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## Sustainable development and the exploitation of mineral and energy resources: a review

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**Abstract** Natural resources, e.g., metals, industrial minerals, water, and soil, are the essential basis for our economy and well-being. We have to know where these raw materials come from and how they are mined. Sustainable development requires the maintenance, rational use and enhancement of natural resources, as well as a balanced consideration of ecology, economy and social justice. Four general rules concerning the implementation of sustainable development for renewable and non-renewable resources are discussed. Examples of the consumption of selected materials from historical times to the present day are presented, as well as of regional distribution, usage (in contrast to consumption), lifetimes of resources, the supply-and-demand cycle, recycling and substitution in modern times. To fulfill the requirement of sustainable development, the efficiency with which resources are utilized has to be improved. The learning process, often driven by financial rewards, leads from one technology to a better one, thus increasing the efficiency of the use of a resource or commodity. Examples of learning curves are discussed. Industrial countries have to transfer their advanced technologies to developing countries in order to avoid undesirable development in the mining industry and use of natural resources in those regions. The use of the best available technology by the mining industry, taking into account economic considerations, and the necessity to establish environmental guidelines are essential if environmental impact of the production of non-renewable resources is to be minimized. Far more critical than the production of non-renewable resources under the aspect of sustainable development and the capacity of the pollutant sinks of the Earth is the element of natural attenuation with regard to the resources soil and water.

**Keywords** Environmental guidelines for mining industry · Learning process · Metallic and energy resources · Soil and water · Sustainable development

### Introduction

In industrialized countries, normally, everything functions. Because the majority of the population usually lives in cities far from any mine or quarry, nobody thinks about the origin of natural resources – they are just “there”; they can be bought at any time and anywhere. Our life is accompanied by natural resources at every step. The water we shower with in the morning comes from water stored behind dams or from aquifers beneath our feet. The porcelain we eat our breakfast from is made of kaolin, from mines probably in Germany. The nickel in the steel alloy of the knife we use for breakfast is – statistically – produced out of 20% recycled nickel. The larger remaining portion originates, according to our import statistics, mainly from five countries: with 58% of total imported nickel metal from Russia, 8% from Norway, 7% from Great Britain, 7% from Australia, and 6% from Finland (BGR 2000). Knowledgeable people, however, know that the nickel from Great Britain and Norway originally comes from Canada, because the Canadian nickel companies, INCO and Falconbridge, own nickel refineries in these countries, which are supplied with Canadian nickel concentrates or matte, respectively. Even the symbol of our information society, the personal computer, contains 31 metals, taken as ore from our Earth and then beneficiated, smelted, refined, and processed (Jeffery 1998).

As a consequence, a responsible society has to consider, now and in the future, where its raw materials come from and how they are mined. Of the 80% of raw materials that are needed in Germany, the bulk of it as construction materials, are still mined in Germany – a figure more or less the same for any industrial country in Europe (Table 1). The remaining 20%, energy resources such as most of the crude oil and natural gas, and all the

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**Table 1** Effective per-capita consumption of mineral commodities per 70-year life span in Germany; those raw materials that are produced partly or totally in Germany are marked with an asterisk (BGR 1998)

Sand and gravel*	316 t	Gypsum*	7.0 t
Crude oil	109 t	Kaolin*	2.0 t
Aggregates*	143 t	Dimension stone*	1.8 t
Lignite*	133 t	Aluminum	1.5 t
Limestone, dolomite*	94 t	Peat*	1.3 t
Hard coal*	66 t	Phosphate	1.2 t
Steel	33 t	Steel alloying metals	1.0 t
Cement*	33 t	Copper	1.0 t
Clays*	22 t	Potash*	0.6 t
Industrial sand*	11 t	Sulfur*	0.5 t
Rock salt*	11 t		

metals with the exception of the recycled secondary part, to be discussed later, have to be imported from all over the world. We are the customers of the world (Fig. 1). Thus, we should have a vital interest to work out concepts for a sustainable development of natural resources within and outside Germany.

## Sustainable development

### The concept of sustainable development

Sustainable development is a normative term – according to the philosopher Immanuel Kant – like liberty and equality. In the UN Report “Our Common Future”, commonly called the Brundtland Report, sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland 1987).

This has become the internationally most accepted definition, defining intergeneration fairness. This definition has been expanded by the United Nations Environment Programme, which has added that this concept also requires the maintenance, rational use, and enhancement of the natural resource base that underpins ecological resilience and economic growth, and that it implies progress towards international equity (UNEP 1989).

The next step was the Rio Declaration at the UN Conference on Environment and Development in Rio de Janeiro in 1992 and Agenda 21, which stresses the three elements of sustainable development – ecology, economy, and social justice: To conserve the basic needs of life, to enable all people to achieve economic prosperity, and to strive towards social justice. All three objectives should initially be considered to have the same priority. Whereas the Brundtland definition above stresses inter-generation fairness, Agenda 21 stresses intrageneration fairness.

### Guidelines for sustainable development

The first practical guidelines for sustainable development came from the German forestry administration. The man credited with “inventing” sustainable development was a miner, Oberberghauptmann Johann-Karl von Carlowitz, who published his book “Sylvicultura oeconomica” (1713; Fig. 2). Von Carlowitz was the head of the mining administration of the famous silver-mining district in Freiberg, Saxony. He was not only responsible for the mining and smelting operations in his district, but also for forestry, because timber was needed in the underground mining operations, and the smelting of the sil-

**Fig. 1** The origin of metallic resources imported into Germany

