Engineering Implications of Chronic Materials Scarcity

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Engineering Implications of Chronic Materials Scarcity

Proceedings of an Engineering Foundation Conference
Organized by the Federation of Materials Societies
for the Office of Technology Assessment
United States Congress and the
National Commission on Supplies and Shortages

Held at New England College
Henniker, New Hampshire
August 8-13, 1976

April 1977

CONGRESS OF THE UNITED STATES
Office of Technology Assessment
WASHINGTON, D.C. 20510

Engineering Implications of Chronic Materials Scarcity

Organizing Committee for the Federation of Materials Societies

Franklin P. Huddle—Conference Chairman
N. E. Promisel—Conference Co-Chairman

CONFERENCE EXECUTIVE COMMITTEE

John B. Wachtman, Jr.–-Chairman
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Preface

National materials policy has emerged into prominence in the United States. It involves both the Federal Government and the private sector. In response, many industrial firms have raised materials planning to the level of corporate policy and established a formal organization, sometimes headed by a vice president. The executive branch of the Federal Government has established a Committee on Materials under the Office of Science and Technology Policy with representatives from Federal agencies having major materials activities; three reports by this Committee, nearing completion, involve an inventory of materials research and development, a study of energy-related materials research and development, and an examination of environmental aspects of the materials cycle.

Interest of the legislative branch in materials policy is evidenced by studies requested of the Library of Congress, the General Accounting Office, and the Office of Technology Assessment.

By another legislative initiative, a new temporary organization, the National Commission on Supplies and Shortages, was established with members from the private sector as well as from both the legislative and executive branches of Government. This Commission is charged with reporting on the possible need for a permanent materials planning institution and with giving special attention to materials information and stockpiling.

The present Conference—the fourth in the series of biennial conferences at Henniker on national materials policy—seeks to examine the interrelationship of engineering and policy implications involved in current national materials policy activities. Two of these activities are explicitly addressed: (1) the work of the materials program of the Office of Technology Assessment and (2) the deliberations of the National Commission on Supplies and Shortages. In addition, attention is focused on conservation of energy in materials processing, the role of materials in defense, and the more effective utilization of renewable resources.

The first Engineering Foundation Conference on National Materials Policy—held at New England College, Henniker, New Hampshire, in 1970–provided a warning of future difficulties, It called attention to the functional relationship of materials, energy, and environment. The following October, the Congress by statute created the National Commission on Materials Policy.

The second Engineering Foundation Conference on materials policy, also at Henniker, was convened in 1972 with active participation by the Chairman and staff of the National Commission on Materials Policy. It explored eight issues that were later to comprise the gist of this Commission's final report. It stressed the need for a cooperative interaction of Government, academia, and industry in the resolution of these issues,

The third Engineering Foundation Conference in this series, in August 1974, was organized by the Federation of Materials Societies for the Office of Technology Assessment. It, too, was held at Henniker and examined options for implementing national materials policy, It stressed the need for reliable and accessible information on all aspects of materials management, the symbiotic relationship of technology -economics-institutions in implementing national policy, and the interdependence of nations with respect to the production, exchange, and the use of materials.

The purpose of this publication is to present the proceedings of the fourth Henniker Conference on National Materials Policy. Like the first three Conferences, it does not recommend or advocate. Its "findings" are exploratory. The Conference searched for options and alternatives, The "findings" contained in the present report are the products of task forces, largely self-selected, of the conferees. No individual responsibility for these reports should be inferred; they stand on their own merits and should be so regarded.

Likewise, as managing agency for the 1976 Conference, neither the Federation of Materials Societies, the OTA, or the NCSS assume responsibility for the substantive product. Its purpose in supporting this activity was to sustain the national interest in materials policy as a subject deserving of close and continuing public attention,

Arrangements for the publication of these proceedings were handled by the Office of Technology Assessment and the National Commission on Supplies and Shortages.

Foreword

These proceedings document the papers delivered, task force deliberations and findings, plenary discussions, and “sense of the meeting” of the fourth Henniker Conference on National Materials Policy.

These conferences, sponsored by the Engineering Foundation, were initiated with four purposes in mind. First, to keep the issue of national materials policy alive, and to remind public interest groups and decisionmakers of its importance. Second, to sustain progress toward the design and development of a national materials policy. Third, to build a consensus as to the essential elements that should comprise a national materials policy. And fourth, to convey to national decisionmakers in the legislative and executive branches of the Federal Government a true perception of this emerging consensus,

There is no good way to measure the effects of these conferences. Certainly, the participants take home with them a lively sense of community in an important enterprise. They share this experience with their associates through trip reports and verbal accounts. The proceedings of previous conferences have literally spread all over the world, are cited widely in the literature of materials policy, are quoted in the halls of Congress, and are summarized or reproduced in official documents.

Another function of these conferences is that of recruitment. Along with the senior participants like N. E. Promisel, J. B. Wachtman, Jr., R. E. Goldhoff, C, E. Ford, and the many who have provided leadership at several past conferences, each time there are new recruits to the materials community, who find at Henniker a crash course in instant expertise.

Above all, the community at Henniker provides entree to people representing the many fields of knowledge encompassed in materials science, technology, and management, No one can pretend to have a firm grasp of all these fields. But meeting for a week to work on important and difficult problems is an ideal introduction,

Moreover, it is not always the experienced senior professional who discovers the way to resolve these knotty issues. Often enough it is the newcomer with a fresh outlook who asks the right question or suggests the novel approach,

As long as these conferences can continue to observe these aims and serve these public purposes, it is likely that ways will be found to continue them, For in the changing world, the design of a materials policy cannot be a fixed decalogue; it must respond to the changing times, and better yet, anticipate them, The present proceedings should be evaluated against that ideal.

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I. Introductory Sessions

CALL TO ORDER

by John B. Wachtman, Jr.
Chief, Inorganic Materials Division
National Bureau of Standards
Chairman of the Conference

Good Morning! I am Jack Wachtman, substituting for Frank Huddle, who is at work in Washington and about whom I will tell you more later.

This conference is the result of the work of many people. It is important to take a few minutes not only to recognize them, but to understand the broad base of interest in the issues to be considered here, and to listen to the written expressions of interest by several people who are in a position to use the products of this conference.

Before describing the general background of the whole series of Henniker conferences on National Materials Policy and explaining the perspective for this conference, I would like to introduce the conference co-chairman, Mr. Nathan Promisel, whom most of you know,

This conference began over a year ago with the agreement between the Engineering Foundation Conference and the Federation of Materials Societies to hold the fourth in the series of Conferences on National Materials Policy. The federation appointed a committee chaired by Frank Huddle and co-chaired by Nate Promisel to organize the conference. A tentative program was developed with the assistance of a steering committee consisting of Cornelius Cosman, Anthony DiBenedetto, George Eads, Richard Harmon, Sheldon Isakoff, Robert Johnson, Ben Kornhauser, Jerry Kruger, Walter Moen, Dana Moran, John Morgan, Albert Paladino, Jerry Persh, Allen Gray, and Robert Vaughn. Contributions toward the cost of printing the proceedings were made by the Office of Technology Assessment, the National Commission on Supplies and Shortages, the Bureau of Mines, and the Federation of Materials Societies.

In May, when Frank Huddle became ill, he asked me to form and chair an Executive Committee to complete the arrangements and manage the conference. This committee consists of Nate Promisel, George Eads, Curry Ford, Allen Gray, and Albert Paladino. Frank is recuperating and has been back at work for several weeks. He has continually provided help and moral support to the Executive Committee. Although many other people have contributed, this is largely Frank's conference and I would like to read a message from him to the conference.

The Library of Congress
Congressional Research Service

Washington, D, C., August 2, 1976

Dr. John B. Wachtman, jr. Chairman
Fourth Henniker Conference on National Materials Policy
New England College
Henniker, New Hampshire 03242

Dear jack:

I am writing to express my hope and confident belief that the fourth Henniker conference on national materiaJs poJicy will be the best and most rewarding of the series. If thoughtful planning, hard work, outstanding speakers, and superior attendance count for anything, it will be.

The theory underlying these conferences is that we bring together a group of diversified and knowledgeable conferees; we put before them a collection of important public problems and issues; we explain and clarify the circumstances that surround these matters; and then we look to the conferees to advise the conference, and subsequently the interested public and its representatives, on possible ways to approach these national problems and issues.

What happens at these conferences is important precisely because the conferees, taken together, are behoIden to no group interest, There is no special pleading. The concern shared by all conferees here is the public interest. The quality of thought is both high and objective, It is important and necessary, of course, that the interests of the different groups in our national society be expressed and considered. But the final product ought to be a consensus that represents a total collective judgment as to the best interests of us all,

There is another aspect of these conferences that I hope will grow. That is the introduction of interests and views on behalf of two constituencies that cannot be adequately represented at this time, One of these is future generations of Americans, whose needs ought to be voiced today. The other is the citizens of the world, our fellow passengers on spaceship Earth, whose views and attitudes transcend national boundaries in the effort to achieve wise, effective management of our total global pattern of resources.

in the future, increasingly, the needs of our own nationaJ community should be reconciled and harmonized with those of the totality of globaJ society, present and future. It will be constructive if the proceedings of Henniker W show some of this scope and direction.

In conclusion, let me wish you and the conferees a profitable week, exciting ideas, thoughtful discussions, new friendships, and a lasting contribution to the body of literature of national materials policy. 1 am sorry that I cannot share the experience with you. May it be a great one!

Sincerely yours,
Franklin P. Huddle.

An important feature of this series of conferences on National Materials Policy is the interest shown by leaders in science, technology, and public policy, I would like to read you three messages to this conference. The first is from Cortland Perkins, the President of the National Academy of Engineering.

NATIONAL ACADEMY OF ENGINEERING
2101 Constitution Avenue, N. W.,
Washington, D.C. 20418

Office of the President july 27, 1976

Dr. Franklin P. Huddle
Congressional Research Service
Library of Congress
Washington, D,C. 20540

Dear Dr. Huddle:

I have read the Program and the Terms of Reference for the IVth Henniker Conference on National Materials Policy with interest. The program appears to address important areas relating materials technology to questions of national policy. As you know, the NAE and the NAS co-sponsored a recent symposium on “Materials and the Development of Nations: The Role of Technology.” Currently, we are considering a follow-up program on issues identified by participants in that symposium.

1 am looking forward to seeing the proceedings of the Conference, which I am sure will be both interesting and informative,

Sincerely,
Courtland D. Perkins
President

The next is from Dr. Guyford Stever, Director of the National Science Foundation, who has been nominated by President Ford as Science Adviser and Director of the new White House Office of Science and Technology Policy.

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

Office of the Science Adviser

July 30, 1976

Dr. Franklin P. Huddle
Congressional Research Service
Science Policy Research Division
Library of Congress
Washington, D.C, 20540

Dear Dr. Huddle:

The Program of the IVth Henniker Conference on National Materials Policy addresses a series of issues which are important to materials science and technology and through them to the national economy and security.

I wish the conferees success in their work and I look forward to the Conference proceedings as useful contributions to national policy considerations.

Sincerely yours,
H, Guyford Stever
Science Adviser

The third message is jointly from Senator Frank Moss, Chairman of the Senate Committee on Aeronautical and Space Sciences and Representative Olin Teague, Chairman of the House Committee on Science and Technology.

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

August 5, 1976

To Participants of the Engineering Foundation
Conference on Materials Policy, Henniker, N.H.

It is with genuine concern for the significant issues with which this conference will be contending, and with much hope for equally significant results, that we take the occasion to extend to you the high interest and best wishes of your national legislature.

We do not presume to suggest to knowledgeable people such as yourselves a list of reasons why materials policy and materials research and development are vital to the nation—and thus to the Congress of the United States. You are far more familiar with such reasons than we. Nonetheless, we do wish to impress upon you that materials problems and materials sciences and technology are now infiltrating the collective consciousness of the Congress to a degree that we believe has not heretofore existed.

Some of you, we are sure, are familiar with the companion bills (HR 14439 and S 3637) now pending in the House and Senate. Entitled "The

National Materials Policy, Research and Organization Act of 1976," these bills have been introduced recently by Senator Moss and Representatives Symington and Mosher. While we hold no particular brief for the precise format of the bill as it presently stands, we believe it will stimulate thought and discussion— and hopefully will provoke some manner of observation, criticism, recommendations or whatever, from this conference. Your constructive reaction would be of great utility to us.

No one expects that we will have good enough answers to basic materials problems, or have them soon enough, to warrant serious consideration of this kind of legislation in the immediate future. On the other hand, we as a nation (perhaps as a species) will not be able to go our traditional, unstructured, exploitive way much longer without creating disastrous materials situations which may prove irreversible.

Your findings can help us– and can do so in time to be effective. We trust you will keep us current and, to the extent your rules permit, make the proceedings of the 1976 conference available to our Committees.

With best wishes for your success,

FRANK MOSS, Chairman
Senate Committee on Aeronautical
and Space Sciences

OLIN E, TEAGUE, Chairman
House Committee on
Science and Technology

Copies of both the companion bills are available; the text is the same. Also, we have copies of the statements by Mr. Moss and Mr. Symington with which the bills were introduced. It is important to read these statements to understand the purposes of the bills, I believe Mr. Daddario will also discuss them later today. Many of the issues to be treated by our task forces are pertinent to the bills. Also, we plan to discuss some of their features at the Panel Meeting on Friday morning. The conference results pertinent to these bills will receive appropriate attention by personnel of the legislation branch. Ms. Gail Pesyna of the staff of the House Committee on Science and Technology is here today.

The plan for the conference will follow roughly the same format as in 1974. Following the keynote and other introductory statements will be tutorial papers addressing the five tasks before the conference. This evening we will hear a technical paper from a foreign guest, Professor Pick from Birmingham, England. Tomorrow and Wednesday, the conference will be divided into task forces to work on the matters of concern to our sponsors. Thursday, the chairmen of the task forces will report, and then we will hear a lecture from a distinguished speaker from private industry in the United States. The Conference will conclude Friday morning with several papers on other materials issues, a general plenary discussion of national materials policy, and a consideration of proposed means to implement it.

The next speaker this morning will be Curry Ford, President of the Federation of Materials Societies. He will be followed by the keynote message to the conference. Let me mention the keynote address because it has several novel features about it. Several months ago, Frank Huddle and I met for lunch at the Cosmos Club with Dr. McKelvey and Dr. Falkie to discuss the keynote address for this conference, We wanted to stress the importance of the functional relationship between the US. Geological Survey, that helps to discover minerals in the ground, and the U.S. Bureau of Mines, that helps to dig them out and bring them to the market for industry to use, Accordingly we agreed upon the device of a joint keynote address, in which the directors of these two great institutions would share the spotlight.

WELCOMING REMARKS ON BEHALF OF THE FEDERATION OF MATERIALS SOCIETIES

by Curry E. Ford
President
Federation of Materials Societies

On behalf of the Board of Trustees of the Federation of Materials Societies, I welcome you to this fourth Henniker Conference on National Materials Policy, The federation is honored to again have the privilege of organizing and managing this conference for the Engineering Foundation.

The findings and recommendations of the conferences of 1970, 1972, and 1974 have had a very significant impact on materials policy legislation, This 1976 conference has the opportunity to generate new insight and thoughtful recommendations that can affect actions on the critical problems of chronic materials scarcity. I am confident we will exercise this opportunity,

Much of the success of the past three conferences was the result of the leadership, knowledge and dedication of the conference chairman, Dr. Franklin P. Huddle. You can appreciate our concern when Dr. Huddle became seriously ill this past spring, just as detailed planning for this conference was getting underway. We were most fortunate when Dr. John B. Wachtman, Jr., Past-President of the Federation, promptly agreed to assume Dr. Huddle's responsibilities. The Federation and alI of us here today are deeply indebted to Dr. Wachtman and his conference executive committee for their outstanding effort which has made this conference possible.

This is not the time and place to review the activities and plans of the Federation. We do feel, however, that your attendance at this conference confirms your interest in materials issues, and we are placing your names on the mailing list for the Federation's Quarterly newsletter, "Materials and Resources News." You may find this publication of help in informing you of Federation activities and other materials matters of interest.

We have a busy week ahead, We hope you will find it pleasant and rewarding.

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JOINT KEYNOTE ADDRESS–PART I

by V. E. McKelvey
Director, Geological Survey
U.S. Department of the Interior

In discussing our roles in this conference, Frank Huddle suggested to Dr. Falkie and me that it would be useful to tell you something about the activities of our respective organizations and the way they articulate with each other and with other organizations concerned with materials problems. This I am glad to do, but just to be sure I don't get into a level of descriptive detail that might be of little interest to you, I plan also to discuss findings as they relate to the conference theme, namely the Engineering Implications of Chronic Materials Scarcity.

The Geological Survey was established by an Act of Congress in 1879, and charged with responsibility for ". ., the classification of the public lands and examination of the geological structure, mineral resources and products of the national domain. . . ." Taken in their broadest sense, those terms still describe our responsibilities pretty well. In its larger part, the Survey is a research and fact-finding organization directed toward acquiring information and knowledge about the configuration and use of the land surface; the composition and structure of the rocks that underlie the United States; the distribution and character of our water, mineral, and mineral fuel resources; and geologic processes that relate to the discovery and use of our physical resources, including the land itself, The Survey is also responsible for the mineral classification of Federal land, the classification of water power sites, and the supervision of operations on Federal lands authorized by leases issued by the Bureau of Land Management. This regulatory activity has been growing in recent years, but even so it makes up not quite **zo** percent of our total activity.

Through its topographic and geologic mapping, its mineral and hydrologic assessments, and its studies of geologic processes, the Survey is the principal public source of information about the distribution, magnitude, and quality of the nation's physical resources; the mineral values ot federally owned lands; the physical characteristics of the natural environment; and the nature of geologic hazards that may affect us or may attend our use of the land in engineering developments, In celebrating the 50th anniversary of the Geological Survey in 1929, George Otis Smith, then Director, said, "The one-hundredth report of the Director of the United States Geological Survey may be expected to be simply a report of progress. " With our centennial less than three years off, I can fully confirm Smith's prediction, for the task of acquiring sufficient knowledge of the Earth and its resources to guide and underpin resource development and conservation is a never-ending one, The results in hand, in fact, are inadequate to allow us to cope with many of the problems we are now facing. For example, we don't yet have much capability for defining prospects for the occurrence of concealed ore bodies that have no surface manifestation or for estimating the extent of undiscovered resources. In spite of such deficiencies, we have acquired extensive knowledge of the subjects for which we have responsibility— enough, as I'll indicate shortly, to provide guidance and assistance on resource-related problems.

Agency Cooperation

A word now about how we articulate with other organizations. First, as a public service agency we consider that our first responsibility is to make the results of our work public. In 1975, for example, we issued about 2,900 reports and nearly 9,000 maps. We have come to recognize that it isn't enough simply to publish results— we must publish them in a form in which they can be understood and used by those who need the information, and in recent years we have been striving to improve the public utility of our reports and maps.

With respect to the mineral industry, we do not ourselves search for mineral deposits, except under emergency circumstances, but instead, attempt to develop information that will help us assess resources, and in addition help industry to identify targets for exploration.

This is a good point to mention our interface with the Bureau of Mines, which can be described in terms of the distinction between reserves and resources—a distinction which the Bureau and the Survey have helped to develop in recent years by agreement on a set of definitions that seem to be coming into wide use. We define reserves as identified deposits that can be extracted profitably with existing technology under current economic conditions. Resources in the broad sense include reserves but also encompass known deposits that are currently not profitable to produce, as well as undiscovered deposits that may or may not be economically producible if and when they are found. Whereas reserves represent the inventory on hand for production, resources include the potential that may come from additional exploration or technological advance or price increases.

In the general area of resource assessment, the Bureau of Mines is responsible for developing information on reserves; the Survey, for information on the remainder. Following that general distinction, we work jointly in the appraisal of the mineral resource potential of lands nominated for withdrawal in the wilderness systems. In other areas, our work diverges, with the Bureau focusing on studies related to mineral and materials production, along lines that Dr. Falkie will describe,

We have a somewhat similar relationship with the Energy Research and Development Administration, with which the Department of the Interior is currently in the process of developing a memorandum of agreement, and in other areas we have close working relationships also with several other Federal agencies, such as the Bureau of Land Management; the National Oceanic and Atmospheric Administration; the Soil Conservation Service; the Nuclear Regulatory Commission; and the National Aeronautics and Space Administration, A good indication of the extent to which the Survey's expertise is utilized by other public organizations may be seen in the fact that in fiscal year 1975, we were reimbursed for services performed on behalf of 103 Federal agencies, more than 550 State and local organizations, 16 foreign governments, and the United Nations, These agencies call on the Survey mainly because of its expertise in Earth sciences research and fact-finding, but a supporting reason for many of them to do so is that traditionally the Survey does not enter into policy issues, It can be counted on, therefore, for objective, impartial data and interpretations not influenced by a predetermined position favoring, for example, resource development, environmental protection, or land withdrawal.

Problems and Solutions of Chronic Materials Scarcity

Let me move now to some of the problems that relate to the theme of this conference—Engineering Implications of Chronic Materials Scarcity. As a geologist representing an organization concerned mainly with Earth sciences research and fact-finding, I don't have much to contribute to the engineering side of the problem; perhaps some comments on our mineral, fuel and water resource position would help provide a useful base for conference discussion of the broader problems.

To the best of m y knowledge, there is no mineral, fuel, or water scarcity now in the market place, except locally, either in the United States or the world at large. Two obvious questions, then, are: (1) could we have chronic resource scarcity, and (2) should we take defensive actions to prepare for, and if possible prevent, such an eventuality? It doesn't take a crystal ball to answer those questions, and I am sure it was the realization that the answers to both questions were in the affirmative that led those responsible for planning this conference to decide to explore some of the implications of resource scarcity.

The problem of potential resource scarcity results from the interaction between an exponentially increasing demand and the depletion of supply sources that were easy to find and cheap to produce, The result of this collision between our ever-rising demands and our dwindling supplies of low-cost resources had been a growth in our reliance upon other countries for minerals and fuels to make up the deficit in our own production. For a very long period of time, we were a net exporter of mineral fuels, including petroleum. Beginning in 1948, we became a net importer of oil –by choice, not necessity–and through 1970, oil imports never exceeded 25 percent of out total supply. In that year, however, our domestic production reached its peak and began a decline which has continued until now. Currently, imports average 43 percent of our supply and the outlook, even with the production from the Alaskan North Slope, is for our dependence on foreign oil to rise still further as demand continues to increase and production from the older fields continues to decline.

In general, our experience with non-fuel minerals parallels that of oil, although the growth of our dependence on foreign sources has been much less precipitate. We have always been dependent on other countries for certain minerals; but across the board, our net imports were rather modest–almost nominal–until after World War II. We now import, by value, about 15 percent of our total non-fuel mineral supply, but this general statistic obscures the fact that we are dependent on foreign sources for more than half our supply of 20 important minerals, a number of which are critical to some of our basic industries. So our dependence is not nearly so modest as the general-average figure might suggest.

I do not consider it at all likely that we shall ever be fully self-sufficient in all minerals. The random nature of their distribution and the fact that we occupy only seven percent of the Earth's land area, (while consuming 30 percent of its mineral production), is enough to convince me that we shall always be dependent on other countries for part of our mineral supply. The real problem is how to avoid becoming even more dependent than we now are as we continue to deplete our known domestic sources. Nothing suggests that this will be an easy matter.

The Geological Survey in 1973 published a review of the long-term U.S. position for potential resources of 65 mineral commodities. The sense of the document is that, aside from a relatively few cases, we shall face extensive shortages by the end of this century unless prompt and effective actions are taken to avoid them.

What are the actions? If we can visualize resources as natural substances useful or potentially useful to man, then a number of things that we can do become apparent.

Immense volumes of known discovered resources await the development of technology that will allow their profitable extraction. This is a remedy which we have pursued with much success for 50 years or more, and it still has much potential. Dr. Falkie will have more to say about this approach.

Another important way by which we can stretch our resources is to find new uses for materials not previously usable. At the turn of the 20th century, only about 30 of the chemical elements were in commercial use. Now there are about 80. Finding a use for many of these made it possible to do something that could not be done before, but some minerals have served as substitutes for scarcer and more costly materials in established uses. Aluminum, for example, which was only a laboratory curiosity a century ago, has displaced wood and other metals in hundreds of uses. The substitution of abundant materials for scarcer ones is an avenue to future mineral supply that is well worth pursuing, and it is encouraging to see the developments in ceramics and composite materials that go in this direction.

A serious constraint in both the improved technology and the substitution approaches is that they often involve an increased consumption of energy. Just the opposite is the case with a third approach, namely recycling used materials, especially metals. Recycling not only saves energy; it also reduces the amount of trash that must be disposed of at the taxpayer's expense and with some risk of environmental damage as well. The Bureau of Mines has been doing some outstanding work in the field of recycling, and I'm sure Dr. Falkie will tell you more about that.

