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# Materials - Man's Essential Link with the Future

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# Materials—Man's Essential Link with the Future[1]

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Materials are essential for the support of human life. At the primitive level they provide food, shelter and protection against the natural elements. At the advanced level of the technological civilization of the 20th century they support the luxuries to which we have become accustomed—and which we insist upon calling our "needs." Today they are essential to our industry, our economy and our national security.

Housewives have seen their homes transformed by the technological development of materials. Vinyl polymers are used in flooring, stainless steel in sinks, pyroceram and Teflon in cookware. The home phone contains 42 of the 92 naturally occurring elements. Polyethylene is an outstanding insulator in radar equipment and one of the myriad of materials used in defense. Production and processing of materials account for 20 percent of our national product but, in fact, without materials we would have no national product at all.

The first radio was the size of an auditorium—today a radio can fit nicely in your pocket. And while the transistor has in fact revolutionized communications, the synthetic fiber has changed drastically the clothing industry and the phosphor crystal has provided millions of homes with color television pictures. The list is endless.

Of course this is absolutely wonderful. The technological wizard produces surprise upon surprise and life has become a shopper's paradise.

Unfortunately our goods are beginning to cost *more* and we are enjoying them *less*. Furthermore, our material resources are dwindling at an alarming rate. Assuming that our personal demands remain the same in the immediate future—an assumption of doubtful validity—the replacement of obsolescent appliances, gadgetry and equipment as well as our continuous attention to our defense posture—not to mention our food, health and transportation industries—will entail our continued acquisition, production and consumption of materials at a rate which is likely to deplete the world reserves of the most common and basic materials in a matter of 50 to 100 years.

Let me cite some figures. Using the U.S. Bureau of Mines Report(1), "Mineral Facts and Figures," the Club of Rome made predictions on the rate of depletion of the common metals and ancillary materials and calculated exhaustion dates by assuming *five* times the magnitude of the known reserves(2). Their figures are—to say the least—alarming. Our world reserves of aluminum are likely to be exhausted in the next 55 years. Chromium in 154. Coal in 150. Cobalt in 148. Copper in 48. Gold in 29. Iron in 173. Lead in 64. Manganese in 94. Mercury in 41. Molybdenum in 65. Natural gas in 49, etc. There is hardly a metal that will last more than 100 years. The U.S. consumption is, on the average, 30 percent of the world total consumption, and the calculation is based on the exponential growth law for all countries—a law substantiated by past experience.

To make matters worse, our "materials crisis" is in fact compounding our energy crisis not only because materials production consumes energy—aluminum production consumes four percent of the total energy consumed—but also because it consumes irreplaceable petrochemicals—our main source of energy production at the present time.

Let me give an example. Permanent antifreeze is made from ethylene glycol, which is also used to make polyester fibers for clothing and polyester tapes for recorders and computers. This is made from ethylene oxide which is an *organic intermediate* (in the language of chemistry). The production value of organic intermediates was of the order of $25 billion in 1973 and accounted for half the production value of *all* industrial chemicals(3).

Note that 90 percent of the organic intermediates are made from petroleum and natural gas. Thus the materials consumption is in direct competition with the energy consumption for precious oil. This is but one aspect of the strong interaction between the energy and materials crises. We shall be touching upon some other aspects later on.

In the light of these observations, only two outcomes appear possible. Either we shall have to enforce upon the world an economy based on galloping consumption, in which case our technological civilization will come to an abrupt end due to exhaustion of materials reserves, or as materials become more scarce their price on the world market will climb to levels which we shall not be able to afford, in which event we shall have to reevaluate our consumer-based economy to survive.

The second possibility seems more likely to me. Furthermore, if current world economic practices do not change drastically, a price war among producers of basic materials seems inevitable.

To give you the relative posture of the United States in this matter, let me quote the following.[3] In 1970 the U.S. imported all its primary supplies of chromite, columbium, tantalum and tin; 90 percent of its aluminum, antimony, cobalt, manganese and platinum; 50 percent of its nickel and zinc; over 33 percent of its iron ore, lead and mercury. On the other hand, on the side of organic chemicals we showed a positive balance of trade—but recall that these are made of petrochemicals, in which we are also not self-sufficient.

To make my point I quote the following news items(4):

> Bauxite production countries have formed a cartel on the OPEC model, driving ore prices up by as much as 300%. 90% of U.S. aluminum production is based on imported ores.

With the diversion of the limited petroleum supplies to

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[3] (3), page 13.

energy uses, feedstocks for the plastics industry have been sharply reduced. Production of resins fell behind demand in 1973 and 1974 and today barely meets industrial requirements. 1975 is likely to be worse.

