NON-RENEWABLE RESOURCES

S. B. Suslick and I. F. Machado
Institute of Geosciences, State University of Campinas /UNICAMP, Campinas, Brazil

Keywords: non-renewable resources,reserves,technology role, non-conventional, scarcity views, global models

Contents

Summary

In the universe of natural resources, minerals are unique in the sense of their non-renewable profile. Their deposits are finite, either physically or economically, and this implies a special concern about their exploitation, use, consumption, and recycling in a way that could prevent or mitigate their scarcity or unavailability for future generations. The optimal use of resources implies the adoption of a rational classification according to two major factors: geological knowledge and confidence; and the consideration of mining, metallurgical, economic, marketing, legal, environmental, social, and governmental factors (the modifying factors). As a general rule, government action is applied to survey and identify resources, whereas private enterprises concentrate their effort on well-defined reserves. As technology advances, non-conventional sources of minerals could enter into the marketplace, as shown by current research on seawater, seabed nodules, and ultimately space mining, all of which may occupy some place in the supply of minerals for the future generations.

Technology is the mainstay of every industry, including mining, due to its ability to change, sometimes in a suprising manner, the way materials are presented to manufacturers and consumers alike. Conservation and sustainability are different sides of the same coin, as the more we conserve the more likely we are to leave an acceptable legacy to our descendants. Thus, environmental legislation has become more and more stringent in industrialized countries over time, reflecting the concern for a high quality of life shared by different stakeholders. In the 1970s many thinkers were concerned about issues like the accelerating industrialization, rapid population growth, widespread malnutrition, depletion of non-renewable resources, and a deteriorating environment. These concerns gave rise to a number of initiatives leading to the design of global

models. The "Club of Rome" was one of the most famous and had profound effects on planning efforts and macroeconomic studies developed by a host of nations. It caused some panic in some circles, disturbed by the idea of diminishing stocks of raw materials and energy sources that could menace the Western lifestyle. Nevertheless, the need to maintain research groups oriented to the design of global models was paramount and continues until our times. Currently, new frontiers attract the attention of leading mining companies, varying from rainforest tropical environments (South America, Southeast Asia) to ice-covered regions (Northern Canada, Siberia, Greenland, Antarctica). At the same time, as technological innovations develop every year, many mines extend their life-cycle or new deposits become feasible, in such a manner that the phantom of world scarcity is always disappearing.

1. Background

Natural resources are undoubtedly the backbone of our civilization. In a broad sense, they refer to all the living and nonliving endowment of the earth, but traditional usage confines the term to naturally occurring resources and systems that are useful to humans, or could be under ordinary technological, economic, social, and legal circumstances. The major classes of natural resources are:

- agricultural land
- forest land and its multiple products and services
- natural land areas preserved for aesthetic recreational, or scientific purposes
- the fresh and salt water fisheries
- mineral resources that include the mineral fuels and non-fuels
- the renewable non-mineral energy sources of solar, tidal, wind, and geothermal systems
- water resources
- the waste-assimilative capacities of all parts of the environment.

Some natural resource stocks are renewable by natural or artificial processes while others are non-renewable – an often-used dichotomy in classifying resources. As renewable, one may cite solar, wind, and tidal energy and farmland, forest, fisheries, air, and surface water. In contrast, mineral ores and fossil fuels exemplify the non-renewables. Although geological processes may be capable of generating new stocks for a given resource along time (geologic time), the human time scale does not allow coping with such "renewability".

It is conceded that renewability often depends on appropriate non-destructive methods of management, as with farmlands, fisheries, and waste disposal, since some changes in natural resource systems are irreversible. In the assessment of natural resource stocks, it is important that interactions with other systems and potentially irreversible changes be taken into account. For instance, when coal is strip-mined, flows of groundwater may be interrupted and streams and wells may permanently go dry. Acid from sulphur exposed to rain and air may foul water supplies and kill plants and fish. Thus natural resources must be looked on as parts of larger systems.

One of the most sensitive questions posed by the world's natural resource context is "How long and under what conditions can human life continue on earth with finite stocks of *in situ* resources, renewable but destructible resource populations, and limited environmental systems? Some facts are quite clear: first, that some currently vital resource stocks (such as mineral fuels) are finite; that rates of consumption of these stocks have accelerated in recent decades far beyond all historical rates; that some major renewable resource systems (e.g., marine fisheries, and some groundwater systems) are being destroyed; and that environmental capacities are being seriously exceeded. To be more specific about this question, when use of a resource grows at 5 percent per year, the rate of use will double in fourteen years. Second, if currently known reserves are 100 times current annual use, such reserves will be exhausted in thirty-six years. Third, even if a huge discovery doubled reserves to 200 times current use, the reserves would last for only forty-eight years.