Then, of course, there is the fundamental approach of discovering new deposits of minerals, which entails not only new tools and concepts for exploration, but also new places to look. It may be hard to imagine, but there are still areas of the United States that have not yet been adequately explored, even with existing tools and techniques. These areas, including most of Alaska and the Continental Shelves, certainly merit closer inspection.

But the great challenge to minerals exploration remains the hidden deposit. Most of the mines operating in the world today were located on evidence visible at the surface. Until this century, mining was in many ways a cottage industry, Anyone with determination and a strong back could go into the mining business, and thousands did, to the point where most of the deposits that could be found by the human eye have already been discovered over large areas of the Earth. Now, the need is for the sophisticated instruments, expanded knowledge of the geology of the subsurface, and exhaustive detective work that will lead to the discovery of deposits that cannot be seen. The petroleum industry has been highly successful in its ability to locate structural traps at great depth, but the mining industry to date has been nowhere nearly as successful in discerning environments where ore bodies may be found.

Nevertheless, progress is being made, While I mentioned earlier that the Geological Survey concerned itself mainly with delineating targets for private exploration, our scientists have done some important work in advancing geologic knowledge of the origin and environment of deposition of mineral deposits, and knowledge of the regional and local geologic relationships to which sound principles and effective methods can be applied in the search for concealed deposits.

Research on the geology of mineral occurrence is of particular importance in the search for blind deposits, for if we can ascertain how mineral deposits are formed, we have at least some clue as to where to look for them. Every piece of knowledge is important. For example, most minerals are more soluble at high temperatures than at low temperatures. Recent research, however, has shown that molybdenite (the most important source of molybdenum) and chalcopyrite (an important copper mineral) may show an opposite behavior under certain conditions. If this is the case, then we may expect copper and molybdenum deposits to form earlier and deeper than ores of other metals such as lead and silver, so that the occurrence of these latter minerals at the surface may indicate deep underlying deposits of copper and molybdenum. Information like this is useful in constructing models of ore deposits and greatly expedites assessment of regions for new deposits by limiting the search to a few well-defined geologic targets. Many such hypotheses turn out to be invalid on further investigation, but some do not, and furnish the basis for further progress in the difficult art and science of mineral exploration. It was such a novel concept (about gold mineralization) that led to the discovery of the disseminated gold deposits at Carlin, Nevada, in 1965–the most important gold discovery in the United States in 50 years.

New and more sophisticated techniques have helped greatly in both geochemical and geophysical investigations. One such geochemical approach involves the chemical separation and analysis of manganese and iron-rich fractions of stream sediments and soils, The manganese and iron oxides are very sensitive scavengers, and concentrate metals such as copper, zinc, and silver, allowing the detection of subtle geochemical anomalies that may indicate hidden ore bodies nearby. This method has been successfully applied to outline metal anomalies in regions of thick rock cover in New Mexico. Here, minute amounts of metallic oxides have migrated through hundreds of feet of barren volcanic rock. Such trace indicators of mineral deposits cannot be detected by the usual geochemical surveys.

Geochemical halos in the soil may give surface evidence of deeply buried deposits. Volatile elements and compounds such as helium, sulfur gases, carbon dioxide, mercury, and light hydrocarbons frequently appear in the air trapped between particles of soil at or just below the surface, and they can be detected and measured by new techniques. Soil moisture conditions may complicate the analysis of soil gas, but the anomalous concentrations of these minute traces of elements and compounds can point to deposits which may lie deep beneath the surface.

In geophysics, considerable research is being concentrated on borehole techniques using electrical and seismic measuring devices. The borehole measurements, which are made from one hole to a second hole or to the ground surface, are expected to extend the range of subsurface probing to as much as 300 meters from the test hole. Obviously, this is a vast improvement over previous well-logging techniques, which had **a** range of only a few meters from the borehole, and would permit a great reduction in the amount of drilling needed to discover and delineate ore bodies. Another borehole measurement technique of great interest is our neutron activation probe, which can detect the presence of copper, nickel, and numerous other metallic elements in the rock section penetrated by the test hole.

Images of the Earth’s surface, recorded by satellite and aircraft, are being processed by recently developed techniques to provide new information on potentially mineralized areas and geologic structures in Nevada, Wyoming, Mexico, and Brazil. Landsat (formerly ERTS) imagery, which is computer-enhanced, has been used successfully to detect and map hydrothermally altered areas that are related to ore districts in south-central Nevada. Thermal infrared images of the Colorado Front Range, near Denver, have revealed anomalous textural patterns that correspond to known mining districts.

These achievements represent gradual improvements over our past capabilities. There are no miracles, no magic, and no breakthroughs in prospect. But we do keep getting better at the job of finding mineral concentrations that were too elusive to be discovered in earlier times, and that is important,

Finally, there is the need for conservation in use. I mentioned earlier that we could not view shortages as merely a problem of supply. Without a sane and sensible policy toward consumption, it is impossible to balance the supply-demand equation, no matter how much emphasis is given to supply, Consider, for a moment, the impact of a steady increase in consumption at the relatively modest rate of 3 percent (anything that increases at only 3 percent a year is modest these days), At that rate of increase, a billion years' stock of anything, computed at this year's consumption rates, would be exhausted in 582 years. Two billion years' supply would be consumed within 23 years after that,

There's a bit of hyperbole in this example, of course, but it is sufficient to show that we cannot go on indefinitely increasing our consumption. Some economic growth is desirable in our society, and some growth in consumption is probably inevitable until we can stabilize our population. But much of what passed for "growth" in the last few decades in this country might more properly be labeled "waste" — waste in the sense that energy and minerals have been used for what are in essence frivolous, nonproductive purposes, Who needs a 5,000 pound car that can go 120 miles an hour, for example? In our development of highway transportation and all that goes with it, how much represents the socially efficient use of energy and minerals, and how much has been unnecessary use for purposes that could have been accomplished just as well in less consumptive ways? Recent reflection on this and many other examples of the frivolous use of energy and raw materials in our society has led me to conclude that we have been wasting our resource capital on a massive scale,

In conclusion, with our current dependence on imports for many commodities, we face the potential for at least intermittent shortages well in advance of true world scarcity. If recent rates of growth in consumption continue to outstrip our development of new sources of supply, we can be certain that true resource scarcities wiIl develop in a few decades for some minerals. We can readily identify ways to add to and extend our supplies — through exploration; through gains in extractive, processing, and materials technology; through the wider practice of recycIing; and through conservation in use. As some of you here know, I am optimistic that if we devote searching, imaginative, and driving effort to the task, we can succeed in satisfying our resource needs far into the future. Accelerated research is an important part of the effort required, but research alone cannot long stand up to the buzz saw of exponential growth in consumption. Conservation in use by choice must become a national effort if the time when it becomes a necessity is to be put off for long.

JOINT KEYNOTE ADDRESS–PART II

by Thomas V. Falkie, Director
Bureau of Mines, U.S. Department of the Interior

Good morning ladies and gentlemen. Thank you for inviting me here to share with Dr. McKelvey the honor of keynoting this important Conference,

Vince has given you a very complete picture of what the U.S. Geological Survey is doing to assist in the discovery of our mineral resources and to define our resource base. Since the programs of the Survey and the Bureau of Mines mesh to form a competence encompassing the entire mineral resource field, I will take it from there and discuss the role of the Bureau in helping, through its factfinding and its research and development programs, to convert our mineral resources into mineral reserves, Clearly, these programs, among others, have contributed greatly to minerals and materials technology, and information will continue to be part of our country's mineral posture.

First, let's remind ourselves briefly just how important the wise development and use of our mineral resources are to our domestic economy. In 1975, the output of such extractive operations as mining, quarrying, and oil production was valued at about $62 billion, excIuding exports, If you take that output through the mineral processing industries—smelting, refining, energy generation —the resulting production is valued at over $270 billion, which is a sizable portion of our $1.5 trillion Gross National Product.

Underlying the issues that will be addressed by this Conference is one of our Nation's biggest current materials problems: the dollar value of our imports has been exceeding that of our exports at a growing rate, except during the recession year of 1975. A substantial part of the reason, of course, is related to petroleum imports, which are costly and are also, unfortunately, still increasing. The possibility that the same pattern could well develop with other mineral materials is your primary concern at this meeting. At the same time, the impediments to increasing domestic production are growing.

As Vince noted earlier, the United States depends heavily on imports for such essential commodities as manganese, chromium, bauxite, platinum, and many other important minerals and metals.

To reduce this dependency– in fact, just to keep it from growing — it will be necessary to make real engineering innovations, to take major steps forward in the technology of exploration, mining methods and ore transport, processing of low-grade resources, materials development, substitution and use, and scrap recovery, Only through genuine progress in each of these critical areas can we hope to assure an adequate supply of mineral raw materials in the future.

Bureau of Mines and Chronic Materials Scarcity

Commodity situations are constantly changing, and if we are to plan realistically for the future we must do it on the basis of up-to-date information. Recognizing that both industry and Government need timely statistical and economic information on mineral developments at home and abroad, the Bureau of Mines decades ago began building a system to provide it. The system has been modified many times over the years, and we are still improving it, It has made the Bureau of Mines the primary authoritative source within the Federal Government of the latest available data on mineral developments throughout the world, and is the basis for publications ranging from periodic statistical surveys of roughly a hundred individual mineral commodities, to such well known general references as “Mineral Facts and Problems,” which will soon appear in a bicentennial edition. This information system, coupled with our wide-ranging technological expertise, has also made the Bureau a respected and much-consulted source of facts, advice, and opinion on mineral legislation and mineral policy for all branches and all levels of Government.

I think you can see how this factfinding and informational program of the Bureau relates to the theme of this year’s Henniker Conference. We can best deal with material scarcities by being well-enough informed to anticipate them and, once forewarned, knowledgeable enough to avoid them,

I don’t claim that the Bureau of Mines, or any other part of Government for that matter, has yet achieved the kind of capability required to foresee and avoid every problem or shortage that might one day confront us. But despite budgetary and manpower constraints, we are working hard to strengthen the Bureau’s capability in that direction, and we are making progress. On the domestic front we maintain a continual surveillance for situations—such as strikes in basic mineral producing industries or in parts of the infrastructure that supports them—that could cause disruptions of mineral supply, When they occur, we monitor them carefully to assure that appropriate government actions can be taken in time to avert serious shortages.

Right now, we are far better equipped than we were a few years ago to deal with materials crises as they arise, Interagency commodity committees, 95 of them in all, have been formed to provide a quick mechanism for obtaining the latest coordinated information available within Government on any commodity to help in developing recommendations for dealing with actual or foreseeable supply problems, Every concerned department and independent agency of the Government is represented on each committee. In the minerals field, Bureau of Mines commodity experts serve as the executive secretaries of the interagency committees dealing with their respective commodity areas, In this way, the government has achieved a capability for quickly gathering and coordinating all the significant input available on any particular problem,

As we all know, world demand for minerals is increasing. With it, competition among nations for the limited supplies that are available is rapidly intensifying, We have witnessed the formation of cartels, first in oil and then, with the success of the OPEC actions as an example, in such vitaIly important raw materials as copper, bauxite, and iron ore. While it seems unlikely that cartel actions affecting those materials could have the forceful impact of an oil embargo, they could nevertheless cause short-term disruptions in material price or supply and those disruptions, in turn, could have repercussions in various sectors of our economy, In such a situation the ability to be able to turn quickly to a domestic source of supply, to have on-the-shelf technology, so to speak, would be distinctly advantageous. Both the Geological Survey and the Bureau of Mines are working–usually together–to make that possible.

In the Bureau we are developing two fully automated data banks. Into one–our Minerals Availability System (MAS)–we are putting every scrap of information we can get on domestic mineral deposits. Data on location, ownership, history, production, reserves, grade of ore, mining, economics . . . everything we can learn about a potential domestic source is being computerized so it will be at the Government's fingertips in any future emergency. We're doing the same thing for deposits of coal, petroleum, natural gas, and other energy sources with our Fuels Availability System (FAS). MAS and FAS represent relatively new Bureau initiatives, and some of the information we are seeking isn't the kind that property owners are anxious to divulge, Nevertheless, our data banks are growing qualitatively and quantitatively, and we are convinced that they will serve the Nation well in years to come. One key to these information systems is the ability to apply experienced technical expertise to the data collection and interpretation process.

Most of the information collected in the programs I've been describing is widely disseminated throughout Government and to the private sector where it is a reliable basis for policymaking and planning decisions, In addition, it enables the Bureau to comment knowledgeably and helpfully on proposed legislation and environmental impact studies and to serve effectively in a consultant capacity to numerous other agencies.

As I've already intimated, the information also guides us in planning our mission-oriented research and development in mining and metallurgy. Mining research is one of the principal avenues through which our objective of avoiding shortages is pursued. I think all of us will agree that, given plentiful supplies of low-cost energy, we need fear no shortages. With abundant cheap energy we could produce just about anything we might need out of common sand, Energy, as we learned the hard way in the fall of 1973, is the key to everything else. To the extent that the United States can again become self sufficient in energy, it will be insured against the political decisions of foreign governments insofar as they relate to material supplies.

That, in brief, is what most of the Bureau's mining research is about, In the fiscal year that just ended, roughly two-thirds of the Bureau's total budget of $158.8 million was earmarked for mining research and most of that (some $92.7 million) was for research in coal mining and preparation (table 1). Our goal, as you no

TABLE I.–Fiscal Year 1977 Budget Request (thousands)

	FY 1976	FY 1977	Increase (+) or Decrease (-)
Metallurgy Research	$ 27.022	$ 25.802	-$1.220
Mining Research	102.873	107.504	+4.631
Data Collection and Analysis	14.465	14.705	+240
Engineering. Evaluation. and Demonstration	13.056	15.247	+2.191
Program Administration	1.402	1.486	+84
Total. Mines and Minerals	$158.818	$164.465	+$5.647

doubt know, is to help advance the technology of coal so that abundant fuel can supply a greater share of the Nation's energy requirements and thereby reduce our dependence on foreign sources. To achieve that goal, we must resolve some of the problems associated with the mining and use of coal. We must find ways to minimize the health and safety hazards of mining, and ways to make both coal mining and coal use more compatible with our demands for a quality environment. At the same time we must provide the kind of technology that can improve a dangerously declining productivity in coal mining and increase the percentage of the resource that is typically recovered.

The Bureau's mining research program has been planned to attack all of these problems simultaneously, because, as you know, it is not practical to attack them separately (table 2), Although an important part of the total program is conducted in our

TABLE 2, –Fiscal Year 1977 Budget Request
Mining Research and Engineering Programs
(millions)

Program	FY 1976	FY 1977
HEALTH & SAFETY RESEARCH		
Coal Health & Safety Research	$ 29.4	$30.0
Metal & Nonmetal Health & Safety Research	5.7	5.7
ADVANCING MINING TECHNOLOGY		
Coal Mining	$ 56.2	59.6
Oil Shale Mining	5.6	5.6
Metal & Nonmetal Mining & Explosives	6.0	6.0
ENVIRONMENTAL CONTROL DEMONSTRATIONS		
Mined Land Investigations & Demonstrations-Anthracite Area	5.8	5.8
Anthracite Conversion Demonstrations Plant	–	3.0
Rock Springs Subsidence Control	1.5	–
Mined Land Investigations & Demonstrations-Bituminous Area (Illinois)	–	1.0
Fire Control in Coal Deposits	0.2	0.2
PAY AND SPACE INCREASES	–	0.6
Total	$110.4	$117.5

own facilities, it is predominantly a contract effort, with industry increasingly participating now through cost-sharing and other types of cooperative arrangements. Such cooperation not only strengthens the effort, but also speeds transfer of the developed technology into industrial practice.

The program is yielding important dividends. Some of the most promising developments so far in terms of increased safety and health protection for miners have come from our work in methane drainage, which was begun several years ago as a means of giving miners added protection against the explosive gas by degasifying coal seams in advance of mining. Degasification already has been accomplished profitably in West Virginia, where methane drained from a coal seam has been commercially pipelined to thousands of homes in the State, Other products of

Bureau research are now in the mines helping to assure greater safety for those who operate coal mining equipment, aiding in the control of mine roof, and improving efficiency and accuracy in the monitoring of noise and dust,

To combat the sharp downtrend in coal mining productivity that began in 1969, we are emphasizing research to speed up the development phase of mining (giving the industry faster access to coal reserves), along with adaptation of highly automated longwall and shortwall systems which, where they can be applied, offer higher productivity and greater recovery of the resource.

On the environmental side, the Bureau has pioneered for years in the development of improved methods for reclaiming surface-mined land; for controlling subsidence and acid mine water; and for minimizing the environmental hazards associated with mine refuse banks. That work continues today, but with greater emphasis than ever before on the design of mining methods and systems that can prevent the environmental disturbances so long associated with coal mining. On the surface, we are looking at innovations like the cross-pit conveyor, which makes it easier for reclamation to proceed at the same pace as mining. Underground, we are developing a new generation of continuous miners that provide their own roof support, along with other features that can help to make the underground mining process truly continuous and, at the same time, environmentally compatible.

All of this effort is aimed at providing the essential key to material abundance: low-cost energy. We are convinced that if the United States is to have that key in the foreseeable future, we will have to get it from coal.

But, while coal represents the largest share of the Bureau's mining research program, it is not the entire program by any means. If I limited my discussion to potential sources of energy supply, I would still have to mention that we are conducting important research on the mining of oil shale and tar sands. We're interested in mining oil sands as well, that is, mining energy-depleted, near-surface reservoirs to recover the 60 percent of the oil, on-the-average, that primary production methods do not get. We are also investigating the possibility of borehole mining as an economic means of tapping small, localized uranium deposits.

The Bureau is making progress, too, in research related to minerals other than fuels, This is loosely called "hard rock" research, and some of it is indeed like our work on developing a continuous drill-blast process for hard rock mining. One approach involves a tunneling machine that detonates frequent small blasts in the face as it drills holes in a spiral pattern, loading the broken rock as it goes. Another uses small charges of high explosives in shallow holes—about 18 inches deep. Other areas of research include studies of airblast and ground vibration from surface operations to develop ways of minimizing the disturbance to neighbors, and development of an emergency hoist communication system, for deep shaft mines, that uses the hoist cable to carry voice messages.

Regardless of how successful our mining research may be, it will surely be a long time before the United States is once again blessed with an abundance of low-cost energy. In fact, if we limit our goals to what seems feasible right now, we will do well within the next decade simply to stop increasing our dependence on foreign energy sources. If we don't want to find ourselves one day in the same position with regard to other essential commodities, we must find ways now to increase our reliance on our own resources (table 3).

TABLE 3.–Fiscal Year 1977 Budget Request
Metallurgy Research Programs
(millions)

Program	FY 1976	FY 1977
Advancing Minerals Technology	$13,9	$12.6
Effecting Pollution Abatement	7.5	3.7
Secondary Resource Recovery	2.1	2.4
Mlnimizing Mineral and Metal Needs	3.5	3.8
College Park Laboratory Replacement	–	2.8
Pay and Space Increases	–	0.4
Total	$27.0	$25.8

That is a major aim of the Bureau's metallurgy research. The abundant nonmagnetic taconites of Minnesota, plentiful domestic deposits of anorthosite and clay, and significant resources of low-grade laterite and gabbro material , , , all of these and others are targets of Bureau metallurgy research. We have had one recent dramatic success with the nonmagnetic taconites, as is evidenced by the existence of a major new commercial mine and processing plant at Tilden, Michigan. The success of the process used at the Tilden plant results from research conducted by the Bureau. Now, we are experimentally applying the same technology, along with alternative approaches, to convert more of the vast nonmagnetic taconite resource into an economic iron ore reserve,

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Although bauxite cannot be said to be in short supply throughout the world, we have little of it here in the United States, and we are increasingly forced to compete with other industrialized countries in seeking reliable sources of bauxite at acceptable prices. Recent trends toward nationalization by bauxite-producing nations point up the need for a technology that will permit us to use our own ample resources of anorthosite, clay, and other alumina-bearing materials as a raw materials base for aluminum production. In cooperation with major aluminum producers, the Bureau of Mines is doing just that. As you probably know, there are several processes that will extract alumina from the kinds of material I've mentioned. The difficulty is that no single one stands out clearly as the best bet for doing it on a commercial scale. So, with financial support from the industry, the Bureau is testing each process on a miniplant scale, about 25 pounds of alumina production per hour. Such a procedure will allow us to judge which particular procedures, or combinations of procedures, offer the most promise for scale up.

An important source of encouragement in this enterprise has been our past success in extracting gold from carbonaceous ores once thought impossible to treat by conventional cyanidation, Nevada's Carlin gold mine exists today as testimony to the ingenuity of Bureau metallurgists in overcoming such obstacles.

Nickel, cobalt, and chromium are all essential metals for which the United States depends heavily on foreign sources of supply. But, both nickel and cobalt occur along with copper in the Duluth, Minn., gabbro deposits, and both chromium and nickel are found in the low-grade laterites in Oregon and California. Bureau researchers are seeking ways of treating these materials, which today can at best be termed a submarginal resource, and in the process improving our self-sufficiency in metals that we cannot do without.

As Vince noted earlier, we still waste a high percentage of our minerals in this country and, again as he indicated, the Bureau of Mines is working to reduce that percentage, Right now, better than half of the antimony scrap generated in the United States is recycled, but it is the only one of ten major metals for which anything like that kind of a record can be claimed. We recycle 25 percent of our iron and copper scrap, roughly 20 percent of our nickel and tin, and from 5 percent to 10 percent of our aluminum, zinc, and chromium. Thirty percent of our scrap lead is recycled, but less than 5 percent of magnesium scrap is reclaimed.

The Bureau has pioneered in application of metallurgical technology to reclaim valuable metals and minerals from urban refuse, and the procedures it has devised are now being adopted by several communities in various parts of the country. Now, we are going after metal values being lost every day in such industrial wastes as flue dust, mill scale grinding swarf, and the solutions used for electroplating, etching, and pickling, Automobile recycling is a good example of a technology area that was given great impetus by Government (Bureau of Mines) R&D. We pioneered technology that makes possible the smokeless incineration of the nonmetallic components of old auto hulks, and our studies have also pointed the way to more efficient procedures for stripping junk cars before the bodies are shredded. We also developed air classification as an effective means of recovering the nonferrous fraction of shredded auto bodies.

Substitution is still another way in which Bureau research is seeking to provide the kind of technology that can help forestall material shortages, by substituting relatively abundant materials for scarce ones, For example, substitution of molybdenum for imported chromium in certain alloys, substitution of rare earths for platinum in catalysts, and substitution of ceramics for metals.

We also can extend our limited supplies of materials with processes like ion implantation, making what are, in effect, new materials. We can give a plentiful material the properties it needs to supplant a scarce one, and give the scarce one qualities that enable it to stand up longer in use. Ion implantation may give us the answer to the problems of scale and corrosion that shorten the life of metals used in casing geothermal wells, If so, it can make our access to geothermal energy significantly less costly.

I've tried to give you a broad picture of the Bureau's activities, particularly as they relate to the problem of material shortages. While the examples I've chosen are typical, they are by no means all-inclusive. The time available did not permit any such review. We are making increased effort to tie economics to R&D and to use this to plan and evaluate our R&D programs (table 4).

Solutions to Chronic Materials Scarcity

Because the Bureau is the kind of Federal agency it is, the questions to be pondered by Task Forces at this Conference are of natural concern to us. While we don't pretend to have all the answers, we do have some thoughts that bear on some of your questions, and before stepping down, I'd like to share a few of them with you.

The question of how conservation should be defined, for example, is one that has interested the Bureau throughout its history. Our first director, Joseph A. Holmes, defined conservation as "the wise and efficient use of natural resources," and for most of the years of the Bureau's existence, that definition has seemed adequate enough. In any case, one definition postulated

TABLE 4.–Fiscal Year 1977 Budget Request
Mineral and Materials Supply/Demand Analysis Programs
(millions)

Program	FY 1976	FY 1977
Data Collection and Verification	$5.1	$ 4.9
Evaluation and Analysis	3.8	3.8
Information Dissemination	3.3	3.3
State Liaison	2.3	2.3
Wilderness and Engineering Investigations	5.5	5.0
Pay and Space Increases	—	0.6
Total	$20.0	$19.9

for **a** Task Force seems to me somewhat narrow, even though I realize that the Task Force's immediate concern is the conservation of energy in materials processing.

