# IV. Introduction to Sustainability: Resource Planning and Global Change

## INTRODUCTION

*"Our entire society rests upon—and is dependent upon—our water, our land, our forests, and our minerals. How we use these resources influences our health, security, economy and well being."*

—J. F. Kennedy, 1961.

*"It is difficult for people living now, who have become accustomed to the steady exponential growth in the consumption of energy from fossil fuels, to realize how transitory the fossil-fuel epoch will eventually prove to be when it is viewed over a longer span of human history."*

—M. K. Hubbert, 1971.

*"If we don't grow or harvest it, we must mine it."*

—Anonymous

## SUSTAINABILITY

Sustainability for the human colony on Earth may be described as balancing natural resources against human resources and the rights of the present generation against the rights of future generations. This balance must attempt to account for expected natural and human-induced changes in the Earth system—the lithosphere, atmosphere, hydrosphere, and biosphere. This is achieved partly by not fully using a variable renewable resource such as water. Thus, when a drought occurs, hardship in the region is minimized.

## CLIMATE CHANGE, RESOURCES, AND GEOLOGIC HAZARDS

As for the unexpected changes in the Earth system, we seek improved understanding of how the Earth system works in order to minimize surprises. Significant long-term climate change produces major differences in weather, water resources, the biosphere, and landscapes. With those changes, some cultures are no longer sustainable and they abandon their communities, as in the American Southwest, Peru, and Greenland. Some climate change in the Earth system over the last 15,000 years has been very rapid. In the past, where possible, cultures migrated to the resources (favorable climate, water, etc.). Today, the migration option has been reduced by human population growth. Most niches are filled.

Future rapid climate change could also occur by asteroid impact (it also might produce a huge tsunami). In some impact events the human colony would be sustainable, but much reduced. In other cases ... well you know the story of the dinosaurs. There is a limit to planning for sustainability in the face of natural events.

## REGIONAL PLANNING: POPULATION GROWTH, FINITE RESOURCES, AND GEOLOGIC HAZARDS

Energy, in addition to water, is a major factor in the sustainability of a species. Humans have been intelligent enough to exploit buried sunlight—those fossil fuels that produced the industrial revolution, power the technological age, and make it possible to accommodate >6.6 billion people on Earth (at least for a while). For long-term sustainability, replacements must be found for fossil fuels, which are finite.

Population increase also provides a challenge to resource use and sustainability; without it we would not need most regional planning. As population centers grow, converting surrounding rural and suburban land use, they run the risk of inappropriate land use. In the simplest terms, we need to find building materials, water, energy, stable nonflooding building sites, and waste disposal areas for an expanding human colony. Some areas are not only short of suitable materials and sites, they are also hazardous to humans and their structures. To avoid loss of resources, geoscientists and most citizens support the concept of regional planning. Such planning requires basic data, acquired by geologic and soil mapping. Essentially we need to determine where in a region we can accommodate people and how many. The guiding concepts are to design with nature in mind in order to avoid loss of life and waste of resources, including those infrastructure resources lost in disasters.

## LONG-RANGE PLANNING

For sustainability, we must take the long-term view of the Earth system, which is not difficult for geologists who think well beyond the next election or budget cycle. Long-range planning begins with determining how to accommodate the human resources (number of humans) with the known and expected natural resources (our geological and biological support system, which includes biodiversity and energy factors). As the Earth is finite, there is a limit to the number of people it can support. Approximating this limit has been attempted in various ways: water and land per person, food calories per person, and renewable energy per person, etc. In long-range planning for sustainability we move from the regional to the global system.

Also in this carrying-capacity approach to planning for human impact on Earth, we must consider the quality of life we can have or will accept, and the changes brought about in the system by humans. Humans are now geologic agents; we capture about 40% of the biosphere and move more material on the lithosphere than the natural geomorphic systems of wind, water, and ice. We are changing the chemistry and temperature of the atmosphere. With climate change, geomorphic processes, and therefore, landscapes change. We are part of and a factor in our changing Earth system—our life support system.

How do we achieve sustainability? How do we balance natural resource availability (assisted by our ingenuity) and human resource use (number of humans × average consumption) in this changing system, which has unknown or poorly defined limits? Many scientists understand that without long-range planning we have actually planned to discover the limits for the human colony by overshoot and collapse.

