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AVAILABILITY, UTILIZATION, AND SALVAGE
OF INDUSTRIAL MATERIALS



A REPORT

PREPARED FOR THE USE OF THE

COMMITTEE ON PUBLIC WORKS

UNITED STATES SENATE

BY THE

LEGISLATIVE REFERENCE SERVICE

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AT THE REQUEST OF

HON. J. CALEB BOGGS



JANUARY 8, 1968

Printed for the use of the Committee on Public Works

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FOREWORD

This paper was prepared by Dr. Franklin P. Huddle of the Science Policy Research Division, Legislative Reference Service, Library of Congress in accordance with the instructions of Hon. J. Caleb Boggs, U.S. Senator, by letter of July 31, 1967. This paper does not reflect the views of the Committee or any of its members, but was prepared to assist the Committee in its considerations of solid waste disposal legislation. Because the Committee recognizes the need to develop methods to convert waste economically into useful materials, the request called for a study of "Industrial Materials Availability, Utilization, and Salvage." It suggested that the study first identify present defects in national materials posture, then describe a hypothetically "ideal" set of conditions for the year 2000, and finally list salient questions arising out of a comparison of present and future. Senator Boggs asked that the factor of environmental degradation by waste materials receive particular attention in the study.

In proceeding along these lines, the author encountered a number of provocative and stimulating questions and issues. The methodology highlighted the influence of demographic change, international relations, and technological advance, on national materials policy.

For purposes of analysis, a "best case" assumption was made concerning the population of the United States in 2000, viz, that it would become stable. This assumption was used for convenience as a base point and without any intention of predicting or forecasting. The contrary assumption—of continued expansion—was found to have so many different and incalculable impacts on materials posture as to make analysis unmanageable. Tentative inferences drawn from the stable-population assumption were based partly on logical reasoning and partly on a rough analogy with the economic character of Western European nations having essentially stable populations. They are intended to be read as illustrations of tendencies rather than as expressions of invariable interactions.

The assumption of a "best case" is convenient because it tends to understate requirements for a more numerous population still expanding. Accordingly, if flexibility in materials policy is required under a condition of population stability, it becomes more necessary under conditions of demographic change; if environmental degradation is important for a stable population, it is more so in a society becoming increasingly crowded; if exhaustion of resources and the need for recycling of wastes appear to be important under conditions of population stability, they are likely to be more so in an expanding population.

For the most part the study avoids the use of quantitative terms and projections. These are of more pertinence when dealing with shorter timespans. In looking ahead to the year 2000, for example, the straight-line projection of the use of bituminous coal amounts to a minus figure roughly equal to the amount of coal currently consumed, while the projection for natural gas consumption would equal the total of all energy consumed in the United States in 1965.

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AVAILABILITY, UTILIZATION, AND SALVAGE OF INDUSTRIAL MATERIALS

I. INTRODUCTION

Materials, won by man from nature, are processed into useful shapes and forms, serve their purpose, and ultimately find their way into a cycle of reuse or else are discarded or expended. Throughout this process, materials of low-recovery value are discharged into the environment as pollutants of land, water, and air. This study is concerned with aspects of this process that degrades the environment and injures the future prospects of society.

The industrial system in the United States in 1968 is largely based on a one-time use of materials, with large volumes of waste generated in the process and additional quantities resulting from artifacts discarded after a briefly useful life. Some of these wastes gradually return to nature, as in the case with 100 million tons of wood wastes generated annually, 6 million tons of agricultural field and animal wastes, and 7 million tons of newsprint. Some kinds of wastes—sooner or later—become permanent additions to the landscape, as is the case with about 150 million annual tons of steel mill slag, 30 billion glass containers emptied annually, and 16 million tons of bituminous coal ash. The quality of the atmosphere and the fresh water resources of the land are degraded by combustion products, discharged industrial wastes, pesticides, fertilizers, human wastes, and other products of a dynamic, resource-consuming, industrial civilization.

It is now evident that the industrial economy of the United States—and indeed of the entire industrial world—must undergo a shift from a use-and-discard approach to a closed cycle of use and salvage, reprocess, and reuse. The timing of the conversion need not be precise; it is likely to go on for a century or more; it may never be total. But it must occur, or else man faces the alternative of a congested planet that has turned into a polluted trash heap, devoid of plant and animal life, depleted of minerals, with a climate intolerable to man.

Although the degradation of the environment is a gradual process, some of the resultant stresses are appearing earlier in a critical form than are others. The conversion of the Great Lakes into cesspools is proceeding rapidly. Nitrate pollution from fertilizers is showing up in ground water. Lead from auto exhausts is detectable throughout the global oceans. The carbon dioxide content of the planet's atmosphere is being significantly altered by man, and with it unforeseeable changes in climate and plant life. Expanding acreages of land are occupied by trash, abandoned highways, strip mines, slag dumps, tailings ponds, unused railroad rights-of-way, saline deposits, and eutrophied lakes. Clearly, pressure for corrective action will not appear all at the same time for all of these and many other evidence of environmental degradation. Priority attention is logically directed toward correcting the most serious, the most acute, and the most rapidly worsening of environmental dislocations. But any social activity that has

a cumulative adverse effect on the environment will sooner or later need to be corrected, halted, or compensated for.