The definition proposed, "continual progress in reducing the energy consumed per unit of output (or GNP)," states a laudable-enough goal. But, I believe that the output itself, the mix of products, must also be taken into consideration. I think Americans are beginning to realize that the phrases "standard of living" and "quality of life" are not synonymous, The word "wise" in Dr. Holmes' definition of conservation becomes more and more meaningful for me as I consider the difficulties of the choices that we, and future generations, will have to make. Do we want to pursue a lifestyle that is essentially wasteful, or are we willing to husband our resources so that all of us, and our progeny, can be assured the necessities of life? Do we want a sound economy, or will we choose to remain at the mercy of foreign powers with objectives quite distinct from our own? If I seem to be echoing my fellow keynoter, I guess I am. Like him, I'm convinced that the choices we make today will determine whether we have any choice at all tomorrow.

With regard to the recommendations being made on materials information systems, we have—as might be expected—some definite views. We concur heartily in the stated need for monitoring the Nation's vulnerability and dependence on foreign sources, for materials, and for conducting research, that can be expected to reduce such vulnerability and dependence. But we cannot concede that additional Federal authorities are needed to accomplish those functions. (Incidentally, in Washington, there is often confusion about the difference between data and interpretation on the one hand, and either commodity supply/demand information or information on technology on the other hand.) In fact, the programs and activities that Vince McKelvey and I have described to you embrace those functions and more. The Survey's Computerized Resource Information Bank, coupled with the Bureau's Minerals and Fuels Availability Systems and its worldwide reporting of mineral information, provides a highly effective monitoring capability, and that capability guides the R&D efforts of both agencies.

Mineral and material policy is shaped by many different forces, including markets, international relations and trade, strategic and military considerations, tax laws, state of the economy, financial and monetary situations, government regulations, public land policies, labor/management attitudes, social attitudes, congressional committee structures, checks and balances among Government agencies, and politics. It's relatively easy to create "laundry lists" of necessary or desirable mineral policy needs, For the most part, the Government already has adequate authority in the mineral technology information and policy area. We cannot ignore the growing Government and other impediments to our own domestic supply situation. However, it seems unlikely that we will have a comprehensive mineral policy in the near future, just as it seems unlikely that we will have a comprehensive policy in any area, unless we have a controlled economy, which I don't advocate.

There are, however, several contemporary principles upon which mineral policy should be based:

1. We should not become over-dependent on foreign sources for our mineral supplies; over-dependence can lead to economic and political problems. However, international trade in minerals is important to us and to the world.
2. We should depend on the private sector to find, produce, and supply our minerals. We must maintain a favorable economic climate in order to allow for reasonable recovery of risk capital.
3. Mineral deposits must be available to be mined, especially those on the public lands, which are generally the most geologically favorable for mineral occurrences. The concept of multiple use has served this country well, and should be maintained.
4. Mineral authorities within the Federal Government should not be overly fragmented to the proverbial 67 different agencies.
5. Governmental laws and regulations must be based on scientific and engineering fact; they must not be punitive;

and they must allow for physical, geological, and geographical differences.

6. International mineral policy must be made with a complete understanding of our free-enterprise economy, By the same token, we must recognize the growing needs of the developing countries. Economic stockpiles and commodity agreements could lead to more Government control of domestic prices and production; however, we should be willing to discuss commodity arrangements on an individual basis. We should maintain our basic free trade position.
7. The Federal Government (Bureau of Mines) has a limited, but important, role in advancing the technology for:
   - finding, mining, and processing ores from lower grade deposits;
   - substituting more plentiful minerals for those which are scarce;
   - conserving consumption of mineral materials, i.e., using less, increasing recovery, and extending useful life;
   - decreasing the environmental effects and the health/safety risks in mining and processing of minerals; and
   - recovering valuable mineral materials from municipal, industrial, and other wastes.
8. Strategic minerals for defense purposes deserve special consideration. The concept of a strategic stockpile, if properly designed and controlled, is a good one.
9. The basic laws governing mining and leasing of public land minerals are fundamentally sound. Perhaps it would be desirable to improve the diligence requirements and environmental safeguards, but the location-patent system for locatable minerals is a good principle and should be retained.
10. The oceans represent a major potential source of some of our critical minerals. Ocean mining policy must carefully weigh the interests of our domestic mineral economy and our domestic mineral needs.
11. In order to maintain our mineral position, we need the assurance of a secure and stable energy supply. (Thus, industry is part of the problem and part of the solution—a good example of the complexity of these problems.)
12. Mineral information systems must be adequate for public and private planning and policy purposes. However, it is not necessary to collect everything, and in many cases, voluntary systems work better than mandatory ones.

The final thought I would like to leave with you is this. There seems a pervasive belief today that the one best answer to every problem is more Government action. Even the agendas for your task forces and the dominance of Government representation here today reflect what seem to me a little too much readiness to "turn the whole thing over to Government." Some persons are apparently unable, or unwilling, to remember that we have a dynamic private sector with intelligence, energy, and talent, and that it has a capability for dealing effectively with a wide range of problems.

Government action is necessary, of course, where the overriding factors are other than economic, as in the case of national defense. But, wherever possible, Government should use the forces of the marketplace to achieve its goal. In fact, there seem to be developing trends to indicate that increased Government interference with the marketplace has contributed more to the problem of mineral and material shortages than to its solution. as in the 1973-74 shortage situation so prominently discussed at these meetings,

Moreover, those Government actions that must be taken should be continually evaluated on a cost-effectiveness basis. When circumstances change, or if the actions do not achieve their intended effect, they should then be rescinded or modified to accomplish the legitimate policy aim. Otherwise, we will continue to see what already is increasingly evident: too much Government, in too many places.

I've been asked to say a few words about the Committee on Materials (COMAT), of the Federal Council for Science and Technology (FCST), and its significance to this Conference. COMAT was established in February 1975, by H. Guyford Stever, FCST Director, as an interagency materials R&D coordinating committee, Jack Carlson, Assistant Secretary, Department of the Interior, was its first Chairman, succeeded in February 1976, by William L, Fisher, its new Assistant Secretary. Three task forces were formed with the following charges:

- To inventory and analyze materials R&D funded by the Federal Government and industry;
- To determine materials requirements and Government-sponsored materials R&D for a national energy program: and
- To develop a governmental perspective between materials production. environment, and health.

As Chairman of the Inventory Task Force, I am pleased to distribute advance draft copies of the first report on materials R&D funding in the Federal Government. As noted by its title "Materials Life Cycle R& D," COMAT'S definition of materials is very broad, including everything other than food and drugs, from exploration to extraction, processing, manufacturing, application, and recovery or disposal. Approximately $1 billion of FY 76 funding by 18 Federal agencies is identified in its computerized inventory. It can easily be searched to analyze the adequacy of programs in relation to national goals, specific missions. functions or stages in the materials life cycle, and materials categories, The excellent help provided by Battelle Columbus Laboratories in this pioneering effort is gratefully acknowledged.

Time does not permit my presenting the inventory data in greater detail. However, the COMAT report, which you now have, can be effectively utilized in identifying the breadth and depth of the Government's current materials R&D program, and relating that information to the issues before this Conference, This factual data base, on the Government's materials R&D spending as identified by specific areas, provides us with the means of analyzing and authoritatively recommending courses of action. The Phase 11 part of this inventory on industry's materials R&D, when completed, will provide us with the total national activity. We recommend that the COMAT inventory be used as widely as possible for effective and productive planning purposes.

CONGRESS AND THE ENGINEERING FOUNDATION CONFERENCES

by Emilio Q. Daddario, Director
Office of Technology Assessment
US. Congress

Ladies and gentlemen, it is an honor and a pleasure to be with you today at this fourth Henniker Conference on National Materials Policy, The title of this Conference, “Engineering Implications of Chronic Materials Scarcity,” highlights our concern for the best use of the world’s materials supplies and the developing need for a US. national materials policy.

The need for an early warning mechanism, not only for materials but for other problems as well, was realized by Congress and a large part of the public some time ago. Technology could no longer be applied without an understanding of its ramifications—both good and bad. This realization was the motivating force behind the creation of the Office of Technology Assessment.

This same need for an early warning mechanism to develop and focus a national materials policy has helped to shape the work of past I-Ienniker conferences, and hopefully will continue to be the backbone of future Henniker conferences. It is quite fair to say, due to the scope of these conferences and the development of a dialog among experts in the materials field, that the result of previous Henniker conferences has been a wider participation and a better understanding between the public and private sectors.

As you know, some of OTA’s initial assessments are concerned with the problem of materials supply and the availability of natural resources. One of these, a program in the area of material resources, will be discussed shortly by the OTA Program Manager for Materials, Dr. Albert Paladino. Other OTA assessments are in the important areas of world food supplies, ocean technologies, and the overall energy situation. The selection of these assessment topics by OTA’s governing congressional body, the Technology Assessment Board, is responsive to the priorities set by Congress in expressing its need for legislative assistance.

Congressional Use of Henniker Conference Findings

During the 94th Congress, approximately 150 bills have been introduced dealing with materials subjects. These bills range from specific topics of materials durability, solid waste disposal, and the authorization to dispose of materials from the national stockpile to the broader, more sweeping subjects of the need for a national materials policy or the establishment of a "Commission on Materials Research and Operations. " Before looking at one of these bills in detail, I'd like to touch on the role Henniker has played and the response Congress has shown to the findings and results of past Henniker sessions.

The first Henniker Conference on National Materials Policy, held in 1970, discussed the topic of "Materials Problems and Issues," The proceedings of this conference were published by the Senate Committee on Public Works. This Committee was instrumental in drafting the bill that created the National Commission on Materials Policy, which was signed into law approximately two months after the first Henniker Conference.

The second Henniker Conference on National Materials Policy, held in 1972, was entitled "Resolving Some Selected Issues," Participants of this conference included the Chairman and Executive Director of the National Commission on Materials Policy, the Director of the National Bureau of Standards, and members of the Interagency Council for Materials. The findings and concerns of this conference were put to use by the 93rd Congress. They were read into the Congressional Record and later cited on the Senate floor during the debate of S. **3279,** a bill to establish a National Commission on Supplies and Shortages, as justification for such a commission. This bill would establish a temporary commission to keep tabs on materials, serve as an early warning system in case of threatened dislocations, propose solutions, and design a permanent institution for congressional and executive consideration.

The concept of such a commission was first introduced in **1952** by the Paley Commission, the U.S. President's Materials Policy Commission, and was again advocated by the National Commission on Materials Policy in 1973, a year after the second Henniker Conference. This bill was passed by Congress and became Public Law **93-426** on September 30, 1974. Since that time, the National Commission on Supplies and Shortages has been active in research looking to the development of public policy.

The third Henniker Conference, in August 1974, examined various options for implementing a national materials policy. It emphasized the need for reliable and accessible information on all aspects of materials management; called attention to the interdependence of nations with regard to the production and exchange of materials; and explored opportunities for materials conservation, recycling, and the improved use of institutions for materials management, Many of the topics for discussion and analysis–for example, "Stockpiling for the Future: A Commentary on Ways that a National Stockpile Could Be Socially

Beneficial,” and “Materials Information, An Examination of The Adequacy of Existing Systems”- received congressional attention, As a result of this concern, Congress asked the Office of Technology Assessment to assess the impacts of stockpiling for economic purposes and to analyze the adequacy of present materials information systems for the technology of materials supply, processing, and uses, Thus, both the stockpiling assessment and the assessment of materials information systems, which have recently been completed by OTA, had their genesis in the third Henniker Conference.

National Materials Policy Legislation

But technology assessments are just one way that Congress is responding to materials-related issues. The many bills dealing with materials subjects introduced in the 94th Congress illustrate the type and scope of problems facing Congress in the materials arena, and reveal how Congress has chosen to respond to these problems.

On June 17, 1976, Congressman James Symington, Chairman of the House Subcommittee on Science, Research, and Development, together with Congressman Charles Mosher, ranking minority member of the subcommittee, introduced H.R. 14439, the “National Materials Policy, Research, and Organizational Act of 1976. ” This bill, if passed, would 1) establish a national materials policy for the United States, 2) create a materials research and development capability, 3) improve the flow of new scientific and technological information arising from materials research, and 4) provide an organizational structure for the effective application of such research capability, These four components of the bill are awesome and require careful planning and analysis if they are to be implemented and coordinated into the present working materials cycle.

H.R. 14439 proposes to establish in the Executive Office of the President a “National Materials Policy Board” chaired by a Special Assistant to the President for Materials Policy. Members of the Board would include the Director of the Office of Science and Technology Policy, the Chairman of the Council of Economic Advisers, the Executive Director of the Domestic Council, the Chairman of the Undersecretaries’ Committee of the National Security Council, and not more than eight public members appointed by the President. This Board would advise the President with respect to alternative methods of implementing materials policy; recommend programs to implement policy; and review and recommend to the President appropriate actions re -

garding programs in the Federal budget affecting national materials policy.

To implement the findings of the "National Materials Policy Board" would be the function of the "Commission on Materials Research and Operations," composed of a number of cabinet officers, the Director of the National Science Foundation, administrators of the National Aeronautics and Space Administration and the Energy Research and Development Administration, and two public members appointed by the President to serve as Chairman and Vice Chairman. The Commission would review programs recommended by the Board to implement national materials policy and establish such programs which seem appropriate. Such programs would include, for example, the development of information systems relating to the materials cycle or the encouragement of proper and efficient use and reuse of materials, including assistance to industry in carrying out such programs.

H.R, 14439 would also create a "Select Congressional Committee on National Materials Policy" in each House of Congress, composed of Members from standing committees having jurisdiction over material problems, Each Select Committee would be composed of 14 Members, 7 Republican, 7 Democratic, These "Select Committees" would assess changes recommended by the President in national materials policy, review recommendations of the "Commission on Materials Research and Operations, " and study and review broad questions of national materials policy.

This bill is currently pending before the House Committee on the Judiciary, the Committee on Rules, and the Committee on Science and Technology, Executive comment is now being received from a number of Federal agencies, An identical Senate bill, S. 3637, was introduced on June 29, 1976, by Senator Frank Moss, who explained at the time that "The bill offers an excellent starting point for what I would like to see become a national discussion, I hardly need remind my colleagues of the considerable energy which has been needlessly expended, the sidestepping and false starts which might have been avoided, or the cohesion and comprehensiveness which have been so seriously lacking in so many of our national debates because of this very failure to promote and administer a full-scale materials/resource policy. The bill provides a vehicle which can go far in alleviating a host of problems which have beset this country ever since we realized that the world's goods and services are scarce indeed and finite to be sure,"

The need for a national materials policy has been emphasized from the beginning with the work of the Paley Commission in

1952, by the Boyd Commission in 1973, in the proceedings of the three past Henniker Conferences, and in numerous publications of the National Academy of Science/Academy of Engineering, like the study by the Committee on Mineral Resources and the Environment (COMRATE),

Thus, for the past 25 years, materials experts in both the public and private sector have been pointing out to Congress the need for an overall national materials policy. While Congress has generally responded to specific materials needs by enacting or at least proposing limited action programs–the labeling of products, transport of dangerous substances, recycling of municipal wastes, research in novel energy materials, and so on — it has only been in recent years that Congress has begun to respond to the overall materials picture. The establishment of the National Commission on Materials Policy, the National Commission on Supplies and Shortages, and the Office of Technology Assessment has provided Congress with three mechanisms for anticipating future materials problems.

As I see it, the role of the National Commission on Supplies and Shortages is to address the more specific question of what institutions and provisions of Government are needed to assure American industry a smooth and reliable flow of essential materials under an orderly pricing structure. The role of the OTA, on the other hand, is longer-ranged. OTA is charged with addressing such questions as: 1) How could the Congress proceed, in the foreseeable future, to meet the policy needs of the United States in the field of materials management and materials technology? and 2) How do we relate our management of materials to full employment, economic soundness, the preservation of our environment, the frugal but adequate use of energy, and our relations with other countries?

Such questions need to be addressed, and here at Henniker both the institutional and supply/demand questions of the Commission and the broad legislative policy questions of OTA are of concern, Your role in this continuing improvement of communication is essential to this ongoing process, and your past record of involvement gives you sound credentials to affect our materials policy.

Before turning the podium over to Dr. Paladino, who will discuss materials assessments for Congress and the role the Office of Technology Assessment Materials Program plays in those assessments, I should like to close by expressing my appreciation for your participation, It is the “spirit of Henniker,” the working together of materials experts from all fields and backgrounds, that has provided a support base of vital information for our work.

II. Special Featured Papers

MONDAY NIGHT LECTURE

DECISIONMAKING IN INDUSTRY AND ITS IMPLICATIONS FOR ENERGY AND OTHER RESOURCES

by H. J, Pick
Professor of Materials Technology
Department of Mechanical Engineering
University of Aston, Birmingham, England

Engineering materials are always a means to an end: the manufacture of a product, Any criterion for assessing their utility, from the point of view of performance or of economics, must be derived from this basic fact.

Metals technology exists to make objects of metal or objects containing metal; plastics technology to make objects of plastics or objects containing plastics; concrete technology to make objects of concrete or containing concrete. These technologies involve a whole range of activities, including the winning of raw materials and all aspects of the transformation of these into final products— with processes; with plant; with skills and know-how; with the design and manufacture, performance and profitable marketing of products; and with relevant aspects of the infrastructure. The full optimisation of a technology will be possible only if all these factors are considered, and this applies equally at all levels of economic activity.

The objective of the present paper is to place materials in the context of some other aspects of manufacturing technology and of the resources required for manufacture. Its concern is primarily with materials and industries in which economic considerations play a major role.

Competition in the Metals Industry

The need to consider a whole variety of facets of manufacturing technology may be illustrated by examining the nature of the competition facing metals and the metals industries as a consequence of the introduction of new materials,

It is commonly believed that many metal markets are safe because metals possess unique properties and combinations of properties. This statement may be true for a limited number of specialised applications with tight constraints on weight, size, performance, or processing. However, in many cases, perhaps in the majority of cases, it is possible to create designs based on any of a wide range of materials. The decision whether to use metals or other materials, or indeed one alloy rather than another, will be determined primarily by economic considerations, in which the processes and cost of manufacture will be the major factor.

It is, for example, perfectly feasible to design automobile bodies of similar performance on the basis of steel, aluminium, foamed polyurethane, fibre-glass, or of several of these in combination. Automobile performance apart, the material or combination of materials selected will be the one giving the lowest final product cost, Steel will be selected if the summation of the costs of all the processes necessary to convert iron ore into a car body is less than the summation of analogous process costs for the competing materials, The competitive position of materials is seen to depend on a whole range of factors influencing process costs in both the materials-using and in the materials-producing industries: such factors as scale of operation, percentage of process waste, cost of plant and tooling, productivity of capital and labour, cost of energy, etc. —each of which will vary with time and place, and with the degree of technical and managerial skill and sophistication.

Within the present general pattern of metals technology, productivity improvement in the metal-producing industries will, through its effect on costs and prices, clearly play a major role in the competitive position of metals. But attention to this aspect alone may not suffice to protect metal markets. One of the big advantages claimed for plastics in the manufacture of motor-car bodies, for example, is a very much lower tool-up cost per model. The invention and development of a lower-cost tooling system for steel could therefore be as important a factor in defending this market as an improvement in the properties or a decrease in the price of steel strip.

The factors controlling the substitution of one material for another is often seen to be less a matter of one material competing with another than of the processes associated with one material competing with the processes associated with the other— the sand casting of cast iron with the pressure die casting of aluminium; the pressure die casting of metals with the injection moulding of plastics; sheet and plate metal work with the casting, lay-up, rotational moulding, vacuum forming techniques, and so on for plastics and composites.

Consideration of the whole of final product engineering, of design as well as of manufacturing aspects, and of the relation of these to each other, will often be a prerequisite to the full exploitation of a material, and thus to the maintenance of its competitiveness, This may be illustrated by again referring to motor car bodies. One of the more promising methods of producing these is by the casting of self-foaming, self-skinning polyurethane, Awareness of the simple fact that the production of a relatively thick foam section could compensate for the low Young's modulus, and for the relatively high cost per unit volume of the solid plastic, has here led to the development of a completely new materials system. Is it possible that the aluminium industry might have captured some of the market now held by plastics by the successful development of analogous processes?

The importance of effective final-product engineering in establishing the competitive position of a material will obviously be affected by prices, but a 20 percent price reduction would be of no greater benefit than any improvements in quality, design, and manufacturing ingenuity or in design data or codes of practice, which would allow a decrease of 20 percent in the amount of metal required for the manufacture of the final product. The competition between materials is seen not to be so much a competition between alternative lumps of stuff, as between the whole of the technologies associated with the competing materials.

Many products, now, and probably to an increasing extent in the future, consist of systems of two or more materials, rather than of a single material. The steel industry already has a large market in construction by providing the materials for frameworks and for the reinforcement and pre-stressing of structures in which other materials are used to fulfill functions for which they are more appropriate, One so-called "all-plastic" car had a bumper made from bent tubular steel with rubber moulded around it. Some designs for plastic cars described by British Ley - land are based on tubular steel frameworks and plastic body panels. The framework-reinforcement concept is again being sensibly employed to produce a design and manufacturing system combining the advantages of steel, its high strength and stiffness, with the ease of shaping plastics.

As materials are always a means to an end, it follows that the "qualities" and "properties," the attributes in terms of which materials are commonly characterised, have no absolute virtue. An attractive surface finish is of no value in objects which are not required to satisfy aesthetic requirements; a high-tensile-strength material has no advantage in a compressive member; a corrosion-resistant material has no advantage in a product which can readily be protected from corrosion. A material with a high

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ultimate tensile strength offers no advantage in making a component which is likely to fail under notch fatigue conditions, nor one with a high Young's modulus for making a component which can readily be thickened or reinforced to allow a cheaper, low Young's modulus material to be used.

The requirement for optimizing materials is relevance and utility, and in descriptions of what is relevant and useful, consideration must be given to the processes of manufacture, indeed to the whole of the technology associated with materials, as well as to the commercial and economic environment in which they are used.

Materials, Manufacturing Processes, and the Economy

How do materials relate to manufacturing processes, to the economy, and to other resources? Consider first the sequence of processes for the progressive conversion of iron ore into final products shown in table 1. The sequence confirms the earlier statement that materials and processes are inseparable aspects of manufacturing. Indeed, it is not obvious what a "material" is. The operator of each of the process stages will tend to call his input a "material" and his output a "product."

There are many stages in the sequence, and it follows that yield—the ratio of input to output —pIays an important role in resource consumption. This may be seen from table z, which shows the weight of material input required per ton of final output in a hypothetical lo-stage sequence with equal yields, in each of which an input weight "a" is required per ton of final output, If "a" = 1.1, then producing 1 ton of final output requires an input of (1.1)10 = 2,6 equivalent tons at the first stage. Improving the yield so as to reduce "a" to 1.05 reduces the input requirement at stage 1 to $(1.05)^{10}$ = 1.6 equivalent tons.

Many of the processes used in manufacturing waste materials. In the engineering industries, up to half, and sometimes more, of the materials purchased are turned into scrap during processes such as machining, forging, and stamping, This wastefulness is of importance not only in the direct way, but also indirectly for a wide range of manufacturing resources such as manpower and capital, and of natural resources such as energy and materials, In the United Kingdom (U.K.), for example, more than 3×10^6 tons of the 16.3 tons of steel bought by the engineering industries in 1968 were resold, not in the form of products, but as process scrap. This means that roughly one in five blast furnaces, one in five steelmaking furnaces, one in five rolling mills, etc., are employed in making steel which will be degraded to scrap in later stages of manufacturing. Not only is a proportion

TABLE I, –Sequence of Processes and Intermediate Products Involved in the Manufacture of Final Products From Steel

Mining and beneficiation

Iron ore
(plus coke, limestone, and sinter)

Blast furnace

Pig iron
(plus ferro alloys, scrap, and fluxes)

Steel making processes

Molten steel

Teeming

Ingot

Primary cogging mill

Bloom

Rerolling

Billet

Rerolling

Hot-rolled products

(black bar, hot-rolled strip)

Pickling

Cold roll or cold draw

Cold-finished products

Machining, pressing, etc.

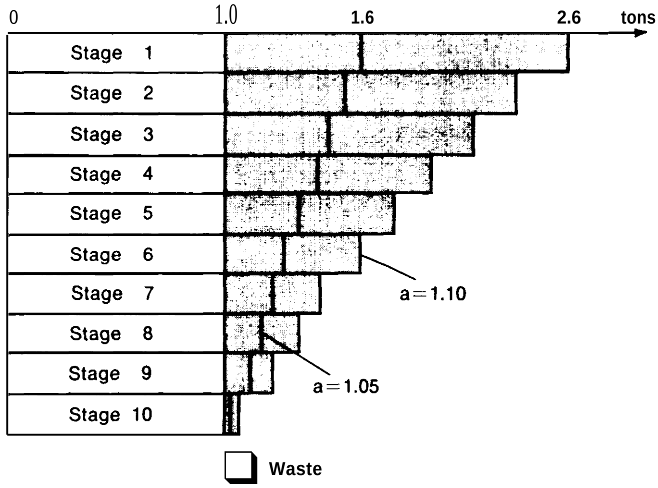
Engineering components
(car. bodies, machine parts, etc.)