The effect of the materials shortage on our defense is not a matter for jubilation, either. At a time when the fragile world peace is maintained by a balance of terror, our defense posture is seriously threatened and will be weakened unless "immediate action is taken to protect our capacity for development, production and operation of our military systems," to paraphrase H. Dana Moran, Director, Materials and Minerals Resources Programs—Batelle Columbus Laboratories(4). He too is concerned that a crisis in the supply of critical materials "could well have a devastating effect on our society."

The question that immediately poses itself is of course the obvious one: "Is there a way out?"

There are many plausible answers, each with its own intrinsic probability of success. Since, however, we are dealing with human life, with the future survival of our very own children, we would wish our solution to be the least risky, the least dangerous to their well-being and the least disruptive to their present culture and general way of life.

Some obvious thoughts spring to mind. Can we make *new* materials, "better" materials? Can we synthesize materials tailor-made for special uses? Can we make materials that are less likely to fracture and are more resistant to wear?

Leaving the economics of the question unresolved for the moment, my answer is: to a degree, in some cases, but not always.

In fact, *technology* has so outpaced in some instances our *scientific* knowledge that in some areas technological improvements are likely to be only of marginal character.

With particular reference to fibers, the following paragraph from the 1973 Report of the American Chemical Society to the National Science Foundation, entitled "Chemistry in the Economy," is to the point(3). I quote:

> Today the chances of producing and developing a new fiber that differs substantially from those now made, is not *too* high. Not only finding a new fiber in this well researched field will be difficult. The cost of building a plant with a large capacity and of establishing the new fiber in a fiercely competitive market, would be beyond the resources—or at least the will to risk—of even the largest industrial organizations.

I would like to recall and underline the sentence, "In this well researched field." Its truth applies to most research fields.

Furthermore what the statement really means is that the present talent, interests, orientation and management of our research teams are such that significant technical breakthroughs in the field of fiber technology are unlikely. My opinion is that this is true of most other fields.

The following is a statement from a comprehensive report published in 1974 by the National Academy of Science, entitled "Materials and Man's Needs" (5). Again, I quote:

> The expanding ability to create radically new materials stems largely from the explosive growth that has occurred during this century—I would say the first part of this century—in our scientific understanding of matter. Our basic understanding of most materials, however, falls short of the level required to design for new uses and environments without considerable experimental effort.

To understand our problem it is necessary for us to draw a clear distinction between "science" and "technology." In the case of materials, "science" is the rational, quantitative understanding of the relationships between the atomic and/or molecular structure of a material and its behavior in bulk, such as strength, fracture resistance, ductility, corrosion characteristics, etc. Technology is the manufacture of materials for various purposes on the basis of this understanding.

If our scientific knowledge is incomplete, then technology is approximate *and imprecise* and is often reduced to a state of practice and *enlightened* art.

Without a doubt our most pressing needs lie in the improvement of our scientific effort. This cannot be done by organization, reorganization and committees. It can only be accomplished by recognizing the scholarly mind, by *identifying* the people with a talent and inclination for research and giving them support and recognition.

Excellence must once again be acknowledged. Our young generation is much more conscious of its self-worth and much more willing to recognize and accept excellence than the previous generation, to whom the word was synonymous with inherited privilege. Excellence is a vital quality that will enable this country to compete against the rising tide of foreign competition.

It must be discovered and nurtured in high school, and find its way to the university, where it should be recognized and put to the service of man.

The manifold role of our institutions of higher learning must also be clarified to the public. The community college has its role to play in training in the vocations and the skills. Undergraduate and lower graduate programs in universities must fulfill their purpose as centers of training for careers in service, business and industry, and also be mindful of their role as intellectual centers that will make the student aware of the human condition and the broader aspects of human life.

Our higher level of graduate education is in serious need of reevaluation. We are graduating Ph.D. students, very few of whom have the knowledge and original minds to achieve conceptual and scientific breakthroughs that are of paramount importance to our survival.

"The system penalizes the original mind" is a well-known —yet only too true—cliché in the circles of the government institutions that support our higher education today.

Sadly, even if our attitudes were to change drastically, even if we were to marshal our resources in the directions indicated, the problem of overconsumption would still be with us. This is a much more difficult problem. It involves the entire structure of the world economic system, which in turn is based on economic principles and practices that have existed in the free world for millenia.

In particular, the principles of competitive trade and profit have been the cornerstones of the world economy for centuries. It is my feeling that world consumption as well as trade will have to be controlled by a world organization on principles similar to those of the European Economic Community. Rates of growth of nations in various stages of industrial development will have to be determined on the basis of their current state of industrialization. Certain highly

industrialized nations, such as the United States, will have to adjust to an "equilibrium state" in the sense of the Club of Rome—i.e., zero growth. Of course internal changes in our industrial emphasis will be possible.

The survivors of the alternative could well be inhabiting warmer climes, doing little in particular and philosophizing about the state of the world.

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