As a general principle, environmental degradation is the result of misplacing materials. Materials useful in one situation become harmful in another. Degradation of the environment can be halted by maintaining control over the location of materials. Application of this principle; however, becomes a complex problem, because materials vary in so many important respects: as to abundance, price, salvage value, useful applications and properties, ease of reprocessing, and injurious effects on the environment.

Approaches to the problem of "keeping materials in their proper places" are also varied. One concept is that the unseen hand of Adam Smith ultimately forces corrective action without purposeful or planned human intervention.¹ Another concept is that since technology causes environmental dislocations, by slowing its progress man can slow the rate of environmental degradation to tolerable limits.² A third concept is that all measurable impairments of the environment must be totally corrected, either to secure man's natural right to an undegraded environment, or in view of the long-range cumulative effect of all forms of degradation taken together.³

The operations analysis concept is that (a) various concentrations of specific environmental degradation, over specific time periods, produce measurable quantitative injury to human health and well-being, that (b) various measurable degrees of correction of these by various specific programs of action entail various levels of cost, so that (c) the problem is one of factfinding to establish priorities of corrective action followed by cost-effectiveness determinations to identify specific programs of corrective action warranting political support. A related concept, the "systems" approach, is that of identifying a more comprehensive goal (e.g., preservation of a viable environment, total resource management, etc.) within which man can achieve numerous specific quantitative trade-offs among costs and benefits, with a benefit in one subsystem paying for a cost in another, aggregating a wider range of progress toward objectives that contribute to the broader system goal.

Since each of these concepts has some force as well as apparent drawbacks, the ultimate course of action adopted can be expected to be some form of compromise reflecting each of them.

Within the foregoing context, succeeding sections of this study will consider in sequence a number of the more salient defects in present management of materials, an idealized materials posture for the

¹ A longstanding assumption in the United States holds that if society is minimally regulated in behavior, technological tools of environmental control will be sufficiently forthcoming to meet man's expanding requirements through operation of private initiative and a free market. This assumption is faulty in that uncontrolled exploitation of technology to satisfy mass markets comes in time to generate intolerable general stresses in man's environment. Specific environmental benefits to individuals are subject to economic law; but generalized impairments of the environment are not.

² This expedient is also imperfect because the effects of technology are neither specific nor predictable. Even more important, some technological developments are capable of causing irreversible impairments of the environment. To retard a development that wipes out a species, destroys an ecosystem, or causes the erosion of square miles of topsoil is no answer if the damage has already been done.

³ This is, of course, counsel of perfection. Nature herself does not achieve it, as is evidenced by such airborne pollutants as sea salt, volcano fly ash, pollen, glacial and meteoric dust, and ozone from lightning storms. The whole effort of technology is to modify the environment which would otherwise be intolerable to man in much of the world. The issue is not whether technology has improved the environment of man—of course it has. The issue is whether the improvement is as good as it could be, whether it will last as long as it could, whether the counteracting disadvantages that accompany it can be eliminated or minimized.

United States for the year 2000, and some questions as to possible programs and policies involving science and technology influencing progress toward this posture during the intervening 32 years. In each section, to the extent convenient, separate attention will be given to the three aspects of materials availability, materials utilization, and materials salvage.

A few assumptions as to the future may be helpful to the study, apart from the obvious ones of no major military, economic, biological, or technological catastrophe directly impacting upon the United States.⁴ One necessary assumption is that the U.S. population become stabilized during the period, both in total numbers and in urban-suburban-rural distribution. Numerical stabilization of age cohorts soon afterward is an obvious necessity. The obligation to maintain national military potency, in terms of both strategic nuclear striking force and for more limited, remote-area conflicts, cannot be assumed away although intensity of conflict needs to diminish rather than increase. The present trend of rising urban tensions needs to ease—and probably will—given a more stable composition and distribution of population.

Finally, it is assumed that U.S. goals directed at the alleviation of poverty in the United States, the application of science and technology to the preservation and control of environment, and the betterment of the quality of life, will all continue to prevail. The primary qualitative effects of domestic programs will be increases in the portions of population engaged in professional and service occupations, and undergoing education or reeducation. Those in retirement will also be more numerous, especially among those manually employed. At such a point, the further expansion of the U.S. economy will reflect changes in the product mix to satisfy changed patterns in consumption, rather than the requirements of an expanding society. Consumer demands for products seem unlikely to expand indefinitely and, accordingly, the rate of economic growth is likely to flatten considerably after 2000. Other measures of progress than growth of GNP will be appropriate to this development. Possibly the best measure of progress at that time will be per capita electric power generation.

⁴The impact of prospective food/population unbalance in the developing countries can be expected to be tragic, but since neither self-denial in the United States nor expanded export of U.S. agricultural surplus offers any hope of permanent solution, the prospect is that the problem will persist unresolved in the future as in the past, although its dimensions will be greater. Indeed, if the assumption as to stabilization of U.S. population by the year 2000 is invalid, then the United States will very possibly share the agony of this historical persistence of the food/population unbalance.