Assembly and finishing

Final products

Source: Pick (1972).

TABLE 2. – Weight of Material Input Required Per Ton of Final Output in a 10-Stage Process Sequence With a Ratio of $\frac{\text{input weight}}{\text{output weight}}$ = a; for a = 1.05 and 1.1



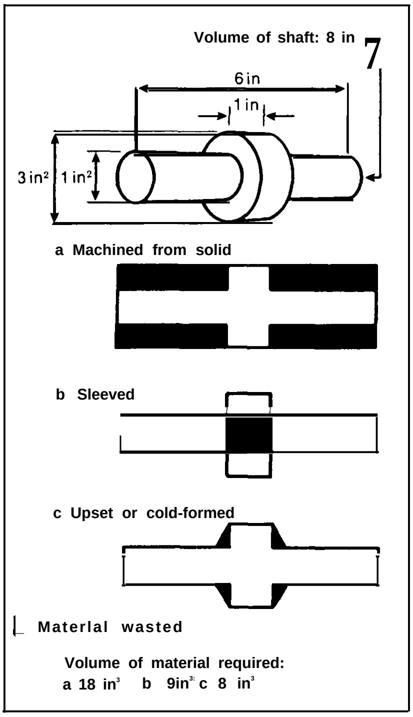
Source: Becker and Pick (1975).

of steelmaking capacity thus wasted, but so also is a corresponding proportion of the labour, electricity, coal and coke, etc., required for steelmaking. In addition, a proportion of the electricity generating, coal mining, and coke oven equipment which produced the wasted electricity, coal, and coke, is also wasted, as are some of the trucks and trains which take the steel to the engineering industries,

But even this is not the whole story, for the waste is spread to those industries which produced this capital equipment. The waste of steel by the engineering industries thus in turn implies a waste of some of the concrete, aluminium, rubber, plastics, and indeed of the steel required to make this capital equipment, Clearly, any reduction in material waste in the manufacture of final products could contribute much to conserve a wide range of resources.

This stresses the importance of design, as is illustrated by the simple example of table 3, which shows the effect of different design approaches on the input of material required for the manufacture of a given product. It also stresses the importance of material specifications: what is specified by an engineering firm will often have a profound influence on upstream process yield and process costs, a matter emphasized by M. Cohen and W. S.

TABLE 3.– The Effect of Design und Manufacturing Method on the Input Weight Required To Produce a Component Having a Volume of 8 Cubic Inches



Source: Pick (1972)

Owen (1975) in a review of the probable directions of steel development in the future.

An impression of the resources consumed in conversion may be obtained, if it is assumed that prices are approximately equal to costs (price = costs + profits) and a steel sequence in which United Kingdom (U. K.) 1975 prices are given is shown in table 4, This illustrates that the cost of materials as purchased by the engineering industries is really a summation of upstream process costs. The original iron ore, a very high proportion of which is now imported into the U. K., accounts for a relatively small proportion of the total cost of final products. An analogous pattern is seen in table 5, which shows 1963 world output of aluminum in both quantity and value terms.

Material costs, then, are a summation of the costs of the factors of production, The range of these is diagrammatically illustrated in

TABLE 4. — Steel Sequence, Showing Approximate 1975 U.K. Prices

Iron Ore	£13
Pig Iron	£58
Molten Steel	
Ingot	£90
Billet and Bloom	£110
Hot-Rolled Products	£140
Cold-Finished Products	£180
Engineering Components	£700

Source: Pick (1972).

TABLE 5.– The Build-Up of Value in the Progressive Conversion of Bauxite to Wrought Semifinished AJuminum Products

World Aluminum Production--1963

VALUE ADDED VALUE OF OUTPUT AT VARIOUS PROCESSING STAGES

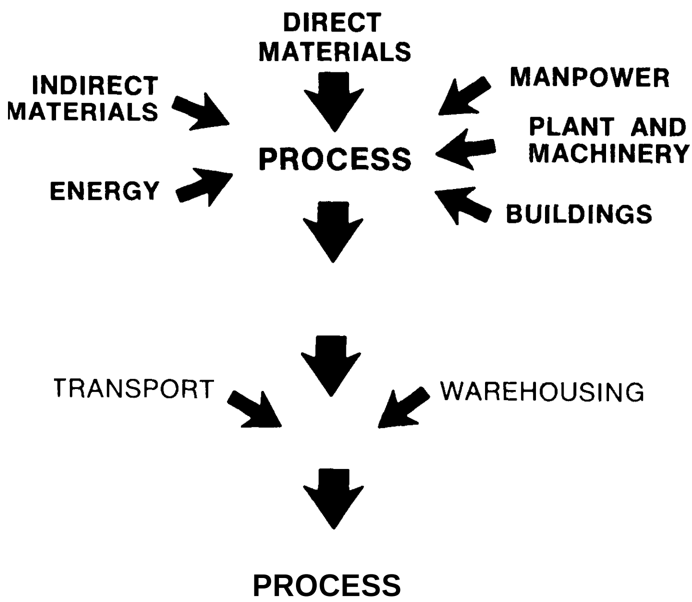
PROCESS	PRODUCT	TONS (MILLIONS)	INCREASE iN VALUE (MILLIONS)	VALUE IN DOLLARS (millions)
Mining	BAUXITE [$8/ton)	30	240	240
ORE REFtNiNG	ALUM! 14A ($75/ton}	12	680	900
A1.UMINUM SMELTiNG ANO REFINING	primary ingot ($450/ton)	6	1800	2700
FABRICATING AND CASTiNG	Wrought Semis CASTINGS ($1000/ton)	6	3300	6000

Source: Pick 1972.

table 6, which shows the inputs to a single stage of a process sequence, and also draws attention to the fact that resources are required for transport and storage between stages, The fact that a wide range of inputs is required for material conversion also means that total conversion costs are cushioned against a price change in any one, This is illustrated in table 7, which shows how the effect of 1972 oil price increases was diluted in the production of plastics products.

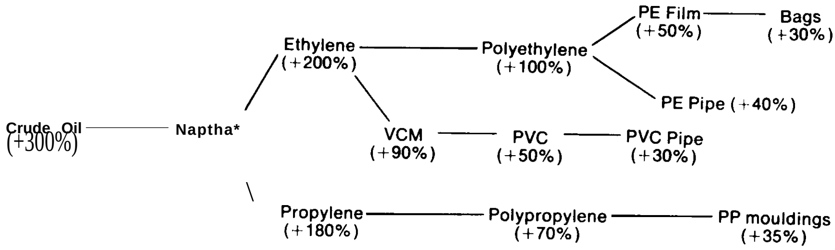
Prices, as has already been mentioned, reflect costs, and hence resource consumption, Relative price movements tend to reflect relative changes in technology and the efficiency of resource conversion. A chart showing the relative price movements of various U.S.A. goods between 1947 and 1970 is reproduced in table 8, which depicts the poor relative performance of metals and metal products during the period, This reflects the fact that improvements in process efficiency have been achieved only at the expense of very high expenditures on capital, According to Drucker (1969), this reflects a stale technology.

TABLE 6, –Symbolic Representation of Physical inputs Into Manufacturing Processes



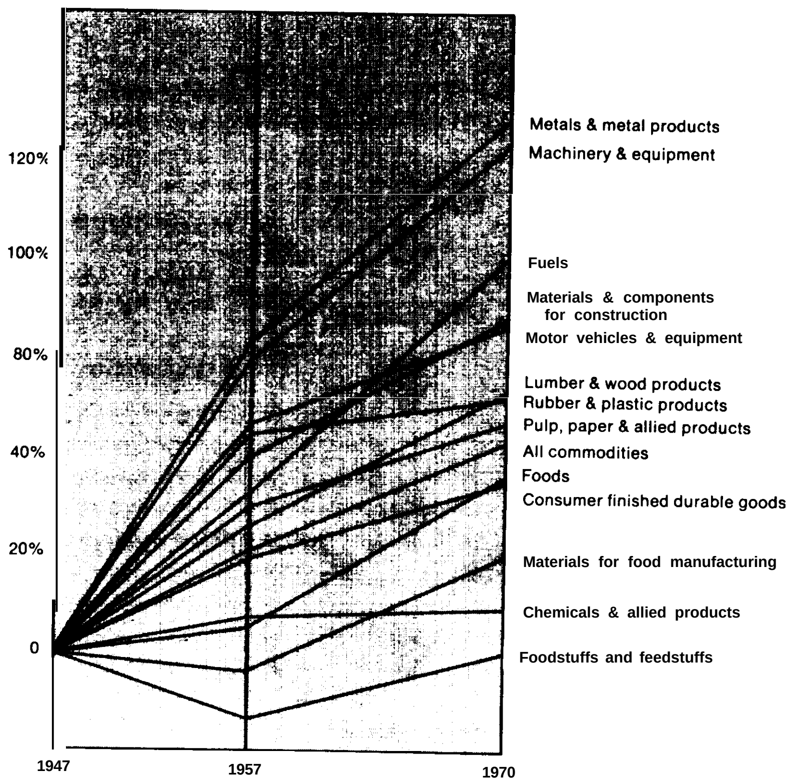
Source: ICI Limited.

TABLE 7, –Conversion Sequence for the Manufacture of Some Plastics Products, Showing the Percentage Increase in Price of Downstream Products Resulting From a 300 Percent Increase in the Price of Crude Oil



Source: ICI Limited.

TABLE 8. – U.S.A. Price Changes in Various Products Between the Years 1947-1970



Source: Data from the Economic: Report of the President, 1971.

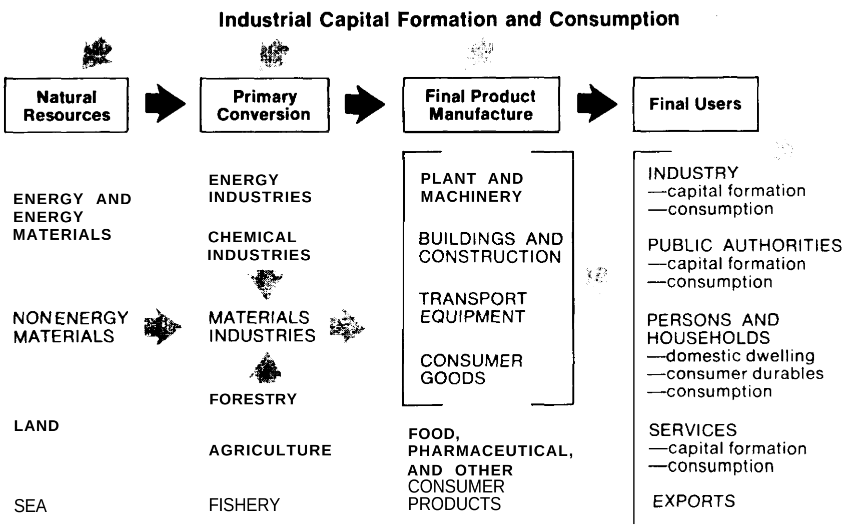
Description of Materials Flow **Patterns**

The flow of resources in materials conversion needs to be considered in the wider setting of the economy as a whole, and this may be done by reference to table 9, prepared for a forthcoming report on engineering materials for the U,K.'s National Economic Development office. The hollow arrows in this table show the flows which are normally considered to be the materials/engineering stream of manufacture. Leaving aside the question of ‘defense, it is presumably an objective of a national materials policy to take initiatives and precautionary measures which are likely to have an impact significant in the context of pattern of flows, or to create new knowledge and understanding to support such initiatives,

It is now proposed to indicate some features of this pattern of flow which may be of assistance in judging what is economically significant. The question of materials supply is being covered in other conference papers, thus only aspects of conversion beyond the raw materials stage will be considered.

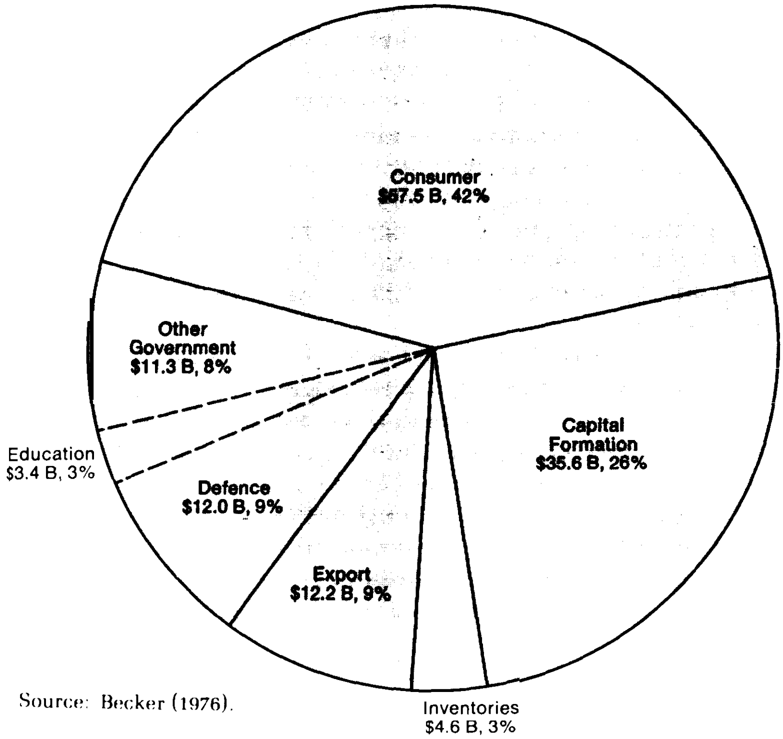
First is the question of the destination of the output of the materials industries. Table 10, based on work by Becker (1976), then a Research Fellow in the author’s University IAston], during a period as visiting Fellow at Brandeis University, shows that

TABLE 9.—The Flow From Natural Resources to Final Products Through the Manufacturing Industries



Source: Forthcoming (U.K.) National Economic Development Office Report.

TABLE 10. –Destination of the Output of the U.S.A. Materials Industries by Categories of Final Demand



Source: Becker (1976).

consumer expenditure in the U.S.A. accounts for 42 percent of the demand for materials, capital formation being next in importance, accounting for some 26 percent.

For a given level of conversion efficiency, the requirement for materials depends on the level of final demand; one possible response to material shortages is to reduce the level of final demand. But the materials content of various levels of final demand is not the same, as maybe seen from the data in table II. The materials content of consumer expenditure is, for example, only 12 cents per dollar, compared with 32 cents per dollar for capital formation. Any government measures leading to a uniform change in expenditure, spread across all categories of final expenditure, would have a much bigger effect on material consumption via the capital goods industries than on materials demand via consumer expenditure.

One of the most important features of the flows in table 8 is that the “materials” flows indicated by hollow arrows are inter-

TABLE 11. — Materials Content of the Purchases by Various Categories of Final Demand

	Total Expenditure $ M	Material Content ¢ per $
Consumer	490.660	12
Capital Formation	110.443	32
Inventories	10.034	46
Export	45.923	27
Defence	71.333	17
Education	39.512	9
Other Government	68.274	17
Total	795.388	17

Source: Becker (1976c)

dependent with other flows, as a variety of inputs is required for each process stage in the manner previously symbolised in table 6. Among these are capital and manpower, and table 12 shows the distribution of capital stocks and employment in the U.S.A. manufacturing industries in 1968. Altogether, the listed materials producing industries account for 42 percent of the capital stock in manufacturing, compared with 32 percent in the material using industries. Employment, on the other hand, is greater in the material-using industries, but even so 5.5 million people were employed in producing the materials required by the 7.3 million in the remaining listed manufacturing industries.

It is of interest to note that there are wide discrepancies in the "efficiency" with which different industries use their resources of manpower and capital in the processing of materials, and indeed to produce their output, as is demonstrated in tables 13, 14, and 15. Tables 13 and 14, for example, show that the motor vehicles industry is by far the most efficient in the use both of capital and of manpower, if the ability of a unit quantity of these resources to process a given value of materials is taken as an indication of efficiency. The aluminium rolling and drawing industry on the other hand, while efficient in the use of manpower, is relatively inefficient in the use of capital. Indeed, it is seen from table 13 that the primary metal industries require more capital to process a given value of materials than any other of the listed industries. The traditional iron and steel foundries are relatively "inefficient" in the use of both machinery and manpower.

TABLE 12.—*Distribution of Capital Stocks and Employment in U.S.A. Manufacturing Industry, 1968*

TABLE A

Distribution of capital and employment in U.S.A. manufacturing industry, 1968.
(Taken from U.S. Department of Commerce, Annual Survey of Manufactures, 1968)

Row No.	*S.I.C.* Code*	*Industry group and industry*	*Gross book value of depreciable assets (in millions of dollars)*			*Employment*	
			Total	*Structures and buildings*	*Machinery and equipment*	*No. of employees (1,000)*	*Total labour cost (million dollars)*
			A	*B*	*C*	*D*	*E*
1		All operating manufacturing establishments, total[4]	231,779.1*	65,105.2	166,613.9	18,681.0	149,151.2
2	24	Lumber and wood products	4,999.4	1,321.7	3,677.7	551.6	3,341.3
3	26	Paper and allied products	16,623.1	3,462.8	13,160.3	642.5	5,305.0
4	282	Plastics materials and synthetics	7,147.5	1,596.9	5,550.6	179.5	1,639.5
5	2851	Paints and allied products	774.7	340.0	434.7	65.1	566.1
6	30	Rubber and plastics products, n.e.c.	6,308.3	1,532.6	4,775.7	541.9	4,237.4
7	31	Leather and leather products	752.5	276.8	475.6	334.1	1,741.9
8	32	Stone, clay and glass products	11,400.9	3,237.6	8,163.3	590.1	1,352.0
9	33	Primary metal industries	36,835.2	7,615.6	29,219.6	1,274.7	12,163.9
10	34	Fabricated metal products	12,720.5	3,638.4	9,082.1	1,357.8	11,301.6
11	25	Furniture and fixtures	2,005.4	852.1	1,153.3	433.4	2,705.6
12	35	Machinery, except electrical	16,638.4	5,044.3	11,594.2	1,848.8	16,564.1
13	36	Electrical equipment and supplies	12,810.7	4,331.6	8,479.1	1,882.7	15,445.4
14	37	Transportation equipment	16,976.0	5,695.1	11,280.9	1,887.6	19,346.4
15	38	Instruments and related products	3,260.6	1,258.9	2,001.7	400.0	3,343.2
16	39	Miscellaneous manufacturing industries	2,241.6	734.4	1,507.2	430.7	2,716.4
17	19	Ordnance and accessories	2,029.8	796.9	1,232.9	446.4	4,573.1
18		Food, textiles, etc.	Remainder				

*Standard (U.S.A.) industrial classification.

TABLE B

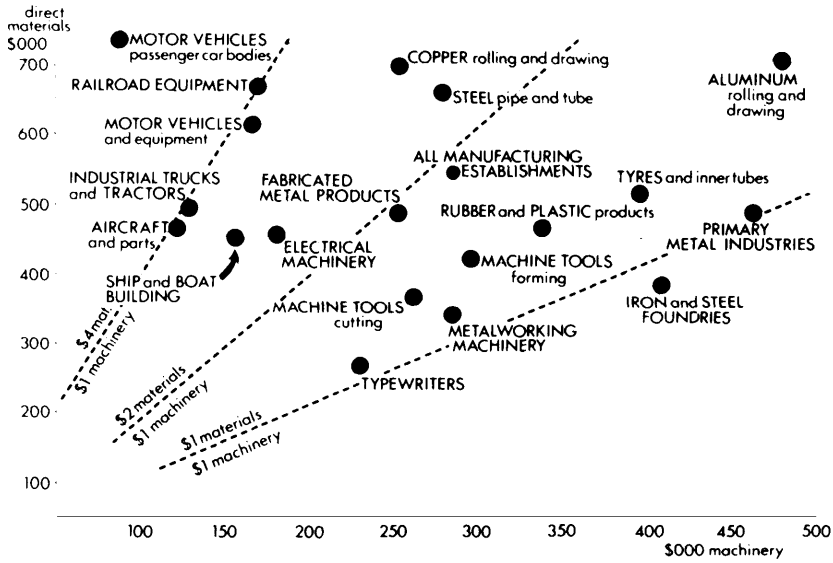
Analysis of data in Table A, for comparison of "materials-producing" with "materials-using" industries, U.S.A. 1968 (Figures in brackets are items expressed as percentage of equivalent quantity for all manufacturing)

	Gross book value of depreciable assets (dollars)			*Employment*	
	Total	*Structures & buildings*	*Machinery & equipment*	*Employees*	*Labour cost*
	A	B	C	D	E
Materials-producing industries (a)	98×10^9 (42%)	23×10^9 (35%)	75×10^9 (45%)	5.5×10^6 (30%)	42×10^9 (28%)
Materials-using industries (b)	74×10^9 (32%)	19×10^9 (29%)	37×10^9 (22%)	7.3×10^6 (39%)	62×10^9 (41%)
Food, textiles, etc.	Remainder				

(a) Rows 2-10
(b) Rows 11-17 of Table 14A

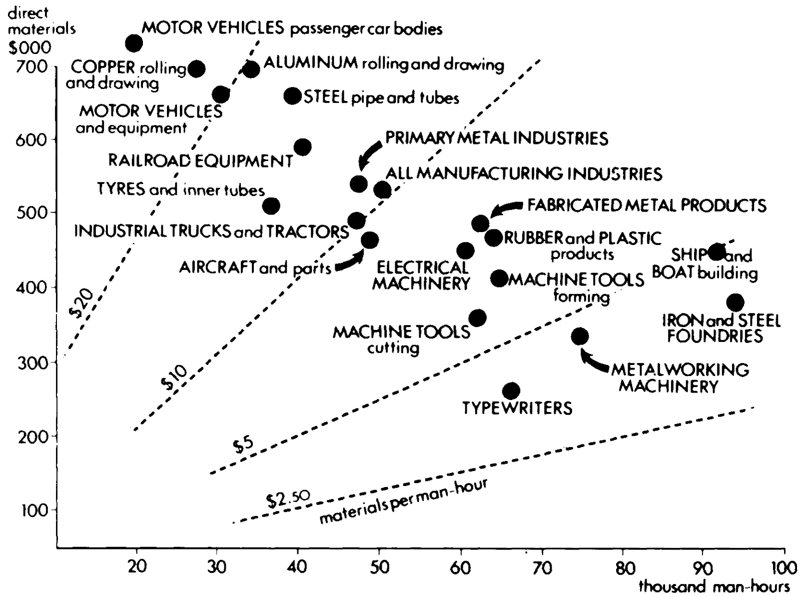
Source: Pick (1972

TABLE I3.– Relationship Between Direct Materials and Capital Required To Produce $1 Million of Output in 1967 *in Various U.S. Industries*



Source of data: U.S. Census of Manufactures for 1967.

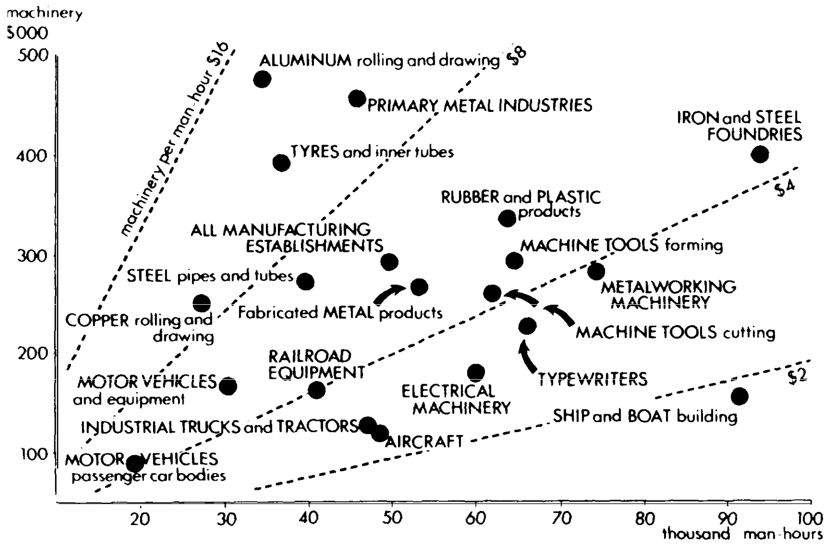
TABLE 14,–Relationship Between Direct Materials and Labor Required To Produce $1 Million of Gross Output in 1967 in Various U.S. Industries



Source of data: U.S. Census of Manufactures for 1967.

Table 15 gives an overall impression of the value of machinery and the thousands of man-hours required to produce a million dollar's worth of output in 1967. Any industry near the origin will be relatively efficient in the use of both these resources, It is seen that motor vehicles are again the best performer, and iron and steel foundries the worst. as assessed by this admittedly crude criterion.