A second major issue refers to the location of known reserves. World petroleum reserves are huge and more is being discovered each year, but those reserves are not located in the major consuming countries of the western hemisphere. The same is true of bauxite, iron ore, chromium, tin, and natural gas. In the past this had strong geopolitical implications for the vulnerability shown by consuming countries *vis-à-vis* developing countries eager to increase their export earnings. Tense relations between consuming and producing countries prevailing in the past were fortunately replaced by peaceful agreements or contracts signed in present times.

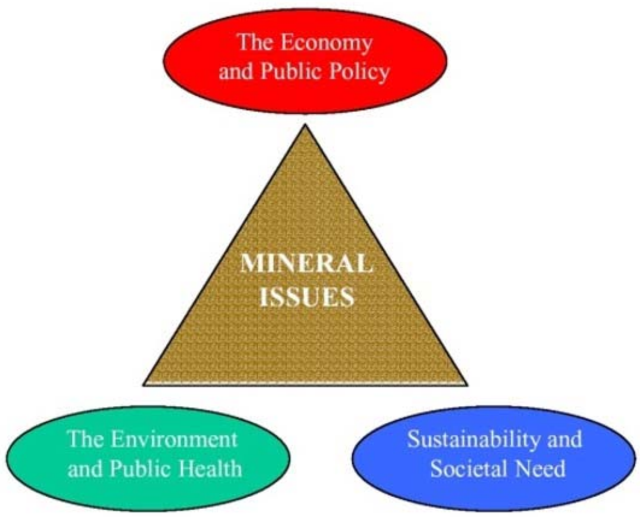
A third issue is the historical "shift away from renewable resources" toward dependence on nonrenewable resources. Some authors interpret the British industrial revolution as the substitution of mineral for vegetable or animal substances. For instance, coal became important when charcoal supplies became increasingly costly, both in terms of distance of forests and in terms of undesirable environmental effects. Another example: in the United States, agriculture has shifted from animal power to petroleum-driven machines, from natural fertilizers to those synthesized from natural gas. To some extent, in the 1980s the use of alternative energy sources, for example biomass and alcohol, meant a reversion of this shift. Would this trend be desirable now?

A fourth issue is the contemporary evaluation of "the wisdom of past patterns of resource utilization". Undoubtedly, there are numerous examples of unwise, shortsighted, predatory exploitation of natural resource systems coupled with their related social systems. The exploitation of coal in Appalachia is quoted as a typical example, even accepting that factors other than coal itself were present, such as monopolistic exploitation, political corruption, and unanticipated technological change. Similarly, were the rich iron ores of the Mesabi Range or of the Iron Ore Quadrangle used up too fast? Was the process of plowing, planting, and abandoning the plains lands shortsighted and unwise? Although many environmentalists and historians condemned those practices, they are not so simple to judge.

A fifth issue closely related to the former is whether or not we have correctly understood "the role and importance of natural resources and environmental services" as factors in our past economic growth. Apparently, too many analysts have placed a great emphasis on the growth of technology and improvement of human capital, as compared with the role of raw material inputs and also the increasing use of the environment for waste disposal. It is possible that these inputs were more important than recognized and, more importantly, they may not be freely available for future generations.

A sixth issue is the growing dependence on "increasingly low quality reserves" of natural resources. In other words, the grades of all metallic ores currently in use are far below those exploited in the past. For many resource stocks, one finds a continuous spectrum of quality versus quantity, implying greater reserves at the cost of exploiting poorer ores. Copper ores are a famous example, as in North America ores containing 0.3 percent copper or less are currently being mined, implying the need to move, process, and dispose of 333 tons of ore to get 1 ton of metal. It is known that seawater contains incredible stores of minerals, but the energy requirements for recovery are, in most cases, prohibitive. One question arises: Will energy availability permit the exploitation of these resources or must we forget them as usable reserves? Since the 1970s this question has been partially solved by the increasing supply of resources originated from developing countries showing richer grades than their counterparts in the industrialized world. In the case of copper, for instance, only in Chile are there are more than six large mines averaging at least 1.3 percent copper. For other ores and minerals, the shift to the developing countries meant that inferior reserves remained a problem just for developed countries, not necessarily meaning a worldwide scarcity.

A seventh issue, closely related to the previous two, is the evolution of limiting global environmental conditions. It is conceded that the most widely discussed item is the buildup of carbon dioxide in the upper atmosphere, mainly as a result of fossil fuel combustion, and deforestation.



Source: USGS, 1998. USGS Mineral Resources Program. *A National Perspective.* USGS Fact Sheet FS-008-98.