II. PRESENT DEFECTS IN MATERIALS MANAGEMENT CONDITIONS AND TRENDS

A. MATERIALS AVAILABILITY CONSIDERATIONS

Some materials are inherently less abundant than others in nature, and even abundant materials are not uniformly distributed among the areas of the world. Moreover, even the most abundant materials occur in various concentrations and chemical combinations presenting different degrees of ease of extraction. Generally speaking, the United States has an adequacy of the following engineering materials in quantity and quality at present prices for the foreseeable future:

List No. 1:

- Wood and wood fiber.
- Building materials.
- Magnesium.
- Titanium.
- Molybdenum.
- Silicon.
- Helium.
- Vanadium.

A number of additional materials exist in the United States in large quantity, relative to demand, and could be made into working sources if supported by an increase in relative price, or possibly additional research in processing, or both.

Although imports of these materials contribute importantly to total U.S. requirements, supplies from domestic reserves could be enlarged greatly if necessary.

List No. 2:

- Iron.
- Aluminum.⁵
- Zirconium and hafnium.

A number of materials are inherently scarce in nature, are widely disseminated, and command high prices. In all of these the United States is a "have-not" nation, and because U.S. industrial requirements are disproportionately large, so also is U.S. reliance on foreign sources for these materials:

List No. 3:

- Gold.
- Silver.
- Platinum and platinum group metals.
- Diamond stones (diamond bort or powder, however, is produced synthetically in the United States).
- Mercury.
- Tantalum.
- Bismuth.

⁵ Aluminum is normally produced in a two-step process in which bauxite (hydrated aluminum hydroxide) is reduced to alumina and then put into cryolite solution and the alumina extracted by electrolysis. No great quantity of bauxite remains available in the United States (mainly mined in Arkansas), but large reserves are being worked in the Caribbean Islands and Surinam. A large potential domestic source of alumina is clay, from which aluminum has been produced at nearly competitive costs on a pilot plant basis.

Four materials are in wide use in the United States and once were exported in substantial quantities, although resources have dwindled and consumption has increased to such an extent that the United States is now the leading importing nation. These are:

List No. 4:

Copper.

Lead.

Zinc.

Sulphur.

A number of very important industrial materials occur in considerable abundance—relative to present world requirements—outside the United States but U.S. reserves are minor, of generally poor quality, or non-existent. These materials include:

List No. 5:

Nickel.

Tin.

Columbium.

Antimony.

Manganese.

Chromium.

Cobalt.

Beryllium.

Tungsten.

The availability of the tabulated minerals in the United States is a changing condition. New surface discoveries are still being made, and geologists are fully aware that they are largely limited to the interpretation of the subsurface from the surface indications. Although geologists have searched the United States intensively for many years, and in some regions have probed deeply, it is certain that the great bulk of the minerals in the ground are still untapped. The reason for this assertion—which can legitimately be regarded as “defects” from the standpoint of national availability of minerals—include the following:

1. The lower depths of the earth's exterior crust are totally unexplored.

2. Instruments for searching even the upper levels below ground are capable of considerably greater sensitivity, by further development.

3. Technologies for rapid exploration and excavation are just beginning to be developed, in order to improve the economy of access to deep mineralized areas.

4. There is available no comprehensive factual inventory of the surface mineral occurrences in the United States—their extent, configuration, value range, and status—for use in the conduct of a computer-guided search for new hidden mineral bodies. (Such an inventory is currently underway in Canada.)

5. There have been developed no technologies for the simultaneous extraction of many low-value percentages of minerals disseminated in such complex “ores” as granite, pegmatite, and greensand.

6. Mineral exploration of the earth's surface under the oceans has barely begun, and technologies for recovery of solid submarine minerals are not yet developed.

It is clear that, given present technology, price structure, and levels of industrialization in the world, the United States is now dependent upon imports for many materials consumed by American industry. With less than 7 percent of the world's population, the United States consumes nearly half the world's industrial materials. Should the rest of the world become industrialized to a degree approaching that of the United States, in quantity and technological level, there would be much greater competition for the minerals for which the United States now provides the primary market.⁶ The industrialization of the rest of the free world is a goal of U.S. policy and bears a functional relation to the problem of population control and world food/population balance. Even so, to the extent that U.S. goals in encouraging overseas industrialization are met, U.S. overseas supplies of essential minerals are placed in jeopardy. Moreover, nations now supplying minerals to this country are in a position to trade minerals for food, and under conditions of world food shortage might be obliged to confront the United States with an awkward choice between a domestic minerals shortage and a domestic food shortage. Finally, the stimulation of rising expectations among populations of developing nations can prove destabilizing—leading to such political upheavals as occurred in Cuba where sources of nickel, cobalt, and chromium were thereafter lost to the United States. (All three minerals are in deficit in this country.) Political instability promises to be a major factor in causing future uncertainties in the supply of important minerals to the United States, including tin, tantalum, and columbium from Nigeria, copper and cobalt from the Congo and Rhodesia, and a number of other important minerals from countries where political instabilities leading to supply interruption are at least possible in the next 32 years. Reserves of metals in the national stockpile would appear to provide a valuable protection against such potential losses of supply.