TABLE 15. — Relationship Between Capital and Labor Requircments for the Production of $1 Million of Output in 1967 in Various U.S. Industries

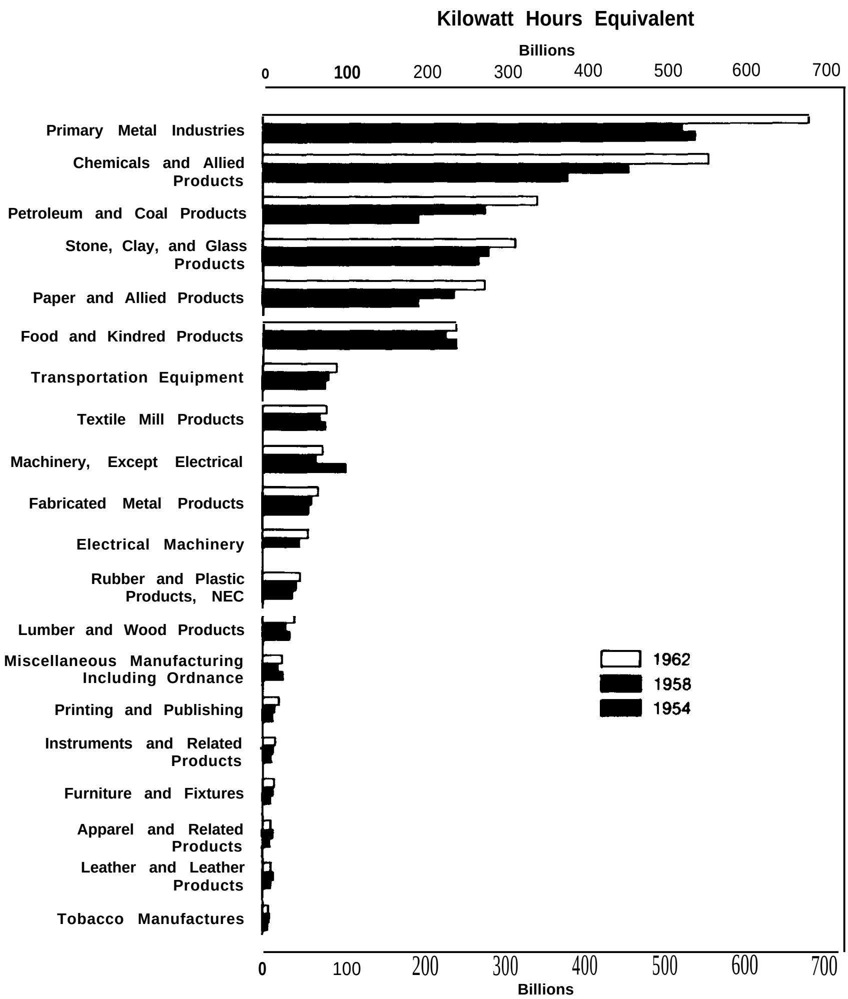


Source of data: U.S. Census of Manufactures for 1967

Materials Interdependence

The interdependence of materials with other resources may also be illustrated by reference to the role of energy in materials conversion. Table 16 shows that the primary conversion industries are the dominant energy consumers in manufacturing, with the primary metal industries in the lead, followed closely by the chemical industry, with two other materials groups (stone clay and glass products, and paper) also high on the list. Numerical values for the uses of fuels and purchased electricity in the U.S. material producing industries are given in table 17.

TABLE 16.– Purchased Energy Used in Manufacturing for Major Industry Groups: 1962, 1958 and 1954



Source: US. Census of Manufactures for 1963.

Energy purchases by the engineering industries, even by the huge transportation equipment industry (which includes land, sea, and air transport equipment), is relatively small. But this relatively low direct purchase of energy by the engineering industries is clearly only part of the story, For in order to assess the total energy content of the products of an engineering firm, it is also necessary to take account of the indirect purchases of the energy used by its suppliers of materials and components, of

TABLE 17. – U.S.A. Consumption of Fuel and Electrical Energy, 1963
(Taken from U.S. Census of Manufactures)

Industry	Cost (10^9 dollars)		
	Total	Purchased fuel	Electrical
All manufacturing industries	6370	3410	2960
Materials and industries:			
Lumber and wood	183	115	68
Paper and paper products	472	305	167 ‘
Rubber and plastics	128	44	83
Stone, clay, and glass	576	403	173
Primary metal	1389	858	530
Fabricated metal products	240	100	139
Total for materials Industries	2988	1825	1160
Materials industrles as percentage of all manufacturing industries	47%	53%	39%

Source: H. J. Pick (1972).
Mater. Sci. Eng., 10 (1972)

capital and transport equipment, and of services. As these suppliers in turn have their suppliers, a complex summation is required to assess total (= direct + indirect) requirements, Account must be taken of all the energy used by upstream firms in sequences of the kind illustrated in table 1,

This total, direct plus indirect, flow of energy may readily be computed by the use of industrial transaction matrices as published by most industrialised countries in the form of Input-Output tables. The results of such a calculation for the U.K. are shown in table 18, from which it is evident that for each of the industry groups, energy purchases via materials are considerably higher than direct energy purchases. And the results given in table 18 are likely to be conservative, since, for reasons of simplicity in calculation, they do not include the energy required to produce imported materials and to transport them to the U.K. Nor do they take account of the energy used to produce the capital stock of the materials producing and engineering industries.

Analogous results for U.S. automobile production were reported by Hirst (1972) who estimated that a direct purchase of 5,850 Btu/dollar of automobiles shipped was matched by an indirect purchase of 48,420 Btu/dollar shipped via materials and

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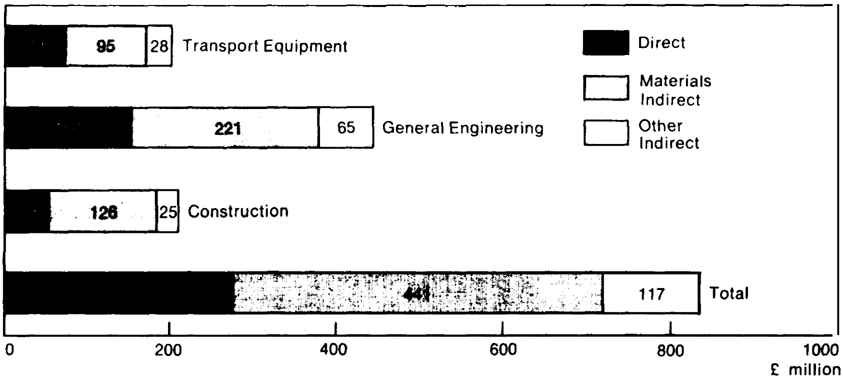
TABLE 18. – U.K. Direct and Indirect Purchase of All Energy by the Engineering-Type industries in 1968



Source: Becker and Pick (1975).

other supplies. Among these, iron and steel play a dominant role because these account for the bulk of the weight of the automobile.

From the above description, it follows that there is an intimate relation between the way materials are produced and used in design and production, and the use of national resources. It will also be evident that there is a gearing effect in the way in which materials are used: in the earlier discussion of the consequences of waste in engineering manufacture, it was shown that such waste produces ripples having effects on resource utilisation at points remote from the point of actual decisionmaking.

From the preceding description of the relation between materials and energy, it follows that any changes in specification, design, or manufacture of automobiles which would lead to reduction in weight would also have widespread consequences for energy requirements throughout the economy, partly through the obvious saving of fuel in running automobiles, but also through savings in materials manufacture, capital stock, etc., of the kind just described. Technical changes of this kind provide a large reserve-in-principle which could, given time for re-equipment, be used in the face of resource constraints, But, as such changes would also lead to a decrease in economic activity and to a change in social habits, their implementation, although widely discussed in the materials literature, in fact becomes an issue for industrial and social strategy rather than for materials policy as such,

Manufacturing Requirements of Materials

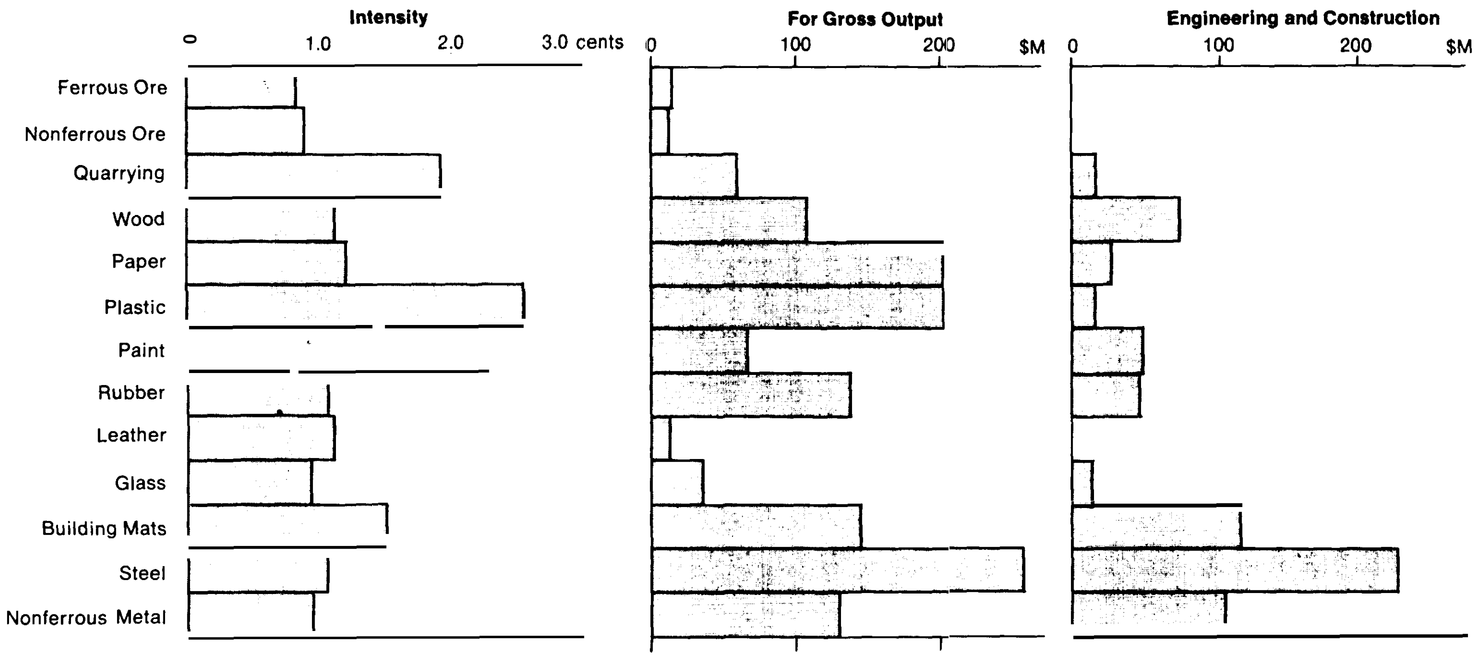
In this final section of the paper, it is proposed to consider the relation between specific materials and the resources of energy, capital, labour, and imports used in their manufacture. This may conveniently be done by using the concept of resource "intensities," which may be defined as the value of a particular resource required to produce a dollar's worth of the output of a particular material.

For reasons previously discussed, it is necessary to take account of both direct and indirect requirements of a particular resource in order to assess the intensity of that resource in the manufacture of a material. For example, of the crude oil and natural gas required for the manufacture of plastics, very little reaches the plastics industry directly in the form of crude oil: 27 percent of it reaches it in the form of refined oil, 55 percent as chemicals, 5 percent as electricity, 2 percent as transport, and the remaining 11 percent in other forms. Altogether, 3.2 cents of crude oil and natural gas need to be produced in order to produce one dollar's worth of plastics, but this will reach the plastics industry only after being processed into other forms, as indicated in the previous sentence. Three and two-tenths cents per dollar is the crude oil plus natural gas intensity of plastics materials.

Extensive investigations of the total energy requirements for materials manufacture have been carried out in recent years, the most thorough probably those on behalf of the recent National Commission on Materials Policy. But values for resource intensities may also be read off directly from the total requirements matrix of published input/output tables, They have been plotted by Becker in easily interpretable form in tables 19 to 21. The first of these shows in the left-hand diagram of table 19, the intensities of crude oil and natural gas consumption by the various U.S. materials industries in 1967. As expected, the plastics industry is the most intensive user of these fuels, followed closely by paint, while other materials such as steel have a relatively low intensity. (From this it is possible, for example, to infer that any increase in the price of crude oil and natural gas will place plastics at a competitive disadvantage with products containing a smaller percentage of these fuels.)

In order to assess the effect of these resource intensities on the economy as a whole, however, it is necessary also to take account of the gross output of the various materials industries, and these are illustrated in table 19. These tables show that the primary metal industries, and in particular the primary steel industry, have an output considerably in excess of, for example, the plastics industry. The result is that, although steel has a relatively

TABLE 19.—Crude Oil and Natural Gas Content of Materials



Source: Becker (

low oil and gas intensity, the overall effect on the economy of a price increase in these fuels would be greater via steel than via plastics.

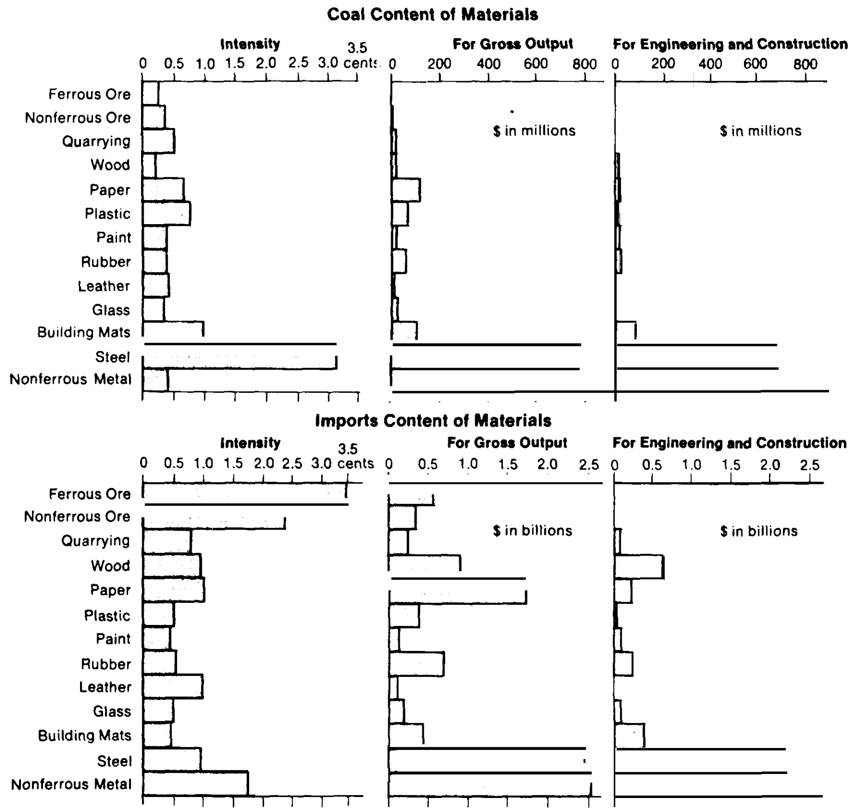
The middle diagram of table 19 shows the total (direct plus indirect) expenditure on oil and gas of the various industries listed, The right-hand diagram is analogous to the central one, but it only shows the oil and gas content of the output of the various materials industries, which has its destination in engineering and construction, From this it is seen that any price increase in oil and gas has its major effect via steel, nonferrous metals, and building materials. Analogous data for some other resources are plotted in tables 20 and 21, It is not proposed to analyze these in detail, but reference may be made to the case of labor to indicate that the labor intensities of different materials are not very widespread. But there are differentials. Wood, for example, is more labor-intensive than plastics, with the consequence that any uniform increase in wage rates would lead to greater price rise in wood than in plastics.

The foregoing discussion will have demonstrated that each type of material has specific quantifiable implications for a wide range of resources, which will be different from those required in the manufacture of other materials.

It is therefore of interest to assess here the effects of material substitution on the requirement of other resources. For the economy as a whole, these may again be calculated by the use of input/output analysis, Becker has developed a method of presenting the results of such a computation in the form of what he terms "Resource Isoquants," A series of these, indicating the effects of the substitution of plastics for steel on capital stock, on labor, and on oil and gas, is shown in table 23. These isoquants are plotted to enable the aggregated effect of substitution on resources to be assessed for a range of substitution ratios (i.e., the number of dollars' worth of plastic required to substitute for one dollar's worth of steel).

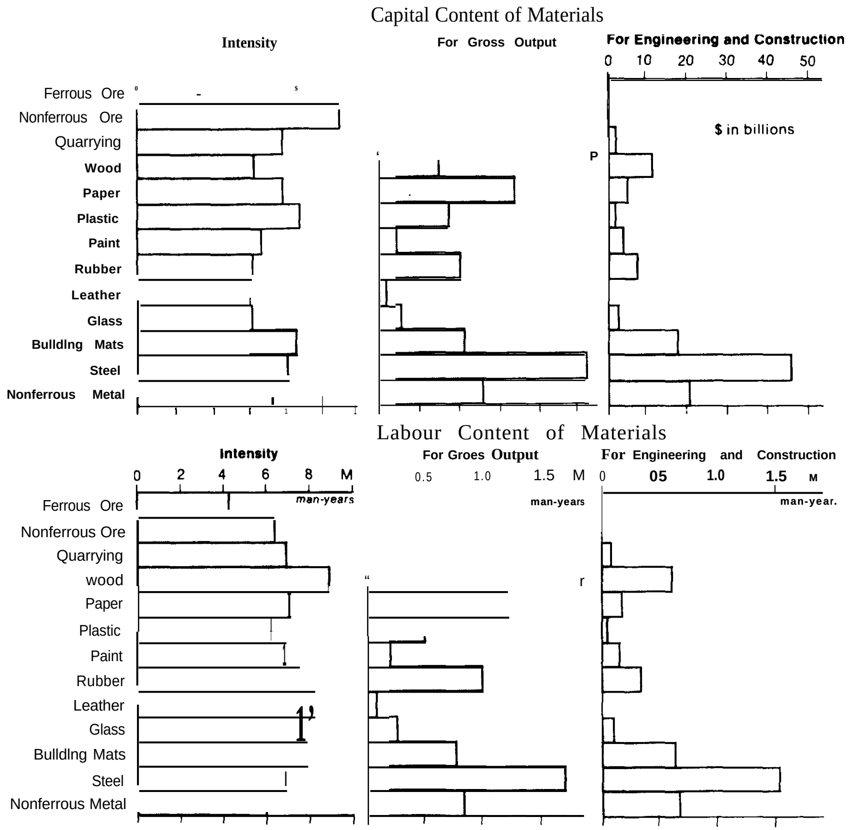
From table 23 it is thus seen that a substitution of $0.95 dollars of plastic for steel would have no effect on capital stock, while a substitution of 20 percent at a substitution ratio of 2 would lead to an increase in the requirements of capital stock by over $8 billion. Similarly, as plastics and steel have roughly the same labor intensity, substitution on a one-to-one basis in money terms would have relatively little effect on employment. To substitute a dollar's worth of plastic for a dollar's worth of steel would require an increase in the labor force. Plastics are very much more oil and gas intensive than steel, Any substitution which required more than about 40 cents' worth of plastic per dollar of steel would lead to an increased consumption of these fuels,

TABLE 20.—Coal Content of Materials. Imports Content of Materials



Source: Becker (1976).

TABLE 21. –Capital Content of Materials. Labour Content of Materials



Source: Becker (1976).

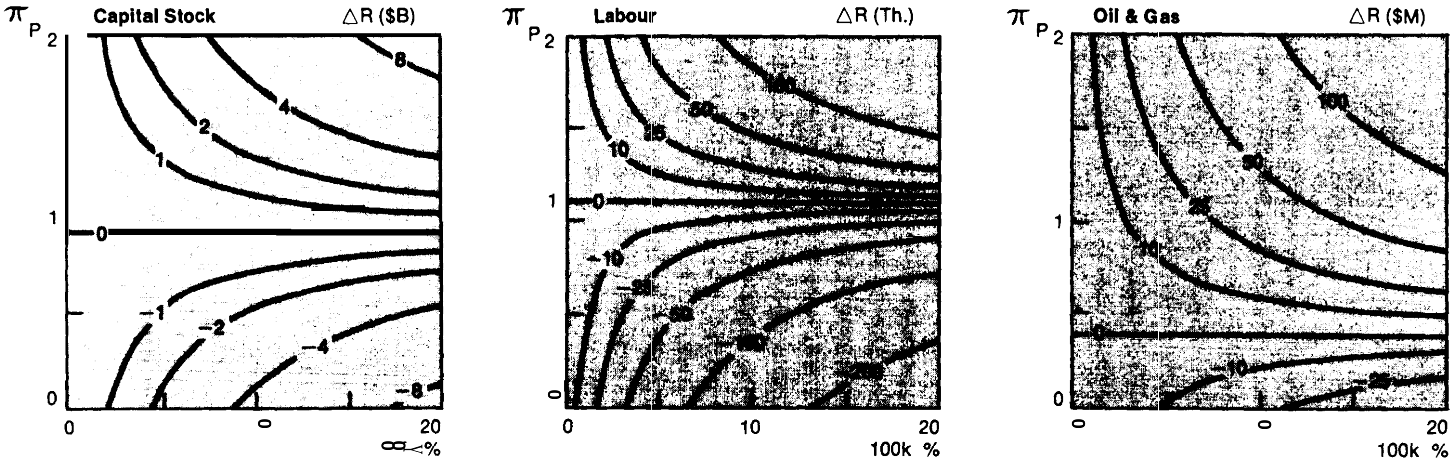
TABLE 22.– Value Added and Value of Shipments of a Number of U.S.A. Industries in **1967**

SIC.	Industry	Value of Shipments $106	Value Added $106
	All manufacturing	557	265
24	Lumber and wood products	11	5
26	Paper and allied products	21	9
282	Plastics, materials synthetics	7	4
2851	Paints and allied products	3	1
30	Rubber and plastics products, n.e.c.	13	7
31	Leather and leather products	5	3
32	Stone. clay, and glass products	14	8
33	Primary metal industries	47	20
34	Fabricated metal products	35	18
25	Furniture and fixtures	8	4
35	Machinery, except electrical	48	28
36	Electrical equipment	43	24
37	Transportation equipment	69	28
38	Instruments and related products	11	6
39	Miscellaneous manufacturing industries	9	5
19	Ordnance and accessories	11	6
20	Food	84	27
	Textiles, etc.	Remainder	

S.I.C,	Industry	Value of Shipments $\$10^6$	Value Added $106
2821	Plastics materials and resins	3-5	1-6
2822	Synthetic rubber	0-9	0-4
3011	Tyres and inner tubes	3-7	1-8
3069	Fabricated rubber products. n.e.c.	3-1	1-7
3079	Miscellaneous plastics products	5-4	3-0
331	Blast furnace and basic steel products	23-1	10-2
332	Iron and steel foundries	4-3	2-6
333	Primary nonferrous metals	3-7	1-4
3341	Secondary nonferrous metals	1-6	0-3
335	Nonferrous rolling and drawing	9-9	3-3
336	Nonferrous foundries	1-9	1-1
3541	Machine tools. metal-cutting types	2-1	1-4
3542	Machine tools. metal-forming types	0-7	0-4
371	Motor vehicles and equipment	40-3	13-7
372	Aircraft and parts	21-1	11’3
373	Ship and boat building and repairing	3-1	1-7

Source: U.S. Department of Commerce, Census of Manufactures.

TABLE 23.—*Substitution of Plastic for Steel: Resource Isoquants*



Effect on capital stock, on labour and on oil and gas. Each curve passes through combination of π_2 (cost of plastic required to replace $1 of steel) and 100 k (percent of steel substituted for) with equal ΔR (changed resource requirement).

Source: Becker (1976a), (1976c).