Figure 1. Mineral issues and basic human needs

This has to do with global changes, affecting the Earth's temperature and climate ('greenhouse effect'). Other examples are found in the increasing pollution of oceans, crucial as carbon dioxide sinks and oxygen sources, and in the buildup of persistent toxins in the soils.

An eighth issue is the role to be given to "market processes in determining how resources will be managed over time". Of course, markets have historically played an important role in determining exploration activity and rates of use. In addition, it has been convincingly demonstrated that changing relative prices has largely introduced technological innovation. Yet most countries, including the United States, have shown a great ambivalence, professing the virtues of free enterprise while, through price controls and bureaucratic regulation, refusing to let the pure market work. The concern with market processes has grown with the end of the planned economies, in 1989, as the former socialist countries move some of them gradually, others faster to a market economy system. Anyway, can market processes work in a socially responsible way in the natural resources area? What will be the role of State? More recently, privatization programs all over the world have brought the redesign of the role of State, which tends to remain solely as the entity responsible for the formulation of policies at a high level, and also as the regulating and coordinating actor.

2. Definition and classification of resources and reserves

The distinction between resources and reserves is not limited to geologic and mining aspects, but it extends into some political and economical implications. As a sizeable number of mining and petroleum companies use to be public-owned, maintaining stocks traded in stock exchanges around the world, the need was detected to obtain reliable reports from those companies by investors, funding agencies, government, and other stakeholders. Therefore, government authorities and regulators have decided that these reports should be presented under principles of transparency, materiality, and competence. This policy would protect investors from biased or incomplete information about company assets. This concern was originally raised in Australia, back in 1989, and was later shared by several other countries. That explains why the US Securities and Exchange Commission now regulates the reporting of exploration information, resources, and reserves, by entities subject to the filing and reporting requirements. Decisions as to when and what information should be publicly reported are the sole responsibility of the entity owning the information, and are subject to US SEC rules and regulations. These rules and regulations vary from time to time, and at any given time may not be consistent with the content of the proper guide.

Geologists, mining and petroleum engineers, and other professionals operating in the mineral field to describe and classify mineral resources, including energy materials, have used various terms. The US Geological Survey, for example, collects information about the quantity and quality of all mineral resources, in its own territory and abroad. Long-term public and private planning must be based on the probability of discovering new deposits, on developing economic extraction processes for currently unworkable deposits, and on knowing which resources are immediately available. This means that resources must be continuously reassessed in the light of new geologic knowledge, of progress in science and technology, and of shifts in economic and political conditions.

Despite general agreement on reserve definitions by mining and petroleum professionals working in industry and finance, geologists, engineers and economists working in academia and government resisted attempts to develop definitions of universal applicability, arguing that the needs of commerce are different than those of resource availability estimates and national planners. In spite of the need for a standardization of definitions and concepts, differences in definitions continue to cloud the absolute meaning of resources and reserve definitions published by technical societies and regulatory bodies.

Resources

The USGS definition of "Resource" is a concentration of naturally occurring solid, liquid, or gaseous material in or on the earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible. To start with, mineral resources are classified into two broad categories: identified and undiscovered resources. This feature is unique to the mineral kingdom as for biological resources there is no meaning about "undiscovered resources" for technical reasons. "Identified Resources" are those resources whose location, grade, quality, and quantity are known or estimated from specific geologic evidence. They include economic, marginally economic, and sub-economic components. "Undiscovered Resources" are resources, the existence of which are only postulated, comprising deposits that are separate from identified resources. Undiscovered resources may be postulated in deposits of such grade and physical location as to render them economic, marginally economic, or sub-economic. To reflect varying degrees of geologic certainty, undiscovered resources are divided into two parts: hypothetical and speculative resources. Hypothetical resources are undiscovered resources that are similar to known mineral bodies and that may be reasonably expected to exist in the same producing district or region under analogous geologic conditions. If exploration confirms their existence and reveals enough information about their quality, grade, and quantity, they will be reclassified as identified resources. Speculative resources are undiscovered resources that may occur either in known types of deposits in favorable geologic settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential. If exploration confirms their existence and reveals enough information about their quantity, grade, and quality, they will be reclassified as identified resources. (see Figure 2)

Mineral resources are sub-divided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories. Portions of a deposit that do not have reasonable prospects for eventual economic extraction must not be included in a Mineral Resource. If follows that the term "Mineral Resource" covers deposits which have been identified and estimated through exploration and sampling and from which Mineral Reserves may be defined by the consideration and application of technical, economic, legal, environmental, social and governmental factors.

An "Inferred Mineral Resource" is that part of a mineral resource for which tonnage, volume, grade, and mineral content can be estimated with a low level of confidence. It is inferred from geological evidence and assumed but has not a verified geological and/or grade continuity. It is based on information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes which is limited or of uncertain quality and/or reliability. An Inferred Mineral Resource has a lower level of confidence than that applying to an indicated mineral resource.

