crisis.[19]

On September 26, 1999, the Central Bank Gold Agreement (also known as the Washington Agreement or Washington Accord) was announced.[20] A group comprising the members of the European Monetary Union (EMU), 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 a programme to stabilize the gold market. Together with the IMF, these participants control well over 20,000 tonnes of gold reserves.[21] The main provisions of the agreement were a freeze on any additional lending by the signatories, and a limit on gold sales to 2,000 tonnes over five years, with no more than 400 tonnes to be sold in any one year. These limits included existing commitments to sell, such as those of Switzerland, the UK, the Netherlands, and Austria but left little or no room for additional sales.

The impact of the agreement was a marked price increase, with the bullion price rising by over 20%. Though this did not last, the previous downtrend was halted. The price has yet to return to the low point reached in summer 1999.

The agreement is, however, neither a legally binding contract nor an international treaty, since it has not been formally ratified at governmental level. Likewise, it is not a memorandum of understanding of the kind that brought stability to the aluminium market in the 1990s. It is a statement of intent, which (it is hoped) will be durable. History suggests that agreements among central bankers based on little more than an informal understanding do in fact hold. What happens at the end of the initial five-year term of the agreement in 2004 is, however, 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.

If the policy of the central banks before the 1999 agreement returns, they will want to sell; perhaps especially in the EMU, Switzerland, and the UK, where nearly 1,500 tonnes of gold will still be held when the initial five year period for the agreement ends in 2004. A total of 2,000 tonnes over five years may seem modest for the renewal, as it would take 25 years to eliminate the gold stocks of EMU members at that rate of sales. At higher rates of disposal, however, the price would again collapse and the industry would be threatened.

Gold Promotion and Demand

The world's larger gold producers believe that they can increase gold demand by a strong promotion of its use, particularly in jewellery. In May 2001, the World Gold Council, an industry-sponsored organization, launched a US$55-million campaign to raise the profile of gold. The aim is 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.[22]

The objective of the World Gold Council is to shift people's perceptions of the value of gold from its traditional status as a monetary asset, to focus on its value as an emotional symbol. 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 and to agree to support the scheme financially for five years.

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 that in terms of total mining employment. Though it is difficult to estimate the number of artisanal and small-scale miners engaged in gold, it is estimated that perhaps 20% of total world gold production comes from this source.

Recovery of gold is well suited to artisanal techniques since it has high value, it often exists as visible free gold, and it can be produced with minimal processing. In many countries where artisanal and small-scale mining is an important source of employment, the sector accounts for the majority of gold production.

Outside the artisanal and small-scale sector, gold mining is a major source of livelihoods in many countries. The top 15 gold-producing companies in 1999 and 2000 employed approximately 200,000 people. (see Table 5-5).

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

	Company	Base	1999	2000	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	N/A
8	Harmony	South Africa	41.4	66.8	42,600
9	Normandy	Australia	58.8	64.5	N/A
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	N/A

[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.

This industry has and can bring other development benefits: it can spur the growth of the formal economy and provide revenues for physical, financial, administrative, and legal infrastructure. The various gold rushes of the last century, for example, played a significant role in triggering development of countries like the US, Canada, and Australia. Gold mining has been central to the development of South Africa. (See Box 5–2.) In many countries where gold mining is currently important, there are, at present, limited options for alternative industrial activities to support economic development.

Box 5–2. 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. 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 half a 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 employed 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).

For some developing countries, the gold mining currently under way represents only a fraction of the potential. Plans being made for many other projects – assume stable or increased prices. Many projects are only at the exploration stage and, if deferred as a result of low international prices, the opportunity costs of lost development could be considerable. The multiplier effect of a failure to proceed with these projects is potentially large and could, in the view of the World Gold Council, put at risk in extreme cases the funding and implementation of the whole process of economic reform. According to the Council, gold accounts for a significant proportion – ranging from 5% to nearly 40% – of the exports of many heavily indebted poor countries.

Environmental Constraints on Gold Production

While gold is an important source of livelihoods and development opportunities, it is also the source of a variety of serious environmental problems. The lowest grade of ore in large-scale production today is approximately 1g per tonne. This means that production of one ounce of gold at a mine having a typical stripping ratio of 3:1 (three tonnes of waste removed for every tonne of ore) requires moving 124 tonnes of material.

The large physical impact for a relatively small amount of material, which can only be achieved by expenditures of correspondingly large amounts of energy and water, is often suggested as a limitation on gold production. Added to this is the fact that this production is commonly achieved through the process of cyanidization, which has at least some environmental risks. Mercury amalgamation is a technique also used in some gold production (especially in artisanal and small scale mining). This is associated with occupational and environmental hazards.

Assessing the Need for Gold

Some suggest that the world does not 'need' more gold or more gold mining. There are few if any uses of gold that do not have competitive substitutes. Though gold is a versatile material, many of its potential uses are prevented by cost. In assessing the need for gold, it is important to understand the nature and origin of decisions affecting demand. The gold market is highly political. If historical trends serve as a useful guide, its future will be determined as much by a set of policy decisions agreed by a limited number of central banking institutions as the impersonal forces of supply and demand.

The future of the gold market will have immense significance for gold-dependent economies, such as Mali, Peru, and South Africa. They also have a major influence on the economic security of people in South Asia and the Middle East who hold their wealth in the form of gold. A reduction in gold mining would impact the millions of rural poor whose livelihoods are based on gold mining. It is clear that arguments about the use and need for gold must include recognition of the differences in value systems of both individuals and different societies. It is also clear that the current revenues from gold should be used to build a more diverse and resilient economy for the future.