Finally, it may be of interest to note that any substitution of materials for one another would have effects not only on total resource requirements, but also on regional requirements, because the production of various materials tends to be concentrated in specific regions. This is shown in table 24, drawn by Becker (1976), the top map of which shows how 915,000 men employed in the U.S. steel industry are distributed throughout the country. In addition to the manpower directly employed in the steel industry, an additional 808,100 men were required to produce the ore, coal, coke, electricity, and all the other inputs required for steelmaking. These were distributed as in the second map, Total employment in steel manufacture and in its supply industries is shown in the third map on table 24. From these maps it will be evident that any change in the pattern of steel usage will have an effect on regional employment, and that the total effect of this will be greatest in the East North Central and Middle Atlantic regions,

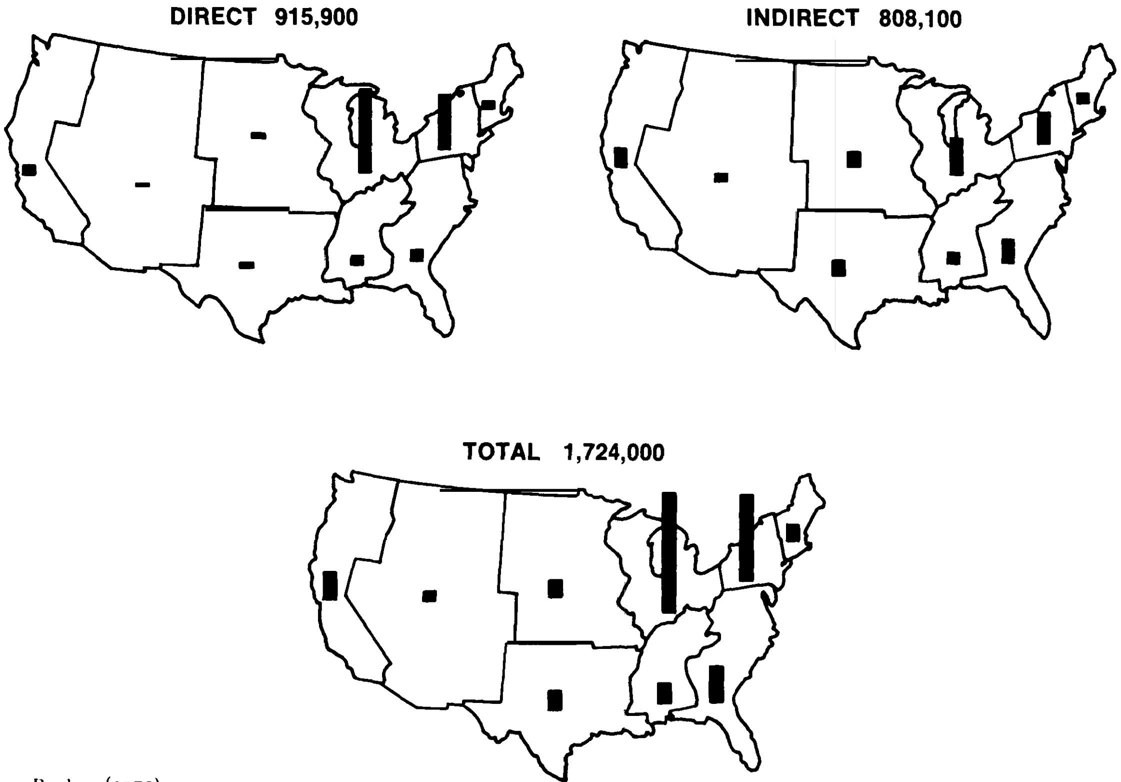
To assess the effect of changes of this kind on regional employment, one must allow for the fact that these regions are also characterized by high total population by calculating the regional intensity of employment for various materials industries (the proportion of the work force in a region employed in a materials industry), Maps indicating regional intensities have also been plotted by Becker, and these are reproduced in table 25, in which the black bars represent direct employment intensity; the hollow bars, indirect employment intensity. From these maps it will be evident that any changes in the use of one material relative to another or to industrial output generally would also have implications for regional employment,

Concluding Remarks

The field of materials is inseparable from manufacturing processes. The demand for materials is a derived demand depending on the demand for goods and services and on the efficiency of the processes involved in converting materials into final products, For a given volume of goods, the demand will depend on product and material specification as well as on design and production skills. The nature and quality of the materials specified in design will determine the range of resources required for manufacture. Conversely, design can only take place within the framework of what is available, feasible, and socially acceptable.

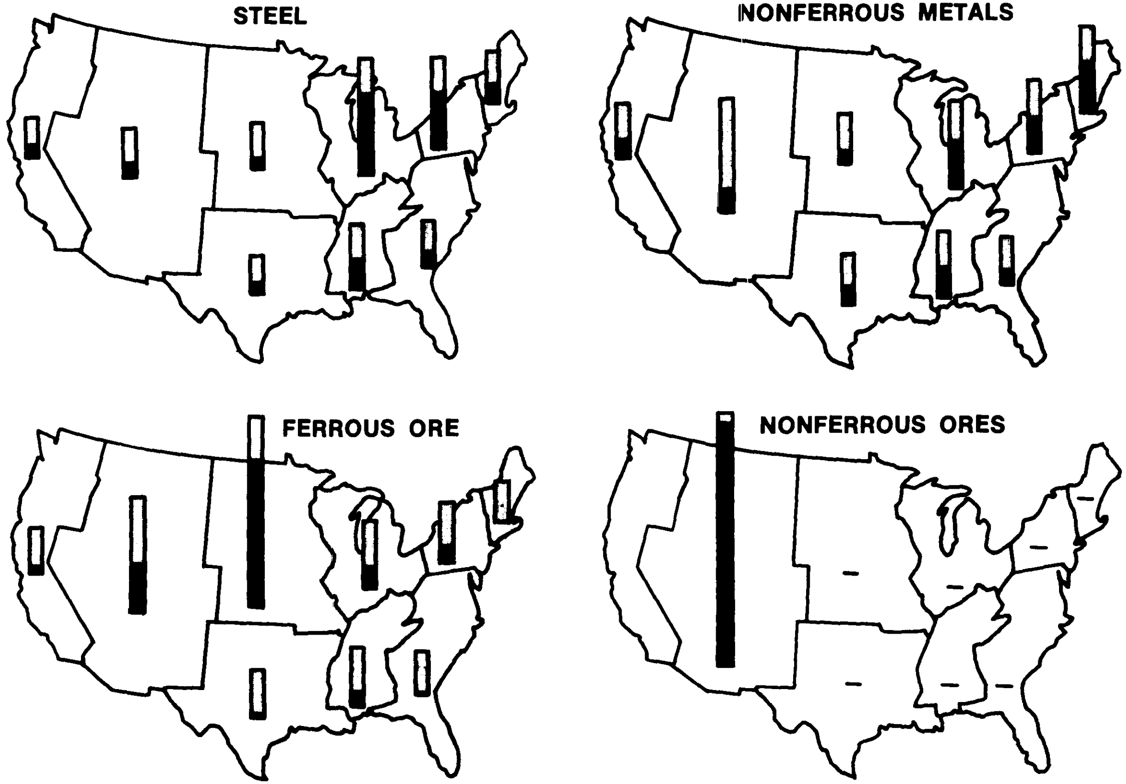
In this paper an attempt has been made to remind the conference of the vast capital stock involved in technology as it is. From this it follows that there is little short-term flexibility in the manufacturing system, other than a reduction in economic

TABLE 24.—Regional Employment in U.S. Steel Manufacturing; 1967



Source: Becker (1976)

TABLE 25.—Regional Intensity of Employment In Materials Manufacturing—Steel, Nonferrous Metals, Ferrous Ore and Nonferrous Ores



Source: Becker (1976 a), (1976 c).

activity, and that time is needed to effect change on a significant scale, particularly as any fundamental changes in materials technology will also need to be supported by appropriate changes in the infrastructure.

One of the themes developed in this paper is the interdependence of materials with other physical resources and with wider aspects of the industrial, economic, and social environment. Recognition of this interdependence has widespread consequences, At the practical level, any decisions on specifications, design, or investment at any point in the system will lead to full optimisation only if account is taken of interactions with other parts of the system. Recognition of this obvious fact may give rise to innovative action in industry and to new directions for research and development, At a more general level, the recognition raises the question whether' the development and optimisation of technology, which is largely determined at company level, is likely to take beneficial long-term directions unless a wider framework of knowledge and ideas regarding the system as a whole is also generated. This matter has hitherto tended to be the province of economists. Perhaps it is time for it to be explored in engineering terms.

Justifiable concern is often expressed, both in the United Kingdom and in the United States, that attention to materials in Government and industry tends to lack coherence. It is hoped that the description of interdependence contained in the present paper will strengthen the case for a coherent approach. At the same time, in a vast field like materials, a high proportion of the initiative and of the work will always need to take place at the level of the particular. It is suggested that obtaining the necessary coherence at the general level may require not only administrative measures, but the development of a coherent intellectual framework as well.

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THURSDAY NIGHT LECTURE

PLANNING IN AN UNCERTAIN ENVIRONMENT

by W. Dale Compton
Vice President –Research, Ford Motor Company

Shortages are a bit like the weather–everyone complains about them, but no one seems to be able to do much about them. Short-lived shortages are so common that we have learned to endure them, perhaps in part because they usually affect only a small segment of the populace or a minor part of the economy.

If the affected groups happen to have a low political profile, we oftentimes do not even hear about the problem. The discomfort or economic strain that these groups experience may be severe, but if they don't have the economic or political "muscle," nothing much is heard of it.

On the other hand, a major shortage will receive high-level attention. If there is a danger that the national economy or safety is threatened, we are bombarded with information and instructions. Following any such event, the headlines are filled with speculation about the long-term possible danger of international boycotts or the consequence of exhausting a supply of a natural resource. While I don't wish to be insensitive to these issues— for there is no question that they represent real concerns—the real issue before this conference is how to reduce the impact of such events by careful forward planning.

The first step in solving any problem is to recognize that the problem exists, and this conference has appropriately highlighted the magnitude of the problem– namely, chronic material shortages.

The next step after recognition of a problem is to try to do something about it, It is easy to say that the marketplace will handle the problem, or that the Government should intervene in each case, or that we should have a national strategy that will preclude the development of such problems.

In fact, none of these answers are adequate. But what can we do? perhaps the answer will be nothing or only something very small; however, at the very least, an answer will be found only if we understand the total breadth of the problem. It follows, I believe, that the manner in which we go about searching for an answer is absolutely crucial. Thus, I would like to share with you a few of my concerns about the way we examine these problems as well as the mechanisms we try to employ to prevent them.

We have become such a complex, interrelated society that actions taken by one element of our society can have unexpected consequences upon another element, particularly when the time that has intervened between the action and the consequences is more than a few weeks, The realization that the future can be adversely affected by today's decisions has led to increased efforts to establish a more systematic review of the possible consequences of many of the actions that are being proposed by both business and Government.

It is this concern for the future that has led to the requirement for environmental impact statements. This is just one of many efforts to urge a longer-term look at the consequences and a corresponding reduction in the risks associated with a planned action — in this case, the environmental consequences of an action.

The term "technology assessment" has been so well integrated into the common vocabulary that it is not unusual for the layman to feel that the long-term consequences of a proposed action are predictable with a high degree of accuracy.

While this awareness of the need to examine the implications of the technical issues is important and should be encouraged, I suspect that the very term "technology assessment" tends to create the false impression that most issues are dominated by the technical aspects of the problem. While most of us would probably subscribe to the view that the technical implications are important, we all too often do not ask how a particular action will affect our human relationships. This has sometimes been referred to as the "socio-technological" implications of an action.

Perhaps we should emphasize the human aspects even more by insisting upon a "humanistic assessment" of the various actions that are planned. The interdependency that exists between Government, industry, and individuals is quite explicit in many areas, but unfortunately it is very subtle in others. While we can see the direct effect of some actions with great ease, the less visible effects are more difficult to handle; hence, we would do well to recognize the subtleties of some of our other relationships, particularly when the results may not become visible for a long time into the future. The impact that such action can have upon the personal well-being of our society is important and must be considered more fully. This is both a people problem and a policy problem.

A few examples maybe of value in emphasizing the people-related problems of these materials issues. In the 1960's, it was perceived at the Federal level that a major deficiency existed in the

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availability of the number of material scientists who were being trained in this country, This was indeed correct. As a result of this concern, a major effort was undertaken to expand the research and the educational capability for materials in a number of our major universities, Materials Research Laboratories were subsequently established, The perceived need for materials research of this fundamental nature has now diminished, but these laboratories are in existence, and are continuing to do excellent research and graduate outstanding people. Note that I said “the perceived need” for fundamental research has diminished, because there is a great effort underway to change the direction of these laboratories toward more applied activities. I suspect that the tendency to divert these laboratories is not well conceived, and ultimately will be found to be in error. The contributions of these laboratories to the solution of specific applied problems may not be great, but I think it is likely that the people being trained will contribute in a major way to finding long-term solutions to our long-term materials problems. Thus, it may turn out that the basic orientation of these laboratories is extremely beneficial to finding solutions to the long-term materials needs of this country.

To take a second example, our national laboratories–reservoirs of tremendous talent and capability—have found it difficult to move from the objectives of military and space agencies to the needs of the civilian economy, We have yet to learn how to help these laboratories move gracefully from an emphasis on nuclear weapons and defense to civilian, energy-related research, Of course, we could accept a major disruption in the careers of the people involved, if we were willing to ignore the human aspects of this problem. It is essential that we maintain a long-term perspective of our national needs. We must find ways to change our national institutions in a fashion that permits a continuity of interest while responding in a timely fashion to changing requirements.

Our technical disciplines are no more immune to these problems than are our formal institutions, Consider, for example, mining engineering and power engineering. Both of these disciplines once languished and had almost disappeared from our universities, with neither proper support for the research, nor an interest being displayed in the subject matter by the most talented and imaginative students. Now, we find a deficiency in students and an absence of genuine research in these disciplines. But we cannot train people for positions for which there are no future opportunities of employment. Neither can we afford to ignore important technical areas. This is a dilemma that we have yet to address fully, and in fact we have not found a way to foresee our long-term needs for specially trained people.

In addition to the people aspects of these problems, there is also the issue of how we develop an understanding of the problem itself. If a technology assessment is to have long-term utility, I would suggest that the following guidelines be carefully followed.

- A clear distinction between "technological assessment" and "technological forecasting" must be maintained.
- A short time frame and a stable environment are critical if the assessment is to be useful.
- An adequate data base must be used if an accurate assessment is to be made,
- An objective assessment requires that no preassumed bias be allowed to penetrate the assumptions of the study,

It may be helpful to expand upon these points briefly. The assessment process tends to assume an existing technology and to explore the ramifications of implementing it. This assumes that the technology is reasonably well-developed. One cannot establish the technical facts by consensus votes. Hard data on the particular technology must be available, and generally must be agreed to by the experts if an assessment is to be useful. This does not mean that implications drawn from the data will be universally accepted, In fact, the conclusions may be controversial. After all, one often is dealing with sociological issues, and the ability to predict social events is at best imprecise. Far too often, assessing the social implications comes down to a matter of judgment, rather than to a prescribed means of making a prediction. But the technical data must exist—and must be valid–before any assessment should be undertaken.

Further, it is basically impossible to anticipate an unusual event, e.g., the OPEC embargo. Assessments are usually predicated upon an extrapolation of the current status. So, if the time frame is long, the chance that an unusual event will occur is great. This suggests that an assessment should be viewed as a living issue, with frequent review and updates to reflect recent unpredicted events.

Forecasting technological developments is subject to even more uncertainty than assessing the impact of technology. Technological feasibility can be established with a fair degree of certainty, but the probability of implementation is often not predictable. As a recent example, the Wankel engine was in production overseas and well on its way to implementation in North America when fuel economy became of increased importance. An engine that had been shown to be technically feasible suddenly became of questionable advantage in the product, when the basis for assessment required that different values be assigned to the various criteria used in making the product decisions.

Thus, the distinction between assessment and forecasting relates closely to the time frame being considered. An attempt to assess the long-term consequences of an event generally is more akin to forecasting than to assessment because of the greater uncertainty in the conclusions and assumptions. A forecast must be viewed as having less credibility than does an assessment.

Furthermore, it is very tempting to use technology assessment as a tool for advocating a particular predetermined bias. It is easy to make the assessment process self-fulfilling by setting up the proper assumptions. The outcome of an assessment study will likely be quite different if one asks, "What are the consequences of Government intervention into the market area?" than if one asks, "How should the Government intervene to affect this market?" Either of these questions may be appropriate, but one must not expect a universal answer to all issues from a single study.

These concerns do not mean that it is improper to attempt technology assessment. What they do suggest is that it is important to maintain an awareness of the limitations of the process and to recognize the dangers inherent in making major long-term decisions based upon such assessments.

Perhaps one of the greatest difficulties with our system is the fact that many organizations act as if they were independent, only to find that their actions strongly influence the options other organizations could exercise. Let me give one small example. The federally legislated fuel economy standards for automobiles have stimulated many of the manufacturers to search for ways to reduce vehicle weight. The bumper system is one of the systems that has been carefully reviewed for possible weight reduction, But in considering what modifications are allowed by the damageability regulations, it is found that a simple constraint on bumper rentability may dictate that thin-guage, high-strength, low-allow steel may not be usable. I seriously doubt that the inclusion of this constraint on rentability was considered as having any impact upon fuel economy when this regulation was adopted. While this is just one example, we could list many more. This just emphasizes that we are a closely coupled society, and that we must be constantly aware of the possible impact of seemingly isolated actions upon other segments of our society, No wonder an adequate assessment is so difficult–if not impossible,

Let me turn now to what may strike you as being a nonexistent problem, That is, who should do the assessment? It is well established that the Federal Government, private industry, and the "not-for-profit" organizations regularly undertake assessments with technical input from staffs and individual consultants. But an entire component of the technical community is frequently excluded from such studies–the technical professional societies. This is such a glaring omission that I would like to dwell on it for just a moment.

While the professions can identify opportunities for new technical developments as well as potential dangers that may result from new developments, they seldom have any direct involvement in setting the objectives that are followed by a given segment of the populace or by the governmental agencies. They may not even be participants in the deliberations. This can be both a benefit and a frustration to the professional organization. The separation from the direct, decisionmaking process tends to remove the professions somewhat from the political process, and thus allows them to remain concerned with the technical content of issues, as well as with the more narrow coficern for the well-being of their members, and the standards of performance of those members. But the separation can be a frustration, for the members may readily perceive of situations in which decisions are being made without proper concern to the technical issues and where the true, long-term consequences of the decisions are not being properly evaluated.

Thus, on the one hand, the profession can benefit from this detachment, but the public will suffer from the absence of professional involvement. On the other hand, to involve the professional organization in the details of the decisionmaking process transfers a responsibility to it that it finds hard to cope with, for few of the professional societies are organized to operate effectively in the political arena. Thus, it is predictable that many professional organizations often withdraw into the seclusion of the technical issues and refuse to participate actively in controversial issues. This often leads to decisions being made which have a future impact upon the well-being of the profession, upon subelements of the profession, or upon the people who benefit from the profession without proper consideration being given to all aspects of the problem being examined.

It seems to me that the regular inclusion of representatives of the professional societies in the technology assessment process should be a key objective of the organizers of the assessment, because the membership of the technical societies has a vast store of information that would be of immeasurable value to the assessment process. Further, this inclusion offers a significant avenue for realistic involvement of the societies in establishing a basis for the more general decisionmaking process.

Because the contributions to the assessment are made by individuals, it is paramount that the roles of individual members on the team be carefully examined. If appointed as an individual because of his personal expertise, the individual can speak for himself. If appointed as a representative of a professional society, an industry, or of an individual company, it must be clearly understood by all as to how that individual will obtain the consensus of the group he represents. Unless this process is carefully detailed, it is easy to be misled about the general acceptance of a set of recommendations it produces.

Finally, then, having talked about the assessment process and who should do it, I would like to review for a moment or two what we should expect the outcome of an assessment to be. Generally speaking, I do not believe that a technology assessment should identify a solution to a particular problem. Rather, it should examine the consequences of various actions; it should explore alternatives; it should identify areas where insufficient information or data exist; and it should indicate areas where further research is needed before an adequate assessment can be made. To identify a solution to a specific problem—the temptation being to invent– may be more satisfying to the participants or to the sponsor, but it is oftentimes less useful to the policymaker, for as I mentioned before the manner in which the question is phrased often determines the answer. If the wrong question is asked, the study will be of limited value. Further, the assessment should be regularly reviewed and updated if it is to have long-term utility.

We must approach with caution those planning studies which suggest actions to manage our system so that shortages are eliminated—be they material, energy, or human, Our past "track record" is not all that good with such plans, Thus, a healthy skepticism is warranted. Further, many of our programs appear to be derived from studies that were based upon insufficient data and too much on the strict technical issues as known at that time. Too little attention was given to what I've chosen to call the "humanistic" issue. We can start programs, but find it hard to turn them off, We can start training people, but are less concerned about how to employ them. We can identify problem areas, but sometimes ignore the fact that we have too few people to search for meaningful answers,

We must attack these overall problems if we are to find ways of utilizing all elements of our society more effectively, The decisionmaking process must include not just the political and regulatory organizations, but also our professional organizations, and the disciplines they represent, and those organizations that are concerned about people.

We must never lose sight of the premise that facts must exist or be developed if a plan is to be well-founded. Speculation and conjecture are contrary to the basic assessment process.

Finally, our planning must include major efforts at examining alternatives rather than looking for a solution to a neatly stated problem, Unless we face up to these problems, we will waste resources, improperly utilize talented people, and be less than effective in finding the solutions to many of our complex problems. It is an awesome task to plan within the uncertainties of our time, but the need for success makes it worth the effort.

III. Tutorial Papers

MATERIALS ASSESSMENTS FOR THE UNITED STATES CONGRESS

by Albert E. Paladino
Program Manager for Materials
Office of Technology Assessment, U.S. Congress

The Materials Program of the Office of Technology Assessment has been in existence for a period slightly longer than that which separates this Henniker Conference from the previous one held in 1974. Several of the topics discussed at the last conference have since become the subjects of OTA assessments. These include materials information requirements for policymaking, materials conservation, stockpiling, and recycling. The background information and analysis, provided by Henniker III, have proven extremely useful in the development of these projects. A number of the participants at Henniker III have assisted OTA in the initial conceptualization of projects; but as members of the OTA Materials Advisory Committee, they have also provided helpful guidance and critiques during the projects. These points underscore Mr. Daddario's earlier comments regarding the important link between your work at Henniker and the interests of Congress.

Today, I would like to do four things:

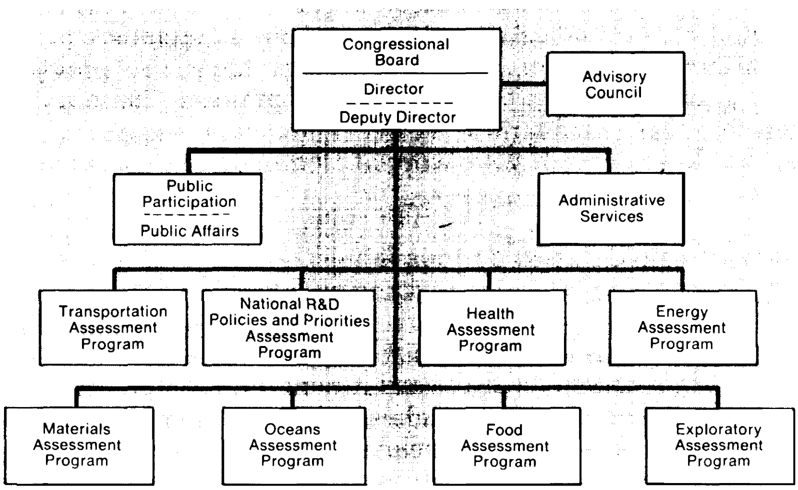
- Describe the OTA organization and its operation;
- Provide an overview of the Materials Program, particularly emphasizing the holistic approach being used to tie together various congressional requests for studies;
- Describe briefly those studies that deal with issues related to materials supply and demand, going into some detail on two studies, Materials Information Systems and Economic Stockpiling. The Task Forces related to the work of the National Commission on Supplies and Shortages will be considering some of the study findings; and
- Provide background for the Task Force dealing with the OTA Materials Program and stresses on the Total Materials Cycle.

OTA Organization and Operation

The function of OTA is to provide balanced, objective, and timely information regarding the possible consequences of applying a given technology. Technology assessment, as initially conceived, was primarily concerned with technical or scientific matters; however, it has since evolved to include any organized, purposeful activity for which the consequences prior to its application must be evaluated or assessed, It is particularly important that such assessments be made before legislative decisions are required and that the assessments present information on alternative approaches for congressional deliberations, This is a very important point: presenting alternative approaches, including that of doing nothing, and providing an impact analysis for each approach. OTA does not recommend any one approach; we merely provide the impact analysis which permits Congress to objectively select one alternative over another.

The OTA consists of a bipartisan Congressional Board, a Director, a Deputy Director, and other employees and consultants necessary for the work of the Office (figure 1). Policies of the Office are set by the Congressional Board which is the oversight body governing OTA.