An "Indicated Mineral Resource" is that part of a mineral resource for which tonnage, volume, densities, shape, physical characteristics, grade, and mineral content can be estimated with a reasonable level of confidence. It is based on exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings, and drill holes. The locations are too widely or inappropriately spaced to confirm geological continuity and/or grade continuity but are spaced closely enough for continuity to be assumed. An indicated mineral resource has a lower level of confidence than that applying to a measured mineral resource, but has a higher level of confidence than that applying to an Inferred Mineral Resource

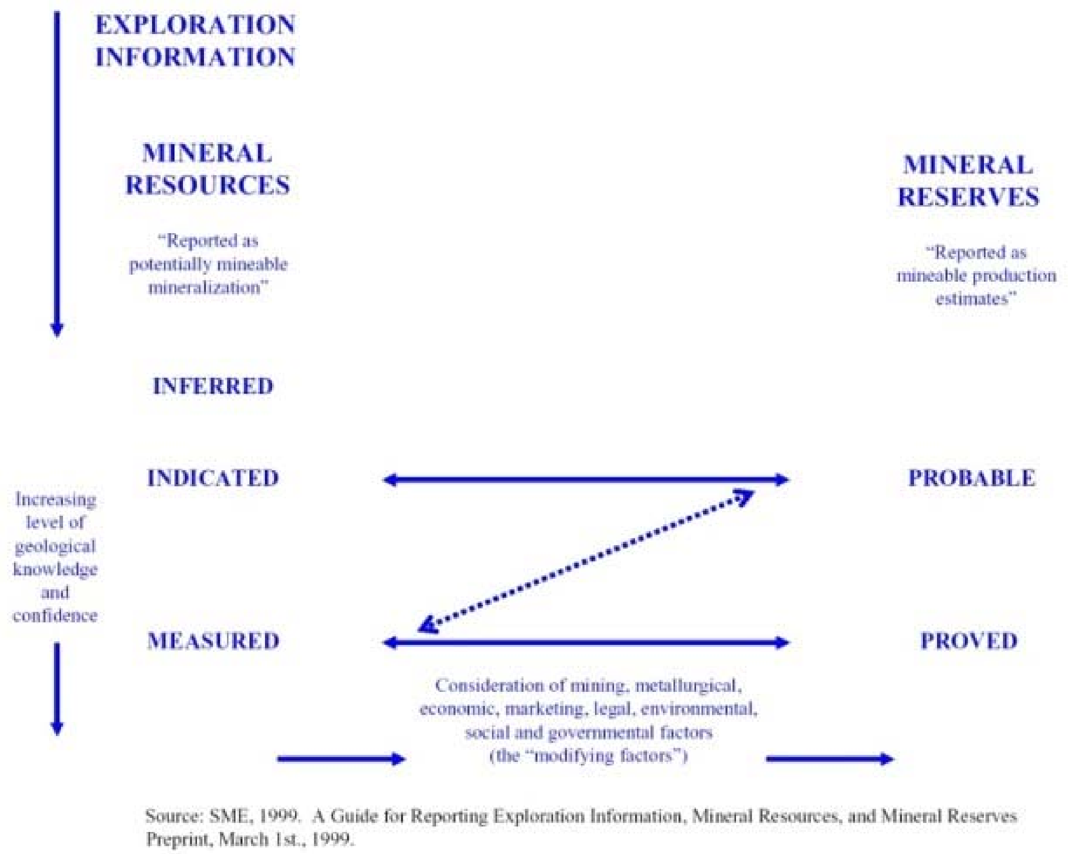


Figure 2. General relationship between exploration information, mineral resources, and mineral reserves

Reserves

A "Mineral Reserve" is the economically mineable part of a measured or indicated mineral resource. It includes diluting materials and allowances for losses, which may occur when the material is mined. Appropriate assessments, which may include feasibility studies, have been carried out and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction is reasonably justified. Mineral reserves are sub-divided in order of increasing confidence into "Probable Mineral Reserves" and "Proved Mineral Reserves."

A "Probable Mineral Reserve" is the economically mineable part of an indicated and, in some circumstances, Measured Mineral Resource. It includes diluting materials and allowances for losses that may occur when the material is mined. Appropriate assessments, which may include feasibility studies, have been carried out and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction is reasonably justified. A Probable Mineral Reserve has a lower level of confidence than a Proved Mineral Reserve.