Are humans capable, intellectually and socially, of a humane approach to long-range sustainability? If we accept this objective as a component of sustainability, we should determine the global resources available to us and adjust to them. There will be technological advances that increase our sustainability; there will be surprises that decrease it. We know that oil production is nearing its peak and "natural" biologic hazards are increasing. We have models of societal failure (e.g., Easter Island); satellite views of current conditions on the land and in the sea; historical perspectives of change in the natural system from marine/lake sediments, ice cores, and human records; and immediate communication (e-mail, phone, TV) between humans (private, governmental, and nongovernmental organizations [NGOs]) about natural and societal change anywhere in the world. We have many tools to assist us in our quest for sustainability. In the end, the laws of nature may well govern sustainability, as individuals and societies in the human colony work to mitigate harmful natural and human-induced changes at the same time that they seek to adapt to those changes. The sooner we understand the options facing Spaceship Earth, the better the chance for a sustainable outcome.

In Section IV the two exercises, Geology and Regional Planning (17) and Global Change and Sustainability (18), address sustainability on both local and global levels. Exercise 17 begins with the environmental factors in solid waste disposal, followed by application of geologic data to selection of land uses in Waco, Texas. In Exercise 18, real-time ozone, temperature, and glacier retreat data are presented to demonstrate change and the human component of some of that change. In this exercise we also examine the ice-core record of longer-term temperature change and the projections for future climate changes. The last activity is an exploration of possible futures, using group discussion, projection of trends, and construction of a brief scenario.

In preparation for the scenario activity and improved understanding of the sustainability issue, the last part of this Introduction examines the finite nature of some key geologic resources.

## GEOLOGIC RESOURCES

A *resource* is something that has economic value. Natural resources such as oil, iron ore, fish, or trees are often defined by the monetary value placed on them. Unfortunately, this definition leaves out some natural resources such as scenic views, favorable topography for exploiting solar and wind energy, and even some gravel deposits and favorable building sites. A simple working definition for a *natural resource* is a "useful material or environment"; a broader definition is "biological or physical phenomenon that exists in nature and can be adapted for use by humans." *Geologic resources* are those natural geological phenomena that can be adapted for human benefit. Natural resources and geological resources may be described as renewable or nonrenewable and exhaustible or inexhaustible.

*Renewable* often is interpreted to mean derived from living matter and replenished with the growing season or at least over a short time period. Some nonliving geological resources, such as water, are renewable. In fact, oil is produced in sediments on a scale of hundreds of thousands of years; gold and other metals are slowly produced in volcanic settings such as the rift at the bottom of the Red Sea, and gravel is renewed annually at the base of an alluvial fan. Most of these rates of "renewal" of geologic resources are slow compared to the rates of human use, and the resources are therefore considered nonrenewable.

*Nonrenewable* is a "one-crop" resource. Nonrenewable is the usual category for mineral resources. When a mining district or an oil field is exhausted, there is no more of that resource to be had. Geothermal energy, when extracted at a high rate, may be a nonrenewable resource. The same geothermal resource, if extracted at a rate lower than the heat and water are recharged, is a renewable resource.

Natural resources are also characterized as exhaustible or inexhaustible. *Exhaustible* resources are (1) of limited quantity compared to rate of use and, (2) those renewable resources whose productivity may be destroyed (whale oil). *Inexhaustible* resources include those available in exceptionally great quantities (magnesium in seawater), those easily renewed, and those with a low rate of use. With unlimited energy, we would be able to mine low-grade deposits for specific mineral resources and to avoid or repair environmental damage. Energy might be the ultimate geologic resource.

If a natural resource is exhaustible, we would like to know when it will be used up. If we are using the resource at a certain rate per year and there is a known quantity, then we should be able to estimate its lifetime, by:

$$\text{Estimated lifetime (yrs)} = \text{Original amount (tons)/rate of use (tons/year)}$$

However, it is not as simple as that. The rate of use may increase or decrease, usually increasing with population and decreasing with substitution and improved technology (we are much more efficient now at generating electric energy per pound of coal than we were in the early 1900s). Also we do not know the full extent of the resources that might eventually become reserves and be used. For this reason, a classification of mineral resources is particularly useful in looking at the availability of all resources in the future.

## MINERAL RESOURCES: CLASSIFICATION AND ORIGINS

*Mineral resources* are concentrations of naturally occurring material (solid, liquid, gas) in or on the crust of the Earth in a form such that economic extraction is currently or potentially feasible. The U.S. Geological Survey and the U.S. Bureau of Mines have classified mineral resources using a scheme developed by Brobst and Pratt (1973). One of the key components of this scheme (Figure IV.1) is the difference between mineral *reserves* and other mineral resources. A *reserve* is a mineral resource whose extent and grade are known and for which extraction is now economically, technologically, and politically feasible. It is a resource that can readily be withdrawn from the "bank."