FIGURE 1.—Office of Technology Assessment



The OTA Congressional Board, figure 2, is made up of six Senators and six Representatives, evenly divided by party, who are appointed respectively by the President Pro Tempore of the Senate and the Speaker of the House. The Director of OTA is a

FIGURE 2.—Technology Assessment Board
1975-1976

Senate Members	House Members
CLIFFORD P. CASE	GEORGE E. BROWN, JR.
ERNEST F. HOLLINGS	MARVIN L. ESCH
HUBERT H. HUMPHREY	MARJORIE S. HOLT
EDWARD M. KENNEDY*	CHARLES A. MOSHER
RICHARD S. SCHWEIKER	OLIN E. TEAGUE**
TED STEVENS	MORRIS K. UDALL

Non-voting Member

EMILIO Q. DADDARIO, **Director,** OTA

- *Chairman. 1973-1974
- **Chairman, 1975-1976

non-voting member of the Board. Requests for OTA assessments may be initiated in one of three ways:

- The OTA Board;
- The Chairman of any Standing, Special, Select, or Joint Committee of the Congress, acting for himself, or at the request of the ranking minority member, or a majority of the committee members; or
- The OTA Director, in consultation with the Board.

Congressional committees have first access to OTA Assessments, and are kept informed on a regular basis of the work progress. If appropriate, preliminary results of the assessments are used by committee staffs in their legislative analysis and preparations for public hearings.

OTA Materials Program Strategy

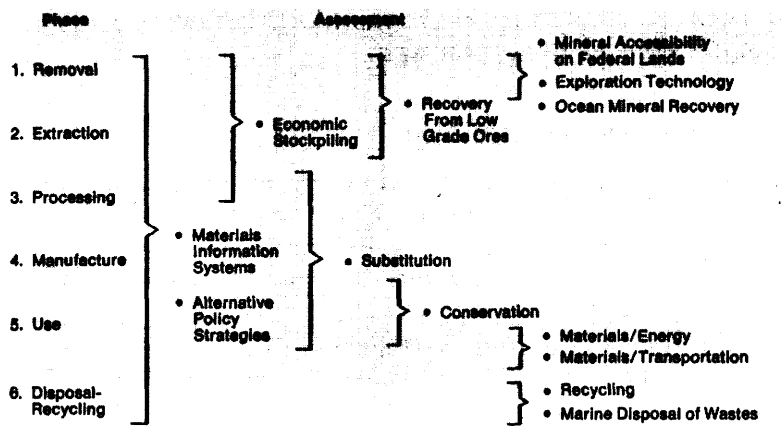
OTA studies are being carried out in response to specific congressional committee requests. These requests generally reflect the jurisdictional viewpoint of the requesting committee, and usually do not take into account the broader aspects of an issue, like the subject of this Conference, materials scarcity. For example, the Interior Committee requests are concerned with such matters as land use, land management, mining, and natural resources—all of which generally relate to material supply. The Commerce Committee, on the other hand, is interested in subjects which deal with product durability and standards, materials wastage, and substitution—all of which relate to material demand.

In planning the OTA Materials Program, our broad strategy has been to make use of the unifying concept of the total materials cycle in an attempt to tie individual Congressional requests for assessments into a totally integrated approach. The concept of the total materials cycle has been presented in the COMAT and COMRATE reports, and is familiar to most of you; some of you no doubt contributed to its evolution and final development. Using the total materials cycle as an analytical framework permits us to assess policy options bearing on one or more phases of the materials cycle in relationship to those bearing on other phases. Often good solutions to problems turn out to be poor ones in the light of broader overviews of total system elements.

An assessment of the materials implications of future trends in automobiles provides one example of this. Meeting the objective of increased fuel economy will require smaller or lighter weight automobiles. Weight reductions may be achieved with the use of aluminum or plastics, both of which add to the complexities of automobile recycling, The cost increase could result in a decrease in recycling, contrary to resource recovery policy objectives. On the opposite end of the cycle, there are already concerns about aluminum supply and our almost total reliance on foreign sources. Using large amounts of aluminum in automobile construction can only exacerbate this problem.

Figure 3 depicts how congressional requests are considered within the framework of the total materials cycle. The phases of

FIGURE 3.—Conceptual Approach for Conducting Materials Assessments



the materials cycle are numbered one through six, and the individual assessments are identified by brief title. Most assessments cover at least two phases, and two cover the entire cycle.

I would now like to present some details of the assessments which relate to the long- and short-term views on raw materials policy in the United States. The long-run view is concerned with whether or not the supply of materials, at reasonable prices, will be sufficient to support economic growth over an extended period, and what steps, if any, should be taken to improve the U.S. position. The short-run view is concerned with immediate problems of supply and demand and ways to avert or mitigate them. For both sets of materials-related problems, a distinction should be drawn between what results, both good and bad, can be expected from the workings of the present system and those which could be expected from direct actions of the Federal Government.

Furthermore, while the focus of each assessment is primarily upon U.S. materials strategy, the analysis takes into account the complex interrelationships between US. policies and various other national policies around the world. The various assessments represent different approaches to the issue of scarcity: some apply to supply; others, to demand.

In sum, materials problems have complex roots, and actions designed to deal with them need to be considered on a truly systems basis, taking into account the interactive manner in which the total materials system influences, and is influenced by, other systems-like foreign policy, domestic policy, environmental changes, demographic trends, the world economy, and so forth.

Ideally, materials should flow through all stages of the materials cycle in order to supply adequate amounts of materials and energy for the basic requirements of nutrition, shelter, and health, while sustaining a dynamic economy with minimum waste and environmental impact. The flow of materials should be continuous, and there should be continuity in prices as well.

Many factors affect materials flow through the economy, and the United States has relied primarily on the marketplace to provide materials at what are loosely termed reasonable prices. However, there are growing concerns that new, and quite different, problems may not be dealt with by relying solely on market adjustments. These problems may be described as stresses which perturb the equilibrium prices and flow rates of materials at any point in the materials cycle. As you look at these examples in figure 4, it is obvious that some of the stresses perturbing the cycle are foreign in origin and others are domestic. The quadrupling of bauxite taxes is an example of the former; the increased costs associated with meeting new environmental and health regulations, the latter. The coupling of energy and materials flows is yet another type of stress which has both foreign and domestic origins.

FIGURE 4.—Stresses on the Materials Cycle

- Worldwide Increase in Population and Demand for Materials
- Adverse Actions by Foreign Governments
- Internal Difficulties in Producing Countries
- Depletion of Concentrated Resources
- Decrease in Rate of Mineral Discovery
- Increase in Energy Costs
- Long-Term Trend in Mineral Industry Investment
- Environmental and Safety Requirements
- Government Regulation
- Other

Developing suitable policy alternatives which will be both timely and effective requires an analysis of when the impacts of the various stresses might be expected (figure 5). On the one hand, short-term stresses like embargoes require quick actions if adverse impacts are to be avoided or alleviated. On the other hand, long-term materials stresses, like the depletion of reserves or the increasing world-wide demand for materials, require different types of policy responses. For the short-term stresses, it is especially important to maintain an up-to-date information base ‘regarding potential situations affecting materials supply/ demand, e.g., the developments regarding the Law of the Sea

FIGURE 5.—*Policy Alternatives To Relieve Stresses*

- Supply Oriented Options
  - —Assist Domestic Production
  - —Expand Mineral Exploration
  - —Improve Access to Federal Lands
  - —Improve Access to Foreign Supply
  - —Promote International Trade Agreements
- Demand Oriented Options
  - —Encourage Conservation
  - —Encourage Substitution
  - —Tax Concessions
  - —Demand Management
  - —Export Controls

Conference or the less-developed countries' proposal at UNCTAD IV for indexing the prices of basic commodities to the cost of manufactured goods. For the long-term stresses, a carefully formulated program of materials research and development, coupled with investment incentives, should be considered.

Identifying the stresses, their anticipated impacts, as well as possible alternative policies and decision mechanisms for averting or relieving them, is essential in order to maintain a smooth, though probably a redistributed flow, of materials through the total materials cycle– and hence a health economy, Moreover, both Government and private sector roles must be properly balanced in considering these alternative policies.

Assessments Related to Supply and Demand

I would now like to illustrate how these previous comments apply to the structuring of the overall materials program by discussing some of the details of several assessments. Five selected assessments are illustrated in figure 6: two relate to supply phases of the cycle, two relate to demand phases of the cycle, and one covers both supply and demand elements of the materials cycle. Also shown are the principal stresses, which to a large extent prompted the requests for these assessments.

FIGURE 6.—Assessments Related to Supply and Demand

STRESS	STUDY
SUPPLY	
—Adverse Action by Foreign Government in Source Country	• Economic Stockpile
—Market Instability	
—Environmental Action	• Mineral Accessibility
—Competing Land Use	
DEMAND	
—Increasing Worldwide Demand	• Conservation
—Depletion of Scarce Materials	• Substitution
—Increasing Energy Costs	
SUPPLY-DEMAND	
—Need for Reliable Forecasting	• Information System

Considered within this framework, these assessments can be viewed as component elements of an overall strategy for dealing with materials-related issues. Both short-term and long-term stresses can be dealt with by a variety of approaches. Economic stockpiling is one short-term response to many potential supply disruptions; another response might include export controls on critical materials. Other studies in this list, which clearly deal with long-term responses, represent a variety of approaches.

A series of congressional requests has resulted in three studies directed toward increasing the future supply of domestically produced minerals. The first study nearing completion is analyzing the potential impacts of modifying and restructuring laws, policies, and other institutional factors which significantly affect the exploration, production, and physical accessibility of essential minerals on Federal onshore lands.

This land encompasses about one-third of the Nation, or an area almost equal to that part of the United States east of the Mississippi, and includes vast acreages in the Western States and Alaska, where much of the hard-rock and fuel minerals are located. The utilization of Federal land is subject to a wide variety of restrictions on mining activity, including statutory and administrative withdrawals for wilderness preservation, national parks, wildlife refuges, agricultural and grazing uses, energy development, mineral conservation and development, and military reservations. The drive for greater energy self-sufficiency is likely to produce strong pressure for large-scale, unprecedented development of such domestic energy resources as coal, oil and gas, and oil shale, much of which lie on Federal land. The use of Federal lands to expand domestic availability requires a carefully planned policy which weighs the full spectrum of environmental and societal impacts.

A closely related assessment is examining the state of mineral exploration technology and mineral exploration programs, The purpose of this second assessment is to assess the potential for discovering new domestic resources and reducing the uncertainties pertaining to U.S. mineral resource information. It will examine the state of exploration techniques now in use and the R&D programs in geology, geochemistry, geophysics, deep drilling, remote sensing, and other activities which contribute to mineral exploration technology, In addition to the technology of exploration and the associated R&D, this study will also examine public resource-evaluation programs by Government agencies, as well as mineral exploration programs in the private sector.

The third study in the series on domestically produced minerals deals with the potential for extracting metals from low-grade resources. The purpose of this study is to assess the potential for developing low-quality, domestic resources as possible solutions to both the short-term problems of dependence on foreign supply and the long-term, worldwide resources demands. For various selected materials, the study will consider U.S. domestic ore resources, facilities and investment requirements, cost of production, and other problems of utilizing domestic resources with available technology, Among the problems of utilizing low-quality resources to be considered include energy requirements, environmental impacts of mining and onsite beneficiation, and transportation availability.

The assessments discussed thus far concentrate primarily on the supply side of the materials equation, On the demand side, a request has been made to assess the potential for materials conservation as one alternative for dealing with the long-term problems of materials scarcity, This study is analyzing the potential for materials conservation throughout the materials cycle, and is developing specific strategies for conservation through improved materials utilization in the manufacturing and use phases of the materials cycle.

Another demand-related study is examining the prospects from ongoing R&D activities in the development of policies to deal with problems of material scarcity. The purposes of this study are (1) to examine for selected materials the state of R&D activities which can lead to substitutions for import-dependent materials and (z) to estimate the time and quantitative impacts which the R&D activities might have on scarcity-related problems. The final study included in figure 6 deals with the supply and demand relationships, and information requirements for materials policy decisions.

Materials Information Systems

The materials information assessment is focused on those aspects of the overall materials information problems which are of most concern to Congress— namely, forecasting and assessing the supply and demand of metals and minerals.

This assessment treats in a unified way the total materials cycle, including the major economic factors associated with the use of materials. Effective management of the materials cycle— providing the right amount of material at each stage in the cycle — requires a broad spectrum of information. To provide this information to decision makers, a large number of formal and informal materials information systems have evolved. Some are in Government, but most are in the private sector.

AIthough these systems have served the Nation well for many years, new stresses on the total materials cycle have raised concern for their continuing effectiveness, and it was against this

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growing concern that OTA addressed the following questions concerning materials information systems:

- Are the systems which currently support Federal materials policymaking adequate to deal with the complex new issues posed by materials shortages?
- In particular, are the systems able to project whether a shortage is likely to occur, estimate its consequences, and evaluate the effects of possible Government actions?
- If not, what kind of new or improved system is needed?
- How might such a system be achieved—by what organizational means and under what institutional arrangements?
- What governmental, economic, social, international, and legal impacts might such an improved system have?

For the sake of time, I will not attempt to present information from the assessment in response to each of these questions. Instead, I would like to give you a brief overview of what is contained in the final report, of which you have the summary volume, and then if you have detailed questions which cannot be covered now, I will respond to them during the Task Force sessions,

The shortcomings of present materials information result not so much from a lack of data as from the more stringent requirements for information management, analysis, and coordination resulting from the increasingly complex problems now facing policy makers. That these shortcomings do exist was determined in large part by interviews with senior policy makers in the Government as well as private industry, These present systems by and large perform well relative to their intended missions. An improved information system would provide policy makers with the means for more adequately testing the effects of likely scarcity situations, Such a system would allow policy makers to assess "what if" scenarios—the effects of a foreign cartel limiting supply, for example, or the consequences of Government incentives to encourage increased domestic production. This capability will not be realized by simply allowing the current materials information systems to evolve.

The study describes a conceptual framework for an improved materials information system which takes into account the complexities linking the amounts of materials produced and used with their domestic and international economic parameters, The conceptual system responds to the need to quantify the most important of these and to make the relationships evident to decision makers formulating materials policy.

The conceptual system developed in the assessment organizes materials information so as to account for the principal sources of supply, demand, and utilization for each critical material, For each material, the system develops an index of scarcity indicative of the need for close Government monitoring and possible response, Nine essential functions are incorporated into the conceptual system (figure 7),

FIGURE 7.– Conceptual System Core Functions

- **Monitoring inventories of resources and reserves.**
- **Monitoring the status of strategic and economic stockpiles, if established.**
- **Monitoring imports and exports.**
- **Monitoring the status of recycled materials.**
- **Monitoring quantities of materials produced and available production capacity.**
- **Monitoring quantities of materials consumed in end products.**
- **Forecasting supply.**
- **Forecasting demand.**
- **Forecasting the interaction of price on supply and demand.**

By treating supply and demand as functions of price, the conceptual system would indicate how much of a material was likely to be produced and used at each stage in the total materials cycle. The policy maker could thus determine whether the normal market mechanisms could absorb the impacts of a given stress. If they could not, and unacceptable economic distortions could occur, then the system could be used to test the effectiveness of alternative Government responses.

The Government's present materials information systems constitute a strong base on which to implement the conceptual system described in the assessment. Some of these, in particular the systems used for forecasting agricultural food and fibre commodities, have been in development for some 40 years. Other, newer systems covering mineral commodities are rapidly undergoing improvement, Many of these systems already perform some of the monitoring and projection functions embodied within the conceptual framework.

Three approaches were identified for improving the Federal Materials Information System:

- Approach 1 would better coordinate the development of the existing separate materials information systems to achieve the desired capability through an interagency committee or congressionally authorized coordinating group;

- Approach 2 would bring about changes in the existing information systems via a series of step-by-step advances by a full-time coordinating organization. The group would more closely coordinate the existing materials information systems and have the authority to add new supplementary information services as necessary; and
- Approach 3 would design and develop the information system from the "top down," using the existing information systems and adding new ones as determined appropriate by a central management office with adequate authority.

Whichever approach is taken, the improved system would incorporate the following basic information services (figure 8):

All three approaches require specific action by Congress and the President. Approach 1 will, at minimum, require an Executive Order, agency directives, and congressional oversight; it may also call for legislation, Approaches 2 and 3, or any other major program implementing the conceptual system or its equivalent, will probably require new legislation,

FIGURE 8.—Basic Services for a New Policy Level Information System

SERVICE	FEATURES
Referral	Provide Awareness of Information Availability
Information Exchange	Facilitate Information Exchange Through Establishment of Standards and Data Reporting Formats
Clearinghouse	Provide Users with Available Serial Publications and Reports
Summary Data Base	Aggregate Data on Supply, Demand, and Utilization
Query Management	Prepare Statistical, Historical Trends From Summary Data Bases
Routine Statistical	Provide Statistical Summaries to Periodic and One-Time Requests
Modeling	Provide Analytical Modeling for a Variety of Materials Problems. Insure Common Data Base and Selection of Forecasting Parameters

A comparative analysis of establishing the system within the private sector, a State or local government agency, a quasi-governmental institution, and a Federal agency (both in the legislative and executive branches) indicated that locating the materials information system within the executive branch would best accomplish its objectives. Within the executive branch, the range of feasible alternatives is illustrated by seven combinations of institutional arrangements and information system approaches, each having the functions and responsibilities indicated by the abbreviated titles (figure 9).

The major impacts of implementing an improved information system are discussed in the report and are grouped into three categories:

1. Beneficial–Strengthening of the Government's capability to forecast scarcity and make contingency plans;
2. Mixed Beneficial or Detrimental–Stimulation of planning in the U.S. economy by increased monitoring;
3. Detrimental—Potential misuse of sensitive information.

The assessment examined the sources of Federal authority to gather materials information from the private sector and concluded that establishment of the conceptual materials information system would (a) be consistent with existing recognized Federal regulatory powers; (b) would not greatly expand, if at all, Federal authority over the materials industry; and (c) need not violate any recognized rights of corporate privacy if adequate attention is given to checks and balances in system implementation.

With respect to the effects of an improved materials information system on patterns of industrial competition, the analysis concluded that the system would collect and provide information which, if properly used and supplemented, could stimulate research and development, possibly decrease major short-term price fluctuations, help stabilize materials-related industries, lower materials costs, and assist in business planning. The information might also increase competition by forcing new dynamics into demand, supply, and use of materials.

FIGURE **9.– Implementation Alternatives**

1. **Materials Information Referral Office**	**Compatible with Approach 1**
2. **Materials Information Coordinating Board**	
3. **Bureau of Materials Statistics**	**Compatible with Approaches 2 and 3**
4. **Bureau of Materials Statistics and Forecasting**	
5. **Materials Statistics Administration**	**Compatible with Approach 3**
6. **Materials Statistics and Forecasting Administration**	
7. **Materials Information Commission**	

Economic Stockpiling

The materials shortages experienced during 1972-1974, coupled with the OPEC oil embargo, raised concerns about other raw materials embargoes and price increases by organized producer countries. At the request of the House Committee on Science and Technology, economic stockpiling has been examined as a possible component of a national strategy for insuring materials supply during peacetime.

The objectives of the assessment were to determine whether or not stockpiling to achieve selected objectives yields sufficient benefits to merit its consideration by Congress as one component in a larger materials strategy, and to develop a generalized methodology for use in establishing and operating an economic stockpile. An economic stockpile is similar to insurance in that acquisition and holding costs are paid in anticipation of reducing the costs of possible future problems. A decision to establish an economic stockpile depends on the belief that there will be eventual net benefits, either through deterrence of a problem, or through relief if a problem occurs.

The assessment addressed the following questions:

- Should the United States consider establishing an economic stockpile?
- What possible economic stockpiling policies might be established?
- What possible impacts might result from implementing these policies?
- What are the alternatives to an economic stockpile?
- What options and institutional arrangements are available to Congress in considering possible legislation? and
- What considerations require further analysis?

Again, for the sake of time, I will not attempt to present information from the assessment in response to each of these questions. Instead, I would like to give you a brief overview of what is contained in the final report, of which you have a draft copy, and then if you have questions, respond to them during the Task Force sessions.

Eleven policies were initially examined, and five were selected for detailed assessment (figure 10). These five are numbered SP-1 to 5, One material relevant to each policy was then used to assess its impacts. The impact analysis covered economic, political, social, legal, and institutional considerations. Both the methodologies and the specific impacts are presented in the final report; however, let me briefly highlight the key findings for you.

Economic stockpiling can be considered one means of responding quickly to the short-term problems, but it should not be con-

FIGURE 10. –Possible Economic Stockpiling Policies

FOREIGN

- **Discourage or counteract cartel or unilateral political actions** (SP-1)
- **cushion the impact of nonpolitical import disruptions** (SP-2)
- International materials market stabilization (SP-3)
- Support friendly nations in the event of temporary shortages
- Increase or maintain foreign country production
- Commodity trading between the U.S. and foreign countries

DOMESTIC

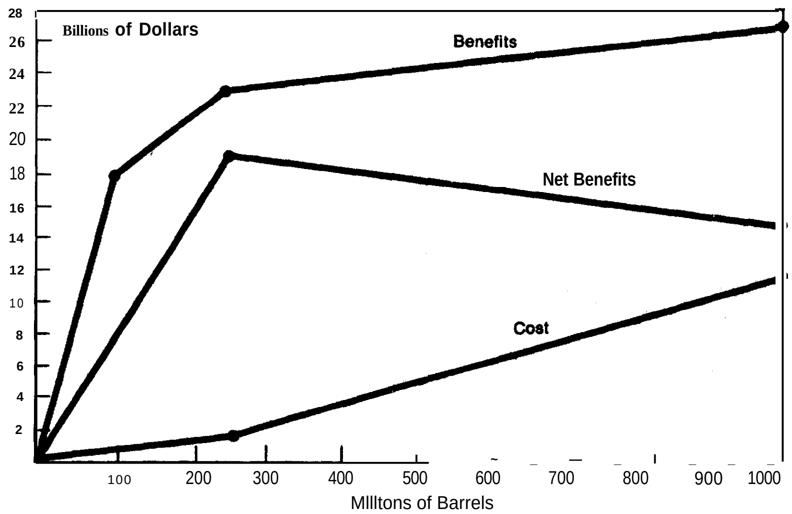
- Conserve scarce domestic materials (SP-4)
- Provide a market for temporary surpluses and ease temporary shortages (SP-5)
- Support domestic production of selected foreign source materials
- Advance new technology for materials supply
- Encourage recycling

sidered a means of effecting long-term solutions to them. On the other hand, an economic stockpile could have value in providing the time required for the United States to implement such long-term policies as substitution, conservation, or the development or alternative supply sources.

Economic stockpiling is inherently a process of market intervention and will create economic impacts (i.e., benefits and costs) which are distributed unequally throughout the U.S. economy. An economic welfare model developed in the assessment permits the stockpile managers to estimate economic benefits and costs in terms of an assumed future, which includes probabilities of supply interruptions and elasticities of supply and demand.

The economic welfare model was used to estimate, for the economy in general as well as for specific groups, the economic impacts of implementing five selected stockpiling policies for petroleum, copper, tin, tungsten, and zinc. These estimates indicate that some policies will have positive economic net benefits and some will have negative economic net benefits. As indicated in figure 11, **a** petroleum stockpile in the range of 250 million barrels would be required to deter cartel actions. It should be emphasized that the estimates apply only to the specific materials examined and within the scenario assumptions described, and should therefore not be taken to indicate that precise quantities of specific materials should or should not be stockpiled. Nevertheless, the nature and magnitude of the estimates are sufficient to indicate that an economic stockpile should be given detailed consideration as one component of a more comprehensive national materials strategy and that measuring the benefits or costs of a supply disruption in terms of its probability.

FIGURE 11 .—**Economic** Net Benefits of SP-I



rather than its certainty, will significantly reduce the quantity of material to be stockpiled.

The United States should consider economic stockpiling in terms of foreign policy as well as domestic affairs. The policy objectives of a particular stockpile should be clearly delineated, Analysis of the Strategic and Critical Materials Stockpile indicates, for example, that it has been used in a limited manner to achieve selected economic purposes. Further, the operation of an economic stockpile will create enough problems and pressures to warrant its being sufficiently insulated from the political process that it may act in the public interest, yet remain responsive to congressional scrutiny,

The decisions relating to the establishment and operation of an economic stockpile—specifically, the acquisition and disposal of materials—should be systematically made and documented, using an approach similar to the decisionmaking process developed in this assessment (Decision Criteria Model).

There are four basic options available to Congress in considering possible legislation.

1. The first option is for Congress and the President to forego establishing an economic stockpile, letting the current market system, with its existing support mechanisms, attempt to prevent or correct the impacts of supply disruptions and price increases.
2. The second option is for Congress to act without drafting new legislation. It could initiate such action by providing

information regarding economic stockpiling within the legislative branch, the executive branch, or the private sector.

3, The third option is for the President to take action, within the limits of his existing authority, without proposing new legislation. Such action could be accomplished in several ways: (a) issue a Presidential proclamation to set overall policy direction, (b) issue an Executive or agency order, or (c) make research and development grants available for analysis of materials problems.