A "Proved Mineral Reserve" is the economically mineable part of a Measured Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined. Appropriate assessments, which may include feasibility studies, have been carried out and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction is reasonably justified. The choice of the appropriate category of Mineral Reserve is determined primarily by the classification of the corresponding Mineral Resource and must be made by the "Competent Person" (a person who is a member of a professional society for Earth scientists or mineral engineers, or has other appropriate qualifications). development of world economies. As pointed out previously there is a growing awareness worldwide of the need for a consistent set of resources and reserves definitions for use by governments and industry in the classification of petroleum reserves. The classification system is summarized in the Figure 3. The classification shows a great similarity with mineral reserves, in general, resources are defined as including all quantities of petroleum, which are estimated to be initially in place; however, some users consider only the estimated recoverable portion to constitute a resource. It should be understood that reserves constitute in this classification constitute a subset of resources; being those quantities that are discovered in know accumulations, recoverable, commercial, and remaining. Two aspects in this classification are important to highlight the inclusion of a resource uncertainty category (low, most likely, and high) and the resource status category. Resource uncertainty categories can be used to define the best estimate range of uncertainty of any resource and provide a basis for estimation tracking which will indicate potential bias in evaluation methodology. Resource status category can be used to define the maturity of projects and to provide a basis of portfolio management.

Every year new exploration efforts worldwide lead to the discovery of additional resources that augment the physical endowment of world non-renewable resources. The experience of recent decades shows that the increment of available resources exceeds the consumed part of those resources, giving a positive balance favorable to the well-being of future generations. In other words, currently there is no scarcity problem regarding non-renewable resources. As stated in the Strategic Plan for the US Geological Survey:

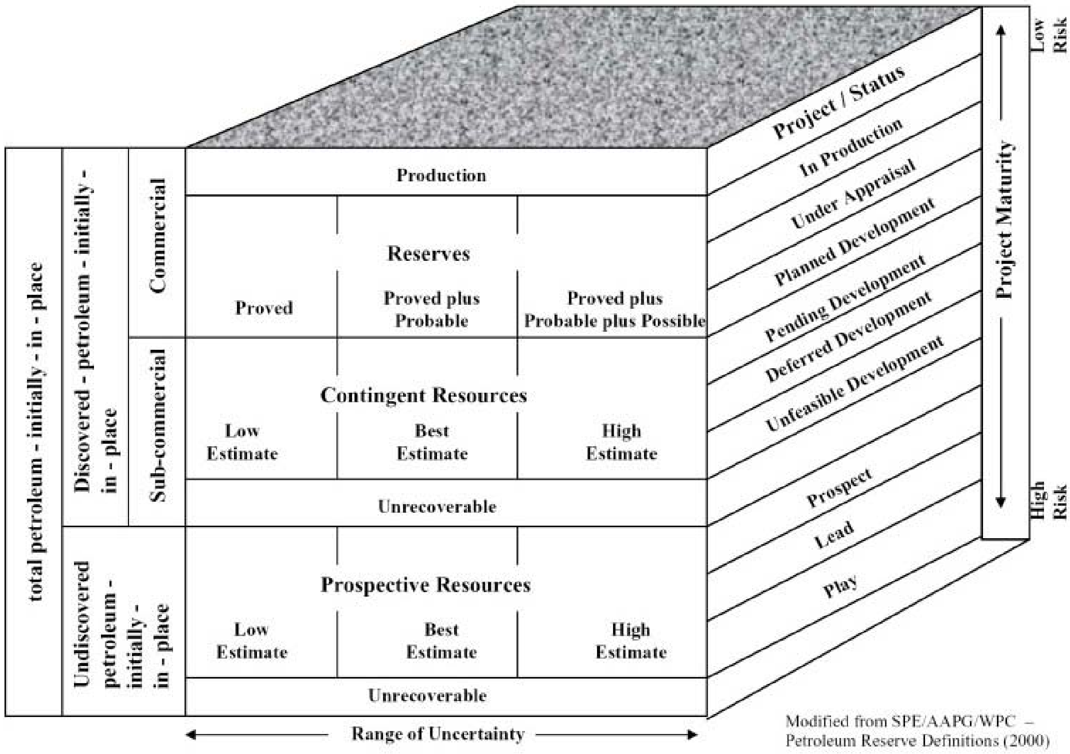


Figure 3. Resources and reserves categories used for petroleum and natural gas.

Today most resources are available, for a price, somewhere in the global economy. Oil and gas are relatively abundant and accessible, even if geographically distant. Minerals are available in necessary quantities from a variety of sources. Global economics, rather than national self-sufficiency, drives decisions on when and where to buy most resources.