B. MATERIALS UTILIZATION CONSIDERATIONS

Within the context of a free economy and a free market pricing structure, American industry is generally characterized by "sharp pencil" calculations in the management of resources. It is possible (although not well documented) that materials per se are less efficiently employed in the United States than in Western Europe, simply because of the differences in relative price relationships of manpower and materials in the two economic regions. Frugal use of manpower is characteristic in the United States because it is more costly; whereas in Western Europe materials are the critical item of cost and receive conservation emphasis. Frugal use of manpower may necessitate generous use of materials and vice versa. (An example is the hand stenciling and cutting of shoe soles from leather versus automatic stamping; the former saves material at the expense of labor and the latter saves labor at the expense of material.) Computer calculation of management strategy is aimed at optimizing these production cost relation-

⁶ That this is a real prospect is suggested by the fact that lead and zinc consumption in the developing countries in Latin America, Africa, and Asia rose from 6 and 3 percent respectively of the total world consumption in 1950 to 10 percent each in 1967. (Iron Age, May 4, 1967, p. 23.) U.S. consumption of lead and zinc amounts to about one-third of total "free world" consumption. Since World War II, domestic production has provided a diminishing share of U.S. requirements until, in 1966, including both new and recovered metal, U.S. sources met only two-thirds of the U.S. lead requirement and only one-half of the zinc requirement. (Lead-Zinc Industry Stabilization. S. Rept. No. 218, 90th Cong., 1st sess. May 4, 1967, pp. 2-3.)

ships within any given price pattern. Since the trend in American industry is toward increased use of computers in management control, it is likely that the overall efficiency of management decisions in the efficient use of resources, already good, will continue to improve.

But from a broader point of view, the efficiency of materials utilization by American industry is open to criticism. The sole function in the use of materials by industry is to produce products and services to improve the human environment. If, in the course of converting materials into products, the process at the same time degrades the human environment, or if the use of the product has this effect, the end result becomes less effective; such as, for example, an insecticide that kills birds or fish. Unfortunately, the transactions involved in environmental improvement are usually specific whereas the environmental degradation is usually general, so that costs and benefits are not considered together as a system. It is necessary, from the point of view of society as a whole, that the indirect costs of environmental degradation resulting from the conversion of materials into products and the use of products be somehow built into the pricing structure so that the efficiencies of the American management process can operate. It is entirely possible that this move would yield not only benefits in environmental quality, but also conservation of industrial materials.

One suggested measure of efficient utilization of materials is the relationship between relative abundance of their occurrence in nature and the relative quantities consumed of each in industry. Taking into account all consumption uses of materials—including not only engineering applications but also chemical, fertilizer, and the like—the use pattern of the United States does not appear seriously out of line. However, silicon is considerably underused relative to its abundance, as is titanium. Conversely, copper, lead, and zinc are consumed disproportionately to their ultimate abundance in nature.⁷

METALLIC ABUNDANCE IN EARTH'S OUTER LAYERS

- | | |
|-------------|--------------|
| 1. silicon | 6. potassium |
| 2. aluminum | 7. magnesium |
| 3. iron | 8. titanium |
| 4. calcium | 9. manganese |
| 5. sodium | 10. barium |

APPROXIMATE RANK OF CONSUMPTION OF MATERIALS

- | | |
|-------------------------|---------------|
| 1. iron | 6. aluminum |
| 2. sodium | 7. copper |
| 3. calcium | 8. zinc |
| 4. potassium | 9. lead |
| 5. silicon ⁸ | 10. manganese |

⁷ These three metals represent a special case. Although inherently scarce in terms of their percentage of occurrence in the earth's crust, they are naturally concentrated when they do occur, and have maintained a more or less consistent output for many years. That is, although subject to wide fluctuations in demand and price, they have remained substantially available. An important fraction of all three metals is also recycled in alloy form (brass, bronze, pot metal) or in pure form (copper conductors, zinc molds, lead storage battery elements).

⁸ It is noteworthy that glass is a chemical compound of silicon and oxygen, the two most abundant elements in nature. Glass has been found to be a remarkably versatile material: easily formed, extremely strong, highly elastic, transparent, dielectric, thermally insulating. Were glass to receive research attention proportional to its potential abundance, it is likely that even more attractive performance properties could be achieved. It is already a strong contender for use in deep-submergence vessels because of its favorable strength-to-weight ratio under compression loading.

Utilization of scarce materials is not efficient from the long-term point of view if they are widely disseminated in nature as the outcome of their use. For example, the use of copper salts in fungicides, lead oxide as pigment, tinplate on "tin" cans, cobalt driers and coloring agents, and the like, removes these materials forever from the cycle of re-use. To the extent that functions employing scarce and dwindling resources can be accomplished economically by renewable or vastly abundant materials, such as silicon, iron, aluminum, or magnesium, there would be at least theoretical virtue in such an alternative. Ultimately, it may be necessary for man to take account of the recoverability of scarce materials as a factor in their utilization.

Another consideration is the exposure of metals to corrosion by which large quantities of metallics are disseminated into the ground. The use of zinc anodes, for example, as a means of protecting pipelines, consumes the zinc completely without recovery. The alternative use of magnesium might eventually be considered as a necessary alternative.

The loss of gold and silver as a plating material results in a similar nonrecoverable dissipation of metallic values. Other examples are the use of mercury in thermometers, molybdenum disulphate lubricants, cadmium plating, and all kinds of bits and pieces, findings, and small hardware of copper and brass.