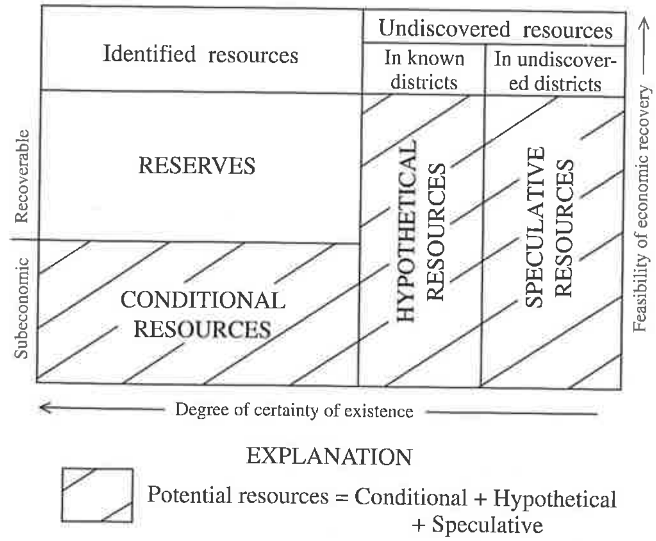


**FIGURE IV.1** Classification of mineral resources by feasibility of economic recovery and certainty of geologic existence (Brobst and Pratt, 1973).

The processes of formation of mineral resources are basically the geologic processes of the Earth system. Mineral deposits form by igneous, metamorphic, and sedimentary processes. The superficial process of weathering also concentrates elements and materials that are useful to humans. Biological processes are largely responsible for phosphorus deposits and sedimentological, biological, and chemical processes play a role in formation of fossil fuels.

## IMPORTANCE OF GEOLOGIC RESOURCES

Mineral resources are an essential part of society and improvement of the quality of life. Use of mineral and energy resources has been positively correlated with gross domestic product, although with conservation measures, renewable energy use, technological advances, and the growing concern about environmental degradation, these relationships could change. In addition to energy resources, both metallic and industrial (nonmetallic) rocks and minerals are essential to a quality life. According to V. McKelvey (1973), a former director of the U.S. Geological Survey, the level of living (L) depends on the following relationship:

$$L = (R \times E \times I)/P$$

where R = natural resources, E = energy, I = Ingenuity, and P = Population sharing those resources. A resident of the U. S. will use more than 2 million pounds of minerals in his or her lifetime, almost half of which will be aggregates (gravel and crushed stone).

We are very near the peak in oil production in the Fossil Fuel Age, living on buried sunlight. The degree of dependence on fossil fuels by the U.S. is readily seen with the mix of energy we now use. For example the average of July 2003 and January 2004 U.S. energy consumption amounted to $8.85 \times 10^{15}$ Btus with petroleum accounting for 38%, natural gas for 24%, coal for 24%, hydroelectric and other renewables for 5.7%, and nuclear power for 8.3%.

Hubbert (1969) and others have documented the change over time of our fossil fuel use. Against a scale of 10,000 years of human history, our use of fossil fuel shows as a "blip." In the 1950s Hubbert forecast the decline in U.S. oil production, which began in 1970. We now import more than 60% of our crude oil. The global peak and decline in production of conventional oil is occurring now (Simmons, 2005; Strahan, 2007; Zwicker and others, 2004).

Alternative, particularly renewable, energy resources are the key to sustainability. Fossil fuel use will decline over the next 30 to 40 years due to availability and its impact on local and global environments. Solar energy will grow in importance. It will be used directly as heat or as electricity derived by heat or photovoltaics, wind energy, ocean currents, ocean thermal gradients, or biomass. Nuclear fusion is not expected to be a factor in the near future but could play a very important role if attained; nuclear fission might be one option to counteract global warming by $CO_2$ from fossil fuels, and this industry is showing signs of recovery. Deep geothermal energy (not groundwater heat pump systems heated mainly by solar energy) is another alternative energy source that could become more important. For many remote localities, photovoltaic cells are providing viable alternatives to connections to an electric grid. In developing countries, photovoltaics will provide major improvements in the quality of life and sustainability without construction of centralized power plants and distribution systems.

## GEOLOGIC RESOURCE AVAILABILITY

Given the importance of mineral and energy resources, it is understandable why so many commissions in the 20th century explored their availability and expected lifetimes. Two philosophical views about mineral resources are common. One view is that the supply of mineral resources is not a problem. Minerals will either be replaced by something else if they run out or an increase in price will make so many resources economic that there will not be a limit to supply. Another view is that many resources are exhaustable, and it is not wise to rely on expected new discoveries. Ultimately, as vividly illustrated by Apollo mission photographs of Earth as a sphere in space, most resources are limited.