Mineral Supply

Many mineral commodities (oil, coal, bauxite, iron, and so on) are typically extracted as single or individual products. Others are produced as joint products from the same deposit or ore body. In such a situation, it is possible to distinguish among mineral resources (mainly metals) the main products, co-products, and by-products. A main product is by definition so important that it alone determines the economic feasibility of a mine. When two metals must be produced to make a mine economic, both influence output, and they are considered co-products. A by-product is produced in association with a main product or with co-products. Its price has no influence over the mine's output, though usually it does affect byproduct production. It is important to emphasize that some metals, such as gold and silver are main products at some mines, co- products at other mines, and by-products at still other mines. To determine the total primary supply for such metals, it is necessary to assess main products, by-product, and co-product supply and then add them together.

Before assessing the general shape of the supply curve, we need to distinguish two types of metal markets, producer markets and competitive markets. Firms in producer markets quote the price at which they are prepared to sell their product. These markets, characterized by a few major sellers, have relatively stable prices, though when demand is weak, actual prices may fall below quoted producer prices as a result of discounting and other concessions. Examples of metals sold in this market are magnesium and steel. In competitive markets, price is determined by the interaction of supply and demand and is free to fluctuate as much as necessary to clear the marketplace. Many buyers and sellers are very common in such markets, and price is often set on a commodity exchange, such as the London Metal Exchange (LME), IPE (International Petroleum Exchange), and New York Mercantile Exchange (NYMEX). Manganese, silver, oil, and gas are commodities sold in competitive markets.

Mineral Demand

Mineral commodities rarely are final goods, gold bullion being the obvious exception. Generally the demand for a mineral commodity is derived from the demands for final goods. Since demand is really a set of attributes, rather than a mineral commodity *per se*, in many end uses one mineral produced can replace another.

The main determinants that are often considered in demand studies are income, own price, prices of substitutes and complements, technological change, and government policies. Income is one the most important variables affecting mineral demand. Gross domestic product (GDP) or industrial output is employed for this purpose. Malenbaum (1978) proposed a measure called “intensity of use,” defined as the amount of material consumed per unit of GDP, which has an inverted U-shape curve type (Figure 4). Countries in early stages of economic development have had low intensity of use (low consumption and low income), as they begin to industrialize, they invest in basic industry, infrastructure, and other material intensive projects, which cause their intensity of use to rise. As development proceeds the demand for basic goods are satisfied and the consumption shifts away from manufacturing toward the service sector.

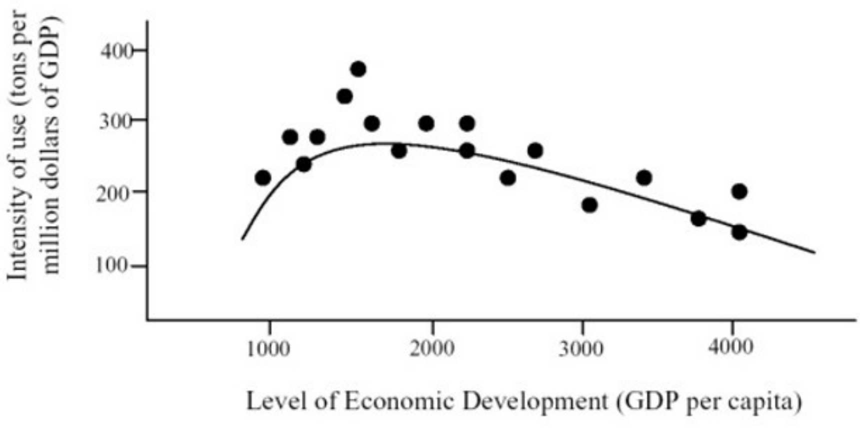


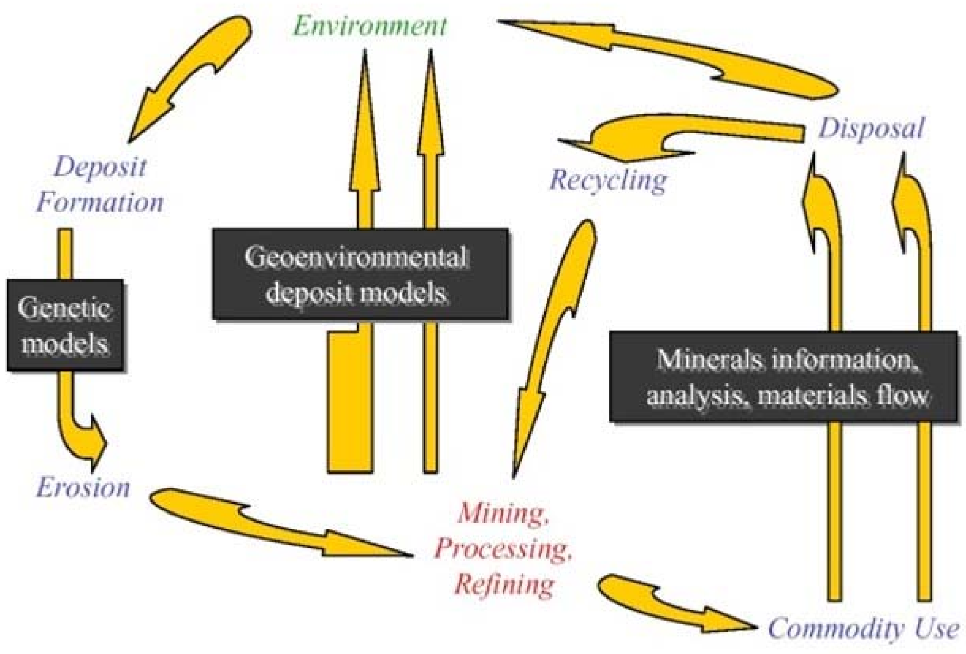
Figure 4. Relationship between Intensity of Use of Steel and per capita income in OECD bloc countries, 1950–1990. GDP is measured in constant US$ 1990 dollars.