Obviously, the entire industrial system of the United States could not be structured to satisfy the single criterion of long-range effective utilization of exhaustible resources. However, at some future point, it is possible that a free market will encourage some movement in this direction. Rising prices, reflecting growing scarcities, will tend to discourage large dissipations of materials and reward recycling practices. It might also be germane to consider whether the urgency of such a movement might be influenced by environmental factors. If loss by dissemination of scarce materials imposes degradation on the environment, then an added benefit might come from the development of an alternative technology to such uses. For example, if the use of tin to coat cans degrades the environment as well as resulting in the total loss of the tin, it might be possible to develop some other material (aluminum, for example), that could be salvaged, or else a system (a returnable container or low-volume disposable packaging) that would impose less of a problem of waste handling. Such a solution would conserve tin as well as relieving the landscape of litter.

In summary, present uses of materials are economical in the context of the values of the marketplace. However, to the extent that their use of disposal degrades man's environment, they lose a part of their effectiveness. There may be some correlation between degradation of environment and dispersal (consumption) use of materials that prevents their recycling. To the extent that materials can be recycled economically on a short turnaround time after service, they do not impair the environment. Use of materials in proportion to their abundance in nature has a favorable effect on efficiency of utilization, but ultimate limits are imposed by the properties of the materials themselves. Implicit in this sequence is the importance of technological development of materials properties toward versatility, with strong reference to materials most abundant in nature. Also implied is the development of alternative technologies in place of consumption uses of scarce materials.

C. MATERIALS SALVAGE CONSIDERATIONS

The social priority of urgency is to conserve the environment as a whole by insuring that wastes do not accumulate. The economic priority is to conserve and recycle materials of value. The question is whether these two motivations can be effectively combined to serve both purposes. The principle of waste disposal is reduction of unusable quantity; the principle of material salvage is maximum recovery of value. Waste becomes salvage if it acquires sufficient value. Materials lose value when they are useless, mixed, or difficult to separate. This is equally true of ore in the ground and waste generated by man. Conversely, waste gains value if it is usable, and segregated or easy to segregate. The ideal is to achieve a system in which materials always retain sufficient value to hold them in the cycle of reuse.

From the long range, theoretical point of view, materials are essentially inexhaustible because as abundance decreases, price rises; in consequence, demand slackens, new production is begun at previously submarginal sources, and greater care is taken to achieve efficient recycling of scrap. However, as a practical matter, when prices of a particularly scarce material rise, they make it useless for some of its applications. As far as these applications are concerned, the material is no longer available. The function of the free market is to bring all these forces to bear. However, the accumulation of useless scrap or waste in dumps is evidence that the market functions imperfectly. Some kind of cost factor needs to be introduced that will enable the price mechanism to operate completely and without waste.

Technology has overcome previous shortages of many materials in the United States by the development of substitutes, alternates, and extenders. Critical materials thus eased have included silk, wool, abaca, waterfowl feathers and down, diamond bort, rubber, selenium, sapphire, shellac, among others. Changes in technology and deliberate measures of military conservation have reduced military requirements for many previously critical materials. Under the dynamic and driving motivation of national defense, remarkable accomplishments have been possible in the utilization of materials. Even in the area of materials salvage and reuse, when military production to meet essential requirements depended upon it, military policies and procedures in scrap handling were a model of efficiency.⁹ The military procedures were based on the concept of segregating (and restoring value) to items useful for military purposes. Commercial scrap management is based on extracting from scrap those items on economic value. Accordingly, the problem in the management of the wastes of civilization is to classify or concentrate wastes in forms suitable for profitable recycling or other use. However this is done, it remains a problem of technology.

The application of technology to improve the handling of waste materials can be applied at three points: (1) by the collecting agency, (2) by the household or unit originally generating it, (3) by the producer of the original product from which the waste is derived.

It is hard to generate a demand for raw materials recovered from the wastes of society. Prices of materials tend to over-react to supply-demand conditions. Under conditions of superabundance, prices are abnormally depressed; under conditions of scarcity they rise sharply.

⁹ For example, a "best seller" among Government publications purchased by private industry in 1956 was the Scrap Yard Handbook, (TM 754-200, NAVSANDA PUB 288, AFM 68-3, NAVMC 1111-SD).

Large producers of materials have a vested interest in price stability, as do large consumers of materials. But there is an overall tendency toward excess capacity. Given this tendency, there are powerful forces opposed to any public effort that would result in an addition to supplies of materials already in surplus. This is perhaps the most formidable issue in devising a general solution to the problem of public waste disposal.

Another obstacle is the resistance of the individual to the discipline required to participate in the scrap segregation process. Under war-time motivation, householders in World War II in the United States collected tin cans, saved meat fats, and bundled papers willingly. But under peacetime conditions, they resist this obligation. European nations that compel the householder routinely to sort out metal, paper, and waste food, in order that each can be collected separately, are able to make more efficient use of these as recycled raw materials. If the United States is to avoid the problem of mountains of unusable waste, there needs to be a choice between regulation of the behavior of the householder—as in Europe—or the development of effective technologies of waste sorting and processing, or reduction in the percentage of the volume of consumer goods that end up as trash.