There was a $10,000 wager between opposing camps in the concern for mineral resources. In the "cornucopian" camp (mineral resources will be available) the late Julian Simon, an economist at the University of Maryland, declared in the 1980s that in ten years there would be no shortages or major increases in costs for mineral commodities. Paul Ehrlich, a population biologist at Stanford in the "sustainability" camp, said there would be shortages or price increases. Ehrlich lost the bet. However, will this condition continue? In 1968, Preston Cloud suggested that the cornucopians had five premises on which their lack of concern for mineral resource availability was based: (1) cheap inexhaustible nuclear energy, (2) economics as the major factor in resource availability, (3) uninterrupted variation from ore to natural crustal abundance, (4) assumed population control, and (5) a technological fix.

Resource availability is impacted by environmental and social concerns. In the 1990s an environmental conscience began to spread globally in the mining world and formal guidelines were proposed for the mineral production sector. At least one example of much delayed mine development by a major mining firm can be traced to inappropriate assessment of environmental and social impacts and poor public relations. Environmental concerns must include impacts of exploration, removal or mining, processing, manufacturing and transportation, resource use, and post-resource-use waste management. Poor waste management results in direct (waste) or indirect (pollution) loss of resources.

The modern viewpoint is that wastes are resources out of place. Urban ore, the mineral resource values concentrated by humans in their landfills, can be recycled and reused. In some cases the "deposits" in landfills are richer than the mineable virgin mineral deposits.

For any finite nonrenewable mineral resource, we should understand the nature of extraction of that resource over time. "Hubbert's Bubble" (Figure IV.2) shows the actual and forecast production curves for world oil. Depletion of any nonrenewable mineral resource, from a mining district or from a country, follows a similar trend.

## QUESTIONS IV, INTRODUCTION

**1.** What is a geologic resource, according to the discussion in Geologic Resources?

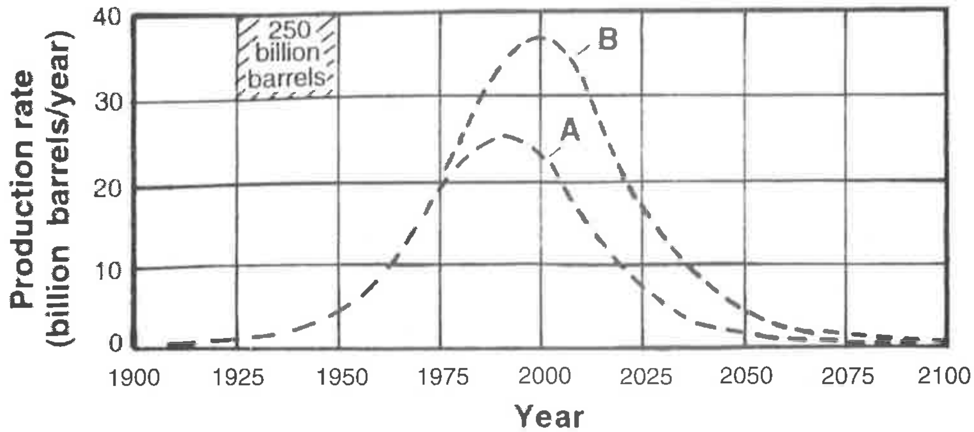


**FIGURE IV.2** Cycle of world crude-oil production at assumed total resources of: A, 1,350 billion barrels, and B, 2,100 billion barrels (modified from Hubbert, 1969). Total world crude-oil production in 2001: 77 million bpd; forecast for 2020: 112 million bpd. In 2000, the U.S.A used 19.7 million bpd; forecast for 2020 is 26.7 million bpd.

**2.** Name one renewable and one nonrenewable geologic resource.

**3.** If you knew the current rate of production of a mineral resource from a mine, what additional information would you need to determine the remaining lifetime of the mine (number of years until it is exhausted)?

**4.** According to Brobst and Pratt (Figure IV.1), what is the difference(s) between hypothetical and speculative mineral resources?

**5.** Would a mining company be likely to extract conditional resources? Explain.

**6.** If you owned a gold mine that could produce gold at a profit only if the price were equal to or greater than $800/ounce, what would happen to your reserves if the price went to $600 per ounce?

**7.** What are the five Cornucopian Premises, according to Preston Cloud?

**8.** Hubbert, in 1956, forecast the peak in U.S. oil production would occur in 1970 and it did. Assuming the total world oil resource is 2,100 billion barrels, when should we peak in world oil production, according to Hubbert (Figure IV.2)?

**9.** In Figure IV.2, the production rate is given in billion barrels per year. If we were producing a steady 5 billion barrels per year, how much would we use in 25 years?

In Figure IV.2, outline (and shade in with pencil) that amount in one of the rectangles.

**10.** Using the literature or other sources, determine the current daily and annual rates of oil production for the world.

**11.** What impact will "peak oil" have on the U.S.A.?

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