Demand tends to fall with increase in price and rise with a decline in price. The reason for this inverse relationship is that higher mineral price increases the production costs of the final goods in which it is used. Another reason is that firms usually may respond to the higher price by substituting another mineral commodity whose price has not risen. As with changes in own price, changes in the prices of substitutes and complements affect mineral demand primarily by inducing firms to alter the nature of their production processes.

New technology can alter mineral demand in several aspects. First, it can reduce the amount of a mineral commodity required in the production of a specific item. For example, aluminum in new alloys used in a beer can. Second, new technology can affect the ability to compete in a particular end-use market. For example, the introductions of polyvinyl chloride (PVC) in plastic pipe capture a sizable market share for home building that belonged traditionally to copper and other mineral commodities. New technology can also change the number and size of end-use markets. For instance, the advent of the automobile gave rise to a major new market for petroleum, steel, and lead.

Government policies influence metal supply and demand in a variety of ways. Environmental regulations and state severance taxes tend to increase costs and reduce supply.

The relationships between supply and demand of a commodity are better understood through Figure 5.



Source: USGS, 1998. USGS Mineral Resources Program. *A National Perspective*. USGS Fact Sheet FS-008-98.

Figure 5. Life cycle models of a mineral commodity

-
-
-

Bibliography

ADELMAN, M. 1990. Mineral depletion with special reference to petroleum, *Review of Economics and Statistics*, Vol.72, pp.1–10. [This paper presents a comprehensive exhaustion model for oil and gas resources].

AUSTRALASIAN INSTITUTE OF MINING AND METALLURGY, 1999. *Australasian code for reporting of mineral resources and ore reserves (The JORC code)*. Prepared by the Joint Ore Reserves Committee of The Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia (JORC). [This code establishes the guidelines for assessing mineral resources and reserves in Australia].

BARNETT, H. J.; MORSE, C. 1963. *Scarcity and growth*: Baltimore, Johns Hopkins Press, Resources for the Future, 288 pp. [This book is a classical reference about scarcity. The authors collect the first data that gives evidence that empirically at the time there is no indication of exhaustion of physical resources].

BLAIR, B. R. 1999. Economics of lunar mineral exploration. *Space Resources Roundtable* – Oct. 27–29 1999. Colorado School of Mines. [This paper focuses the potential commercial use of lunar resources, gaining relevance as technology and infrastructure increase, depending on adequate foundation of geological information].

——2000. The role of near-Earth asteroids in long-term platinum supply. *Space Resources Roundtable II*, Nov. 8–10, 2000. Colorado School of Mines. [The potential existence of a high-value asteroid-derived mineral product is examined from an economic perspective to assess the possible impacts on long-term precious metal supply].

BRUTON, AMY. 1996. Global model matrix. *Simulation*, Vol. 66, No. 5, pp. 321–30. San Diego, California. [A survey of major global models encompassing issues on natural resources, politics, population, energy, environment, and economics].

CLUB OF ROME. 1999. *All About the Club of Rome*, Hamburg, Germany. http://www.clubofrome.org/right_blank.htm [10.28.99] [A general description of current activities of the Club of Rome, giving emphasis to global issues such as: environment, demography, development, values, governance, work in the future, information society, new technologies, education, the new global society, and world economic and financial order].

ERNST, W. G. 1999. *Earth Systems: Processes and Issues,* Cambridge, UK, Cambridge University Press. 566 pp. [This book explains in an accessible language the complex relationship and feedback mechanisms linking the geosphere, biosphere, hydrosphere, and atmosphere].

GERTSCH, L. S.; GERTSCH, R. E. 1999. Successfully mining asteroids and comets. *Space Resources Roundtable*, Oct. 27–29 1999. Colorado School of Mines. [This paper emphasizes that economics, technology, and geology will determine the success or failure of long-term space activity].