Elaborate programs of research are currently underway, under the sponsorship of the Department of Health, Education, and Welfare, searching for technological solutions to the problem of segregating and processing municipal wastes. Numerous local communities have reported success stories about various techniques for the economical recovery of values from trash and garbage. New technologies are appearing for the chopping up of automobile sheet for remelt, the composting of newspapers to produce cattle feed, and so forth. Less promising are disposal methods by burning, that reduce trash volume at the expense of air pollution. And no solution has yet appeared to solve the problem of some 30 billion glass containers a year.

A general approach to the problem of urban trash disposal might be found by providing free electrical power to any urban area for experiments in economical waste disposal and recovery; and for continued availability of free electrical power for use by an urban area in the segregation and processing of waste materials for recycling. The rationale of such a possible approach is that both the movement of large quantities of materials and the thermal processing of them into usable forms take a great deal of power. In view of the long-range abundance of electrical power from nuclear reactors, such an application would serve the public interest by pointing toward an ultimately efficient system of total recycling. It would also establish a firm market base for "dump power" in the future. (From the current standpoint, it might have a further plus, in that materials imported from abroad, and recovered from scrap, would reduce the overseas dollar drain.)

Attention might also be given, in systematically approaching the problem of salvage, to the possible contributions of the initial producers of products that end up as waste. For example:

Should components of such durable goods as autos, refrigerators, washing machines, et cetera, be more thoroughly standardized, so that fewer used items need to be retained to be cannibalized for parts? Should they be designed to be scrapped so that they are easier and cheaper to disassemble? Should repair and reuse of consumer dur-

ables be more vigorously encouraged? Should they be designed to reduce to a minimum the unusable volume of the materials they contain?

Should the container industry be studied with a view to improving the possibility of recovering and recycling its product? Or of altering it to make it useful in some other application? Or of reducing the volume of cardboard, paper, and other nonfood materials required per quantity of food contained?

If the cost of ultimate disposal were partly shifted back to the producer initially responsible for decisions resulting in volume waste disposal problems, or if the responsibility for participating in the waste disposal itself were to be shared by the source, economic pressures would be generated toward solution of the problem. Alternatively, responsibility for research and technological development might be shouldered by the Government in these possible directions. This is particularly appropriate for the development of technologies applicable for the segregation of household waste materials in the private household or farm.

In summary, the goal of materials salvage is to close the materials cycle, so that all trash becomes input material. Opportunities for improvement in the present arrangements for trash disposal are offered at three points: The product manufacturer, the consumer, and the trash-collection agency. Control can be effected by regulation or technology, or both together. Social costs of trash accumulation should be made available as an incentive at these three points to develop systems of salvage that move toward the closing of the cycle. Efficiency in the use of materials to make products to modify the human environment needs to include as a negative factor the injury done to the environment by incomplete cycling of materials in this process.

III. AN IDEAL POSTURE FOR MATERIALS IN THE YEAR 2000

A. GENERAL

Ideally, the general policy governing the management of materials in the year 2000 would be sustained yield, at beneficial terms, contributing to gradual but sustained rates of improvement of the environment in the light of longer range future analysis, planning, and programing.

Under the assumptions stated in the introduction, certain conditions respecting materials seem to follow. For example, under conditions of a stable population, requirements for materials of construction (for housing, elementary schools, retail outlets, municipal and community services, etc.), might begin to stabilize at a replacement level after reasonable standards of capacity have been achieved. Emphasis might tend to shift somewhat from volume production and price competition toward quality of design and construction, durability, and esthetic values. Materials requirements for construction, if these conjectures are valid, would decline in quantity, and become more diversified.

It seems likely that similar processes would also apply to consumer durable goods. With declining mass markets, there would be a proportionately large scope for competition on the basis of quality, service, and durability. First cost might then become less important than life cost (i.e., cost of the item over its entire useful life). Possibly, large industries would even be restructured to accommodate themselves to this change. Already something of the kind is appearing with the retail sales-and-service outlets of major mail-order houses, and the long-term performance guarantees offered by major auto manufacturers. In military systems procurement, the concept is quite well established. Reduced rates of sales might induce retail sales outlets to expand their scope to multiple product lines or to service functions along with sales. The sale of service might even replace the sale of hardware, in some items.

The extent of population mobility under a stable population, with stable urban-suburban-rural distribution, cannot be foreseen. However, the necessity for professional and clerical personnel to commute might well be reduced by the availability of audiovisual communication systems linked to data storage sources to enable most transactions now conducted face to face to be handled at remote distances. A major shift in technology and in materials requirements would accompany any departure from the general use of gasoline-powered automobiles as now employed. Such large changes in hardware and systems pose some very difficult problems necessitating the preservation of broad technological flexibility.

Under conditions of stable population, there would probably be a tendency toward freezing or institutionalizing of manufacturing, services, public institutions, and the flow of goods and services. There are dangers to national security and economic health in excessive stability. It might well become a deliberate goal of political policy to strive for a posture of flexibility, to assure the capability to absorb unforeseen external stresses, and to respond to internal economic and technological dislocations. An opposite danger is that of overresponding to such pressures. The availability of computer aids to management seems likely to become helpful in striking proper balance under surges in a generally stable system.