The ethics and economics of future agreements affecting the gold market will be of key concern. If, in the absence of any agreement, there were a large sale of gold by central reserves and others and resultant in a fall in the price, many higher-cost producers might not survive. In such a scenario, affected producers and their host countries would undoubtedly begin to question the accountability of these decisions.

Coal

Need and availability

Coal has been an important energy source for centuries.[23] In 2000 it provided 24.9% of the worlds primary energy requirements.[24] In addition to the generation of electricity, coal is also 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.

Types of coal may be ranked in order of increasing carbon content and decreasing moisture content as follows: 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. Amongst the hard coals, steam or energy coal is employed 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. For example a plant designed to burn bituminous coal can not burn brown coal. Coking coal is always bituminous.

Coking coal is employed by the steel industry in the stage involving production of blast furnace iron. Whilst all coking coals can be burnt in suitably designed power plants to generate electricity, the reverse is not true in that not all bituminous steam coals can be converted into coke. An important feature of all coals used by the steel industry is that they should have as low a level of ash and sulfur as possible.

Significant deposits of coal exist in all of the World's 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, world hard coal production was 3,639 million tonnes and production of brown coal was 895 million tonnes.[25] On this basis, the World has over 200 years of coal reserves. It is important to remember that while coal production in Europe is declining rapidly, this is not true of all industrial countries. Coal production in the United States for example increased from 710 million tonnes in 1980 to 899 million tonnes in 2000. Most importantly, not all types of coal are suitable for all purposes. Neither are all types found at comparable grades all over the world.

Table 5–6. Known reserves of coal.

	Reserves billion tonnes	% of total
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

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 this year represents only 16% of the total world production of this type. Due to the high moisture content of brown coal , it is uneconomic to transport over long distances. In the three larges coal consuming and producing economies (China, US and India), over 95% of their production is consumed 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 whereas 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. For instance, 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 the European nations has been that the cost is greater than in the case of 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

Technology
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 during the same period from 548 million tonnes to 497 million tonnes. This is partly as an increase in the efficiency of blast furnaces, but also more stringent environmental controls. Demand for coking coal is linked closely to pig iron output across the world.

Steel companies have introduced coal injection equipment that injects coal directly into the blast furnace in substitution for coke. It is estimated that currently 32 million tonnes of coal is 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 employed mainly in Asia and South America. These coals are often the same as those employed 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 that are referred to as hard coking coals.

Energy policy and environmental concerns
As with other carbon fuels, policy set by governments and producers has always had significant implications for coal use. For instance, following the oil price shocks of the 70's electricity utilities turned away 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 it 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 combustion for electricity generation. Many of these need to be addressed by investment from the industry in technologies that are relatively well established in the industrial countries, such as the removal of sulphur from flu gases (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. An 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.[26] Coal has the highest carbon to hydrogen ratio amongst the fossil fuels 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. By employing this route 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.

Clearly, 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).[27] The Kyoto Protocol (part of the 1992 Framework Convention on Climate Change) may cause the governments of many countries to change their policy 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 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 coal 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 referring 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.[28]

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.[29] Of this total, 8.4 billion tonnes of reserves are categorized as commercially exploitable.[30] 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.[31]

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 is associated with 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.

Key factors affecting future demand for potash

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 that 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 the 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.[32] The demand for 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] Unless otherwise indicated, statistical information in this chapter is from CRU International. Information is also provided by McCloskey Coal, Gold Fields Mineral Services, the International Iron and Steel Institute, the United Nations, the US Geological Survey, and the World Bureau of Metal Statistics.
[2] 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.
[3] World Aluminium Institute at http://www.world-aluminium.org/production/recycling/index.html.
[4] Defined as the US, Canada, Western Europe, Japan, Australia, and New Zealand in the statistics shown in this chapter.
[5] 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.
[6] 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).
[7] A standard automotive SLI (Start, Light and Ignition) battery is composed largely of lead and sulfuric acid.
[8] Wedepohl (1995) estimates that there are 2.5 parts per billion of gold in Earth's continental crust.
[9] CRU International
[10] World Gold Council, at http://www.gold.org/finalgold/html/index.html.
[11] CRU International
[12] 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.
[13] In Table 5–4, '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.
[14] Gold Fields Mineral Services Ltd. (2001). Total includes fabricated items as well as bar hoarding and net producing hedging and investment.
[15] World Gold Council (2001) p.17.
[16] World Gold Council
[17] Ibid.
[18] HSBC (2001).
[19] 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).
[20] Orellana (2001).
[21] World Gold Council. http://www.gold.org/finalgold/gold/Gra/Pr/Wr991006.htm
[22] World Gold Council, London. Press Release 10th May 2001.
[23] 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
[24] BP Statistical Review June 2001, http://www.bp.com/centres/energy/world_stat_rev/
[25] IEA Coal information (2001).
[26] Houghton et al.(2001).
[27] World Commission on Dams (2000).
[28] This section is based largely on data provided by the International Fertilizer Industry Association, Paris.
[29] US Geological Survey (2001).
[30] Measured in terms of the mass of potassium oxide.
[31] UNEP (2001b).
[32] FAO/World Health Organization (1999).