——2000. Mine planning for asteroid ore bodies. *Space Resources Roundtable II*, Nov. 8–10 2000. Colorado School of Mines. [This paper discusses the engineering necessary to bring a mine online, and the opportunities and challenges inherent in asteroid mineral prospects].

GERTSCH, R. E.; GERTSCH, L. S. 1999. Economic analysis tools for mineral projects in space. *Space Resources Roundtable,* Oct. 27–29 1999. Colorado School of Mines. [This paper analyses the most important factors to consider in a commercial venture in space, including R&D, exploration, mine and processing plant construction, fly to asteroid, mine and process asteroid, fly & process, and sell product].

HERRERA, A. ET AL. 1976. *Catastrophe or New Society?* International Development Research Center. IDRC, Ottawa, 108 pp. (Documentation of the Bariloche world model). [A classical book giving the Latin American insights about "Limits to Growth"].

HOTELLING, H. 1931. The economics of exhaustible resources: *Journ. Political Economy*, Vol. 39, No. 2, pp. 37–175. [This paper is a classic reference for exhaustion resource model based upon a fixed stock].

Howe, C. W. 1979. *Natural Resource Economics: issues, analysis, and policy.* New York, John Wiley. 350 pp. [A classical book on this field of economics].

MALENBAUM, W. 1978. *World demand for raw materials in 1985 and 2000*, New York, McGraw-Hill. [This is a classic monograph in the world demand estimation for mineral commodities].

MCLAREN, D. J.; SKINNER, B. J. (eds.) 1987. *Resources and world development*: New York, Wiley-Intersci., pp.13–27. [This is a classic contemporary collection of contributions for the impact of economic development in the commodities supply and demand].

MEADOWS, D. H. ET AL. 1972. *The Limits to Growth*: *a report for the Club of Rome's project on the predicament of mankind.* New York, Universe Books. 205 pp. [This model was built to investigate five major trends of global concern: accelerating industrialization, rapid population growth, widespread malnutrition, depletion of nonrenewable resources, and a deteriorating environment].

MELNIKOV, N. N.; NAGOVITSYN, O. V. 1999. The role of mining for space development. *Space Resources Roundtable*, Oct. 27–29 1999. Colorado School of Mines. [This article discusses the need of space mining aiming at: first, production of useful components to sell them in the Earth markets; and second, to provide materials and energy for construction of extraterrestrial bases, spaceships and life sustaining].

ONISHI, A. 1998. *Fugi Global Model 9.0 M 200/80.* http://fufimoswl.t.soka.ac.jp/FUGI/ [09.06.2000][This model aims to envisage the future of global interdependence and to provide global information on the development and environmental changes under alternative policy scenarios for the sustainable development].

SME. 1999. *A guide for reporting exploration information, mineral resources, and mineral reserves*. Submitted by The Resources and Reserves Committee to the Board of Directors of The Society for Mining, Metallurgy and Exploration, Inc. Littleton, Colorado. [A milestone for the assessment of mineral resources and reserves in the American territory].

SPE. 2000. *Petroleum Resources Classification and Definitions*. Society of Petroleum Engineers. [A draft update of the main definitions and classification for reserve estimation on a worldwide basis].

US GEOLOGICAL SURVEY. 1997. *USGS Strategic Plan 1997 to 2005.* Washington DC, USGS. [A classical work accomplished by the USGS establishing its guidelines and actions for the next years].

——1998. *USGS Mineral Resources Program: A National Perspective*. USGS Fact Sheet FS-008–98. Reston, Virginia. [This fact sheet addresses mineral issues related to: (a) environment and public health; (b) sustainability and societal need; and (c) economy and public policy]. http://greenwood.cr.usgs.gov/pub/fact-sheets/fs-0008–98/fs-0008–98.html [02.23.2000]

Biographical Sketches

Saul B. Suslick, geologist, age fifty-one, is currently Professor at the Department of Geology and Natural Resources, Institute of Geosciences, State University of Campinas – UNICAMP. He obtained a PhD degree at the University of Sao Paulo. He is responsible for Mineral and Petroleum Resources Exploration and Economic Evaluation Methods courses. Main areas of interest are Decision Analysis Techniques in Petroleum and Mineral Markets and Quantitative Methods for the Estimation of Mineral and Oil Resources (Forecasting, Geostatistics, etc.).

Iran F. Machado, geologist, age sixty-three, is a retired Professor at the Department of Geology and Natural Resources, Institute of Geosciences, State University of Campinas-UNICAMP. He obtained a PhD degree at the University of Uppsala, Sweden, in 1967. For sixteen years was responsible for the course on Mineral Resources Policy and Management for graduate students. He authored a book on Mineral Resources, Policy, and Society (in Portuguese), published in 1989.