A search is underway for environmental stresses (including those imposed by materials) that are deleterious to man or that cause changes in man's ecology that are ultimately harmful to him. It is likely that this search will in the next 32 years turn into a systematic analysis of man's total environment to identify, calibrate, and alleviate harmful stresses. One consequence of this activity seems likely to be the selection of materials for use in the environment that will optimize stress reduction. The outcome of this search cannot be foreseen, of course, but it can be conjectured to have a considerable impact on the pattern of materials in use by the year 2000. Herein is an additional reason for maintaining flexibility in the materials system. Moreover, it is not unlikely that new human allergies to specific materials will make their appearance, and that the materials input mix will never be completely stabilized in terms of perfect compatibility with changing man.

The requirements of an ideal materials system for the year 2000, then, are to achieve a posture of flexibility within a generally stable society, to continue the technological search for environmental optimization, and to respond in a measured way to internal or external perturbations.

B. MATERIALS AVAILABILITY CONSIDERATIONS

The general principle governing materials availability would be the achievement of a flexible policy of dynamic stability, maintaining the flow of materials to meet as precisely as possible, without waste or surplus, the changing needs of industry under changing external conditions and changing technology, by sensitive and long-range planning and programming.

To insure flexibility and quick response to national supply interruptions, a reserve of every material in substantial commercial use would be maintained either in a national stockpile or in industrial inventories. The reserve, ideally, would be in the highest form uncommitted to an end product and would be held for emergencies.

To achieve flexibility of supply, a detailed inventory would be developed and maintained of all mineral deposits of actual or potential commercial significance, containing information about their location, ranges of values, configuration, working history, et cetera. This information would be available as a data base, both to enable national calculations as to the status of resources, and to provide guidance in the conduct of computerized searches for new mineral areas.

To broaden the area of access to materials, detection instruments of increasing sensitivity would be available for use on the surface

to detect mineralization at progressively deeper levels in the earth. Extensive core drilling would be carried out, to enlarge the knowledge of the geology at these levels. Mining at greater depths would be feasible, with more efficient and rapid equipments for excavation and tunneling.

The preliminary search of the ocean bottom for surface minerals would be essentially completed, and core drilling begun at promising locations. Technologies would be in use for the recovery of submarine surface minerals, and would be under development for subsurface mining under the ocean floor.

An abundance of electrical energy would be available from breeder reactors and the effort to achieve nuclear fusion would continue, in recognition of the unlimited utility of abundant energy for human purposes. Atomic energy would supply about half of all electricity consumed, with the prospect that replacement and further expansion of power generation capacity would be entirely nuclear.

Electricity would provide the heat for dwellings and public buildings, and thermal energy for industry. A trend would be evident toward the development of very large industrial complexes, to exploit waste heat from nuclear power reactor stations, along the lines of the Bolsa Chica desalinization plant. The use of large amounts of electric power to process complex ores yielding multiple products (if this technology were available by this time) would enable mineral producers to respond flexibly to day-by-day changes in market requirements for metals. General-purpose refineries of metallic ores would be able to accept and process ores of widely differing content.

Automated aeration of rivers and lakes would be generally practiced as an ecological conservation measure. Restoration of areas denuded by strip mining, overlain with tailings and railroad roadbeds, or impregnated with chemical wastes, would be systematically undertaken. A conscious and systematic effort at ecological as well as human environmental restoration and improvement would be generally underway.

The anticipated future national requirements for materials possessing unprecedented and extreme properties would be determined systematically and routinely; research approaches to attain these properties would be blocked out and initiated far enough in advance of need so that useful social projects would not be obstructed for want of requisite technology.

Periodic surveys would be undertaken of national materials posture, trends, potential weaknesses and vulnerabilities; material strategies would be devised to strengthen the national posture, and then implemented; potential impacts of new technology on national materials supply would be forecast, evaluated, and provided for.

C. MATERIALS UTILIZATION CONSIDERATIONS

The general principle governing materials utilization would be the achievement of total effectiveness of performance in the environment. All relevant consequences of the use and management of materials, for both the immediate and the long-range future, would be considered. Materials would be selected for use in the construction of products on the basis of such criteria as:

1. The health of the consumer.

2. The life cost of the product, involving acquisition cost, durability, reliability, repair costs, and operational costs.

3. The performance of the product.

4. The salvage and recovery value of material in the product when the product life ends.

Technological capability would be high and research would be continuous in such areas as:

1. Determination of the properties and capabilities of the most abundant engineering materials—singly and in various combinations.

2. Determination of the smallest feasible number of optimally performing alloys best satisfying all design requirements, and standardization of these alloys to facilitate production, inventory, repair, and salvage economies.

3. Techniques for minimizing environmental degradation of materials (especially corrosion) to reduce life costs of hardware and systems by extending the operational life and reliability of components.

4. Utilization and recovery of industrial wastes as coproducts, such as the milling of steel mill slags for soil conditioner or portland cement, etc., with tax credit given for waste utilization practices to preserve or improve the environment.

5. Exploitation of the unique property capabilities of composite materials, bearing in mind the additional difficulties inherent in eventual disposal of such composites.

6. Exploitation of material properties achieved by higher orders of purity, and the development of additional techniques for economic achievement of such levels where advantageous.

D. MATERIALS SALVAGE CONSIDERATIONS

The general principle governing salvage would be the achievement of a nearly "closed system" in which materials retained value throughout the system and were recycled rather than discarded. Waste collection, classification, processing, and distribution of recovered values, would be a major industry, deriving a part of its revenue as a disposal service, part from the sale of recovered values, and part from contracts for environmental protection and restoration services. Discarded wastes would be held to minimum volume.

To recover values, restore the environment, impart education in public behavior, and train future workers in waste disposal technology, national salvage campaigns would be systematically conducted in one geographic area after another. A systematic delittering program would be coupled with a technological development and demonstration effort, to maximize the values collected in the operation: First targets of such a program would be the public lands, railroad right-of-way, informal dumping areas on public highway right-of-way, and negotiated arrangements with municipalities and other publicly owned properties. General application of the program could presumably be arranged on an equitable basis.

By exploiting the capabilities of the computer for detailed record management, the profitable operation of "used part" supermarkets would be possible. Such institutionalized sales outlets for salvage

would contribute to the effectiveness of the recycling of disassembled consumer durables.

An experimental program would be conducted to explore the economics of recycling of low-grade scrap to primary mineral extraction industries for reprocessing. (E.g., the use of scrap tinplate cuttings to recover copper values from mine drainage is already standard commercial practice; wide extension of this principle seems to offer attractive possibilities.)

To achieve safe, effective, and economical use of the very large quantities of radioactive materials generated by nuclear power reactors, it would be necessary to devise fail-safe methods of compact encapsulation for long-range storage in specific environments. Heat generated by these products could then be employed for programs of environmental control and improvement. Among the possibilities:

1. Automatic air-bubbling system to restore eutrophied lakes and to purify rivers.
2. Maintenance of ice-free channels in the Great Lakes.
3. Prevention of snow accumulation on urban thoroughfares.

An essential feature of a "closed system" would be the recovery and utilization of valuable biological wastes. This would require the development of sewage system capable of separating and treating sludge for agricultural use, recovery of fixed nitrogen, and water treatment. For compelling esthetic reasons, it might prove essential to construct dual waterlines to dwellings, one of which would be a closed system for waste disposal and the other an open line of potable water.

The wide spreading of chemical agents to achieve biological effects (fertilize the soil, control pests, destroy bacteria, inhibit algae, defoliate leaves, etc.) would be kept under close surveillance with regard to long-term adverse effects on the environment. A vigorous research and development program, emphasizing biological methods of control, and nontoxic systems, would be maintained to provide safe alternatives where these were found to be necessary.

IV. SALIENT QUESTIONS

A. What political decisions would be warranted in the immediate future, and in what sequence, to maximize progress toward an ideal national materials posture in the year 2000?

B. What irreversible decisions are being made now, by default, that may obstruct future progress toward an ideal "steady state"?

C. What organizational and administrative arrangements will be required to facilitate orderly progress in materials posture—

1. As to programs of applied research, technological development, and pilot plant tests and demonstrations?

2. As to the design of projects involving Federal-State-local cooperation?

3. As to future materials supply/requirements balance under changing world political conditions, and domestic technological conditions?

D. What research needs can be identified now that call for research of a long-range nature to meet technological requirements of the year 2000?

E. What data systems could be implemented now, and then progressively refined in procedures and enlarged in scope over the years ahead, to achieve materials posture goals of the year 2000?

1. A national mineral resources inventory?

2. A materials input-output balance sheet?

3. A technological impact forecasting system?

F. Should studies of the economic value of various specific quantitative reductions in specific environmental impairments resulting from "materials out of place" be initiated now, to provide economic justification for funding corrective actions?

G. Should economic motivations be devised and applied now to encourage efforts by private industry—

1. To design hardware and containers for optimal salvage, or disposability?

2. To devise systems for experimental application in selected communities, explicitly designed to apply electric power freely in the processing of waste materials?

H. Is the concept of multiple benefits fully exploited in present materials-oriented programs sponsored or conducted by the Federal Government to preserve or restore the environment?

IV. SALIENT QUESTIONS

1. What is the present position of the Government in regard to the question of the establishment of a national bank?
2. What is the present position of the Government in regard to the question of the establishment of a national currency?
3. What is the present position of the Government in regard to the question of the establishment of a national mint?
4. What is the present position of the Government in regard to the question of the establishment of a national treasury?
5. What is the present position of the Government in regard to the question of the establishment of a national post office?
6. What is the present position of the Government in regard to the question of the establishment of a national telegraph?
7. What is the present position of the Government in regard to the question of the establishment of a national railway?
8. What is the present position of the Government in regard to the question of the establishment of a national road?
9. What is the present position of the Government in regard to the question of the establishment of a national harbor?
10. What is the present position of the Government in regard to the question of the establishment of a national port?
11. What is the present position of the Government in regard to the question of the establishment of a national airport?
12. What is the present position of the Government in regard to the question of the establishment of a national seaport?
13. What is the present position of the Government in regard to the question of the establishment of a national river?
14. What is the present position of the Government in regard to the question of the establishment of a national lake?
15. What is the present position of the Government in regard to the question of the establishment of a national mountain?
16. What is the present position of the Government in regard to the question of the establishment of a national plain?
17. What is the present position of the Government in regard to the question of the establishment of a national valley?
18. What is the present position of the Government in regard to the question of the establishment of a national hill?
19. What is the present position of the Government in regard to the question of the establishment of a national peak?
20. What is the present position of the Government in regard to the question of the establishment of a national summit?