4. The fourth option presumes that, for one or more reasons, the first three options will not be sufficiently effective in dealing with current or anticipated materials supply and price problems and that authorizing legislation is required,

There are six institutional arrangements available to Congress in considering possible legislation.

First, a unilateral economic stockpile controlled and operated by the U.S. Government might be established. It could be another component of the strategic stockpile, or it could be an independent stockpile whose operations are carefully coordinated with those of the strategic stockpile.

Second, a unilateral economic stockpile, controlled by the U.S. Government but operated by U.S. industry, might be considered.

Third, a unilateral economic stockpile, controlled and operated by a public-private corporation, could be established. It could be funded by the Government, vested by Congress with a mandate and guidelines on U.S. stockpile purposes, and given independent authority to acquire and maintain national stockpiles without direct Executive control but with provisions for Executive consultation. The corporation would be able to maintain a certain degree of political independence comparable to the Federal Reserve System on monetary matters.

Fourth, the United States could participate in an economic stockpile operated by two or more nations, either multinational or international in nature, formed along such existing political or organizational lines as the Organization of American States (OAS); the European Economic Community (Common Market); the United Nations; or just with friendly nations having materials requirements similar to those of the United States. At present, the United States is conducting several discussions/negotiations which do consider this arrangement: the United Nations Conference on Trade and Development (UNCTAD) discussions within the United Nations and the International Energy Agency.

Fifth, the United States could participate in an economic stockpile through the creation or expansion of producer/consumer councils like the International Tin Council which is run by both producers and consumers and maintains its own buffer stock to help stabilize the supply and price of tin.

Sixth, the U.S. Government could establish and control an economic stockpile, but operate it according to international guidelines. Arrangement 6 would recognize the fact that some national economic stockpiles are being created, but that some countries like West Germany have not implemented them because of serious concern regarding their impact on domestic and world market systems. An international code of operations might help reduce this concern, as well as develop effective mechanisms for alleviating U.S. supply problems without increasing the world shortage.

Conclusion

As Mr. Daddario stated, the role of OTA is to consider the long-range needs of the United States in the field of materials management and materials technology. I have presented today the approach we are taking, building on much of what has been developed before–particularly the unifying concept of the total materials cycle.

The principal continuing objective in carrying out OTA assessments will be to provide Congress with an analytical framework, a methodology, and a current information base for examining the various interrelated policy instruments of a national materials strategy—and in so doing, establish a response capability to address congressional inquiries regarding materials-related issues, We are asking the task forces to assist in meeting this objective by evaluating the importance of various stresses in terms of their anticipated intensity and timing, possible policy alternatives to avert or relieve the stresses, and finally the decision mechanisms to implement the alternative policies.

These then are the general directions which we hope the task forces dealing with the materials assessments for Congress will take. In this way we hope to utilize the special expertise represented here to assist in developing component strategies for U.S. materials policy.

Thank you for your attention. We look forward to working with you in the task sessions.

THE WORK OF THE NATIONAL COMMISSION ON SUPPLIES AND SHORTAGES

by George C. Eads, Executive Director
National Commission on Supplies and Shortages

Many of you have probably heard of the National Commission on Supplies and Shortages, and are aware of its history. For those of you who are not, and for those of you who may have lost track of us, let me bring you up to date,

We were created by Public Law 93-426 which was signed on September 30, 1974. The legislation setting us up specified that the Commission be composed of two members of the Senate, two members of the House, four senior Administration officials, and five individuals from the private sector. The first group of appointments were made quickly. Senator Brock, Senator Tunney, Congressman Rees, and Congressman Stanton were named to represent the Congress. Secretary Simon, Mr. Lynn, Mr. Seidman, and Mr. Greenspan were named as the senior Administration officials. However, there was a delay of about one year in appointing the five private-sector Commissioners. Finally in the late summer of 1975, Philip Trezise, a senior fellow at the Brookings Institution and a former Assistant Secretary of State for Economic Affairs; George Kozmetsky, Dean of the Graduate School of Business at the University of Texas at Austin; Nat Weinberg, the retired Chief Economist for the United Auto Workers; Hendrik Houthakker, Professor of Economics at Harvard and formerly a member of the President's Council of Economic Advisers; and Donald Rice, President of the RAND Corporation, were named. Dr. Rice was designated as Chairman of the Commission. The Commission met for the first time in September, and at that meeting I was named Executive Director.

During the one-year interval between the first appointments I mentioned and the time when the Commission membership was filled out and began meeting, our congressional members, anxious to get things under way, requested the Office of Technology Assessment to initiate two projects, one on economic stockpiling, and a second on materials information systems. Both are topics that the Commission is required by statute to examine.

Al Paladino has already briefed you on the contents of these two assessments, so I will not comment further on them.

As I just mentioned, these two assessments were requested by our congressional members in order to give us a head start once we began operating, They realized that we would be under a tight schedule, and indeed we are. We are required to complete our final report on or before the end of December 1976. To do this, we must have a draft final report ready for Commission discussion by the end of October. To meet this deadline-and we will meet it—the staff's job of gathering information and data must be pretty much completed by just about now. **And** it is, During this month and next, the Commission, in a series of three meetings, will complete framing its general policy positions so that the report drafting can begin. In certain areas, such as stockpiling, this guidance has been received and drafting is now proceeding.

What I want to turn to now is a brief summary of where we now stand in regard to certain of our findings and conclusions. I must preface this with a caveat. The results I will be outlining here represent staff conclusions, not conclusions of the Commission, They should not be attributed to the Commission, but to me.

Now, what have we found?

A recent front-page interview that some of you probably noticed in American Metal Market was headlined "U.S. Supply Panel Finds Metals Levels Unperiled." This would seem to be totally at variance with the title of this conference: "Engineering Implications of Chronic Materials Scarcity," It may be, but let us not jump to conclusions.

We have not found that the world in the future will be untroubled by materials supply problems, that materials will be available in unlimited abundance at declining real or even nominal prices. We have found that the sort of problems we are likely to be facing in the years to come will not be of the sort that many people implicitly mean when they use the word "scarcity" or "shortage." Instead, they are likely to be quite similar to the sort of problems that arose during 1973 and 197LI, problems that had little or nothing to do with the level of the world's reserves of key materials.

Extent of the 1973-74 Shortages

The shortages experienced during 1973-74 were perceived by observers at the time as both widespread and severe. A special report in the June 30, 1973, issue of Business Week entitled "The Scramble for Resources" began by stating:

> The prices of raw materials and industrial commodities from rubber and oil to scrap steel and copper spiral higher. Purchasing agents complain that supplies of everything from wool to zinc are becoming increasingly difficult to get, The United States faces a full-fledged energy crisis, , . .

Articles appearing daily in the business press told of purchasing agents' difficulties in securing necessary materials. Discounts disappeared. Customers were put on allocation. Inventory positions were jockeyed in an effort to adjust to the shortages.

Furthermore, the shortages affected behavior even after they disappeared. Our discussions with companies tell of a new concern on their part for stability and continuity of supply—even if it means that they must pay higher prices, For example, The Wall Street Journal recently reported the case of a purchasing agent who passed up an offer by a foreign supplier of cost savings of approximately $67 per ton on steel products because he didn't want to risk alienating his traditional domestic source of supply.'

The scope of the shortages was evidenced by a survey taken in March 1974, by the Permanent Subcommittee on Investigations of the Senate Committee on Government Operations. This study. titled Industry Perceptions of Shortages, queried the 500 largest U.S. firms about the shortages of both primary and secondary materials they were then experiencing or expected to experience in the near future, The respondents to the survey (52 percent of those questioned) indicated that aluminum, copper, chemicals and petrochemicals, steel, paper, and plastics were areas of particular concern. Other less serious shortages were being experienced in caustic soda, chlorine, zinc, and various steel products.

The shortages experienced during 1973-74 were pervasive. They were also unique. The Commission staff requested commodity specialists at the Department of Commerce and the Department of the Interior to review the 30-year period, between 1946 and 1976, and identify periods when the commodities they follow were either in short supply or in surplus. What these two surveys reveal is that the onJy comparable period of widespread shortages was during the Korean War. With limited exceptions, the period from 1953 to the middle 1960's was characterized by a surplus of productive capacity in our basic industries. Throughout this period, there were occasional spot shortages involving a variety of products. During the Vietnam buildup these spot shortages became more frequent and widespread. But even then, they had a limited impact on the ecconomy and were generally quite shortlived.

Causes of the Shortages

The belief was apparently widespread at the time, and has prevailed among some to the present, that the shortages of 1973-74 were somehow related to a growing inadequacy of our natural resource base — that they were the first manifestations of the

I "HOW Lloyd Konrad, A Purchasing Agent, Wheels for Good Deals," The Wall Street]ournal. October 7, 1975. p. 1.

catastrophes that had been predicted by the authors of Limits to Growth.

The staff has searched diligently for indications that any of the shortages during 1973-74 were directly related either to a depletion or an inadequacy of natural resources. With the possible (and highly arguable) exception of natural gas, we can find no such example.

This is consistent with the entire record of postwar experience. I earlier referred to studies of shortages conducted at our request by the Commerce and Interior Departments. In addition to identifying the instances in which shortages occurred, the commodity experts were asked to list the causes of these shortages. A brief review of the results is instructive.

The primary cause of the shortages that occurred during the Korean War was the substantial and unexpected increase in demand that accompanied the outbreak of the war. The various spot shortages of particular commodities that were experienced during the mid-1950's to the early 1970's had a variety of causes, but none were related to a basic inadequacy of resources. For example, cattlehides experienced a brief shortage during 1965 as a result of a drought in Argentina which reduced supplies. There were shortages of nickel during 1966 as a result of an extended strike against Canadian producers, Zinc was in tight supply during 1963-65, in part due to the demand generated by the Vietnam buildup. Zinc was also affected by plant closings accelerated by EPA regulations. Between 1970 and 1974, domestic production of primary slab zinc fell by 40 percent in spite of sharply rising worldwide demand for the product, Other examples can be cited, but they uniformly tell of problems that are essentially short-term in nature.

The surveys that were made during the height of the shortage period in 1973-74 tell a similar story. The publication Industry Perceptions of Shortages identified four major causes of the shortages that were then occurring: first, a sharp increase in demand for most commodities; second, reductions in available supplies caused by factors such as price controls; third, the relatively low level of investment in capacity expansion that had occurred in the late 1960's and early 1970's due to low profitability, high interest rates, and the diversion of funds from capacity expansion to meeting environmental regulations; and, fourth, the increase by approximately 1 year in lead time required to build new industrial facilities.

A study undertaken in 1974 by Arthur D. Little, Inc. for the Department of Commerce placed particular emphasis on the effects of governmental actions, The impact of Government policy on shortage conditions was found to be most apparent in benzene, steel scrap, and synthetic fibers. Price controls were said to have contributed to shortages in 25 of the 26 commodities. In addition to the governmental factors, other causal factors mentioned included, first, an insufficiency of productive capacity which had been brought on by the overcapacity in the late 1960's, which in turn had reduced profitability and led to reduced capital expenditures; and, second, the strong surge in foreign and domestic demand, which made the already tight capacity situation unmanageable.

In an effort to test the results of these broad surveys, the staff commissioned seven in-depth studies of specific commodities—titanium, aluminum, iron and steel scrap, pulp and paper, livestock and feedgrains, fertilizer, and low sulfur coal. These examples were chosen to span a wide range of market structures and a wide range of Government involvement. In each case, the contractor was asked to determine what caused the problems that were observed during 1973-74, and what adjustments were made by various parties, With the results of the Arthur D, Little study in mind, the contractors were asked specifically to see what impacts (either direct or indirect) Government actions had in creating the shortage or in easing it. In addition to these seven studies, the staff itself conducted a less extensive study of petrochemicals, Let me highlight the results.

Capacity limitations linked to low rates of return earned during the late 1960's were mentioned as a major shortage cause in five of the six cases where manufacturing capacity is a relevant limiting variable, Operation at substantially less than capacity levels had been the general rule from the end of the Korean War until the mid-1960's. While the Vietnam buildup and the economic expansion that accompanied it strained capacity for the first time in nearly a decade, it also set off an investment boom. The new capacity resulting from this investment began to come onstream in the latter part of the 1960's, just at the time the economy entered a downturn. The downturn itself would have reduced corporate profits; the depressing effect of the new capacity compounded the problem,

The decision by industry to defer adding further to capacity in the late 1960's was understandable, given this erosion in corporate profitability and the high interest rates that prevailed throughout much of the period. But low profitability was not the only factor tending to cause businessmen to exercise caution.

Beginning in the early 1970's, a new source of investment uncertainty appeared. At about this time, it first became clear that the growing demands to clean up the environment and to improve the health and safety of workers were going to result in Federal legislation, At this early stage, it was not clear exactly what the ultimate impact of this legislation and the regulations that were certain to accompany it were going to be, but it was evident that complying with them would be expensive, particularly for the basic metals, chemical, and paper industries. It was also evident that engineering necessary controls into new plants would generally be less expensive than retrofitting existing plants, This uncertainty about what the regulations eventually would be and when they would apply did not create a climate particularly conducive to new investment. To the extent that business had to begin to take steps to bring existing plants into compliance with standards as they were promulgated, some funds apparently were diverted from capital expansion,

Another factor complicating both investment and production decisions during the early 1970's was price controls. In some cases, such as aluminum and petrochemicals, prices appear to have been frozen at levels that had been depressed by the price competition that had broken out during the 1970-71 recession. This directly undermined the incentive to add capacity. Even where this was not the case, the uncertainty generated by the rapid and seemingly unpredictable changes in the price control regulations and by the mere fact that the Government had instituted the controls after having repeatedly declared that it would not do so, tended to depress investment in new capacity.

If a slowdown in capacity expansion during the late 1960's and the early 1970's was the factor that set the stage for the shortages of 1973-74, our commodity studies confirm that the primary event that actually set them off was the worldwide surge in demand that began in 1972, The causes of this simultaneous boom in the economies of most of the industrialized countries are still not satisfactorily explained, Cooper and Lawrence[2] attribute the boom in primary commodities to the acceleration in the rate of U.S. inflation during 1972 and 1973, the stimulating effect of large U.S. balance of payments deficits during 1971 and 1972, and the sharp movements in currency exchange rates during 1971-73. Others have advanced explanations more consistent with a monetarist view of the world. But, regardless of the reasons for this upsurge in demand, the fact that it occurred almost simultaneously in most of the industrialized countries meant that when things became tight in the United States, we could not relieve the pinch by relying upon relatively cheap imports. If imports were to be a safety valve at all, they were going to be expensive,

2. Richard N. Cooper and Robert Z. Lawrence, "The 1972-73 Commodity Boom, " Brookings Papers on Economic Activity, 3:1975, pp. 672-677.

Finally, even the slowdown in the rate of capacity expansion and the boom in demand do not fully account for the pervasive nature of the shortages that occurred in 1973 and 1974. Capacity utilization was high in 1973, but the levels it reached were not unprecedented. Yet as we have seen, the magnitude of the shortages was. The critical additional factor in the equation is what one of our contractors has referred to as the "shortage mentality" that existed at the time. During late 1972 and early 1973, something happened that made purchasing agents hypersensitive to any sign that a shortage might be developing and especially quick to take defensive measures. The precise causes of this "shortage mentality" are hard to pin down. The publicity surrounding the publication in 1973 of Limits to Growth may have been a factor. The spot shortages created by quirks in the price control regulations may have been another. The point is that the phenomenon, though elusive, appears to have been real.

To cite one case, by 1972 paper producers were operating at close to rated capacity, In an effort to get more output out of existing plants, the industry began to rationalize its product lines, dropping off low profit items. These items had been added during the previous recession as the industry had attempted to maintain near-capacity operations by engaging in "product tailoring. " This practice had shortened production runs and increased downtime on the papermaking machines.

However, the industry's efforts to reverse the proliferation of products it offered and thereby to increase its effective capacity to produce generated a misperception on the part of paper users. As our contractor put it:

> Though entirely appropriate from the point of view of sound business practice, the industry's 1972 product rationalization programs became viewed by many buyers as evidence of an incipient product shortage. This stimulated a defensive surge in orders, which hit the industry at a moment when wood pulp inventories were unusually Iow.[3].

This reaction was typical. Similar examples are cited in our studies of titanium, aluminum, fertilizer, and petrochemicals. To be sure, most of the shortages evaporated once the true state of affairs was recognized, but not without substantial cost to the economy.

This last point requires some elaboration. Our commodity studies and the surveys that were taken at the time uniformly point to the last quarter of 1973 and the first half of 1974 as the period of the most severe shortages. Yet this was the period

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j Harbridge House draft **study,** pp. **4-21.**

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when, looking back, we now see that the economy was actually well into a downturn. This paradox seems explainable only by the "shortage mentality."

The oil embargo that OPEC announced in late 1973 was a traumatic phenomenon. Whether the embargo actually was effective or not is a matter of considerable dispute. What is important is that most people at the time apparently believed that it was effective. The tight capacity situation that then existed with regard to most materials, the apparent disruption in the supply of probably the most important industrial commodity, and the talk that immediately began to be heard from other raw materials suppliers in the Third World that they intended to emulate OPEC created a situation in which the natural reaction of purchasing agents was to build up inventories.

We now realize that the increase in oil prices acted very much like a substantial tax increase, Thus, it sharply reduced potential economic growth. In a recent book, Fried and Schultze have quantified this impact and have shown it to be substantial.[4] Given such a sharp change in the economic outlook, and given the fact that consumer spending on durable goods had turned downward as early as the second quarter of 1973, purchasing agents should have been slowing their rate of inventory accumulation. Instead, they sharply increased it, from an annual rate of $14.2 billion in the third quarter of 1973 to an annual rate of $24.4 billion in the fourth quarter of 1974.[5]

Once the full extent of the drop-off in consumer demand became evident, purchasing agents began to take corrective actions, canceling orders and liquidating their inventories. The correction was drastic. Between the fourth quarter of 1973 and the first quarter of 1975, investment in inventories shifted from accumulating at an annual rate of $24.4 billion to being liquidated at an annual rate of $19.0 billion. Industrial production, which had been artificially sustained by the surge of orders resulting from the inventory buildup, dropped precipitously, from an index value of 125.6 in August, 1974 (1967=100) to 109.9 only 6 months later,'

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[4] Edward R. Fried and Charles L. Schultze, editors, Higher Oil Prices und the World Economy, Brookings, 1976.

[5] There was a major revision in the inventory statistics during mid-1974. According to the old series, during the fourth quarter of 1973. inventories accumulated at an annual rate of $10.9 billion. According to the revised series, during this quarter, inventories accumulated at an annual rate of $24.4 billlon. The Commission staff has been told that as soon as the revised inventory figures were published, a number of economists immediately realized that a serious recession was imminent and revised their forecasts accordingly.

6 The drop-off in primary metals was even more severe but occurred over a more extended period. The index peaked at 130.7 in December 1973 and fell to 89.9 in May 1975.

Consequently, the "shortage mentality" and the behavior it generated, helped create the shortages that were observed during 1973-1974, artificially extended the boom, and contributed substantially to the severity of the recession that followed.

Implications for the Future

1 have gone into so much detail about the experiences of 1973-74 because it is my belief, based upon all the results of our work, that for the immediately foreseeable future (and by this I mean at least until the year 2000 and perhaps well beyond that date) the primary issues the United States must face with regard to the supply of basic materials will have relatively little to do with whether the world has sufficient quantities of natural resources extractable at reasonable cost, where "cost" includes the cost of protecting the environment from undue harm. This is not to say that we need to be unconcerned about the state of both U.S. and world resources, We are indeed beginning to exhaust our higher-grade domestic deposits of certain of our important minerals, Furthermore, due to the concern over the environment and the increasing price of energy, extracting the minerals that remain will be more expensive than previously expected. However, our concern over the state of our resource base, while real and deserving of attention, should net blind us to the fact that the important policy problems during the next several decades will be similar to the sort that created the shortages of l973-74, what might he called "above-the-ground problems. " With this in mind, it is useful to evaluate how well we have been able to anticipate the appearance of such problems, monitor their development, decide when action is called for, and act in an appropriate and effective manner. In my view, we cannot give ourselves very high marks in any of these areas.

The situation that developed in 1973-74 was partly foreseeable and partly the product of uncontrollable events. Most of the basic trends were visible long in advance. What was happening with regard to investment in capacity expansion was clear to all who took the opportunity to look at the relevant data. Many of the factors tending to produce this drop-off were also clearly evident: the sharp decline in corporate profits after 1966, the record high interest rates of the late 1960's, and the sharp decline in capacity utilization between 1970 and 1972.

The force of the surge in demand that began in 1972 apparently was underestimated, and the fact that it occurred virtually simultaneously in all the major industrialized countries was a surprise, although the factors tending to tie the major world economies together (the factors mentioned by Cooper and Lawrence) should have raised policy makers' sensitivities to this possibility. The impact that such a demand surge would have on our economy, given the situation we were in with regard to industrial capacity, seems not to have been appreciated.

Also not understood or appreciated was the impact upon businessmen of the increasing scope of involvement and method of operation by the Government in the economy. The passage of the environmental and occupational health and safety legislation signaled the intention of the Federal Government to interject its presence forcefully into areas where it previously had been only peripherally concerned. The imposition of price controls greatly expanded and made much more formal the movement of the Government into firms' pricing decisions. Both these moves signaled the rise of an important new source of uncertainty for the businessman, the uncertainty of Government policy.

The way the Government moved to exercise its new influence did nothing to quiet concern in this regard, In both the environmental and the occupational health and safety areas, the Government initially acted with little knowledge or even apparent concern about what the ultimate consequences of its policies might be. It was not until the mid-1970s that it began to assess in a serious and systematic way the impact that even a single agency's various rules and regulations might have on a specific industry, Even today there is extremely little information about how the totality of Government policies impacts on given industries and sectors and how these policies interact. Very little attention still is given to reducing the inconsistencies in the policies and regulations of various agencies.

In the case of price controls, the problems that inevitably arose were handled by one "quick fix" after another. Little thought had been given as to how to impose the controls in the first place. More, but still inadequate, thought was given regarding how to remove them. Once the controls were formally removed, the question of what type of continuing Government presence, if any, ought to exist was never really resolved,

It is little wonder that in contemplating how the Government had handled the substantial increase in the level of its involvement in the economy that had begun in the late 1960's, businessmen began to question the Government's ability to form and carry out rational and consistent policy, There can be little doubt that this climate of confusion and inconsistency played havoc with business' attempt to undertake the kind of long-range planning that is needed if they are to undertake investments which require large amounts of "front-end" money and take years to show a return.

What also was not adequately understood by the Government is that, all else held equal, it requires a much higher level of sophistication and skill to manage an economy that is operating at or near full capacity than one that is operating at well below capacity. Such relatively blunt fiscal policies as across-the-board tax cuts and increased public spending can work effectively in stimulating the economy in a situation in which bottlenecks are not immediately encountered. The 1964 tax cut is a good example of this, However, as became painfully evident during the 1972-74 period, a similar spurt in demand when the economy is already operating at close to full capacity can produce very different results. .Monetary policy used primarily as a "fine tuning" instrument at times when the economy is close to capacity has turned out to be not as precise an instrument as policy makers would have liked. Furthermore, attempting to deal with such a situation by undertaking ad hoc actions that ignore the fundamental interrelatedness of the industrial sector or by random jawboning do as little good and embody as much potential for creating harm as tying down the safety valve on an overheated boiler,

Another factor that was not adequately appreciated during 1973-74 was the importance of paying attention to factors which affect the attitudes of relevant decision makers in the private economy when the economy finds itself in a tight situation. If there is enough talk in the press predicting that we are about to run out of resources, and if responsible Government officials lend credibility to such talk, it is only natural for purchasing agents to be particularly alert for signs that the commodities they must acquire to keep their factories running are about to experience supply difficulties. And when they see such a signal—or believe that they see such a signal —they are bound to take steps to protect themselves, thereby producing a classic "run on the bank," In such times, it is especially critical that the Government be aware of the true state of the situation that exists in certain industries so that the potential impacts of its various actions or inactions are fully appreciated.

I have argued above that, when viewed in the context of our postwar experience, the shortages of 1973-74 were extraordinary events. But are they likely to be repeated?

Investment spending increased in 1973 and 1974 as the economy expanded and price controls were removed. However. the recession of 1975 caused many projects to be canceled or delayed. Now that the economy is emerging from the recession, capital spending is beginning to increase, but there is no sign yet of the sort of investment boom that would make up for the underinvestment of the late 1960's and early 1970's. The sharpness of the recession and the speed with which the shortages disappeared should not divert our attention from the tight situation we almost certainly would find ourselves in if demand picked up abruptly and remained at high levels for any extended period of time. The severity of the demand surge would be heightened if, as in 1972, all major industrial countries boomed simultaneously,

Certain basic industries continue to be heavily impacted by events such as the increased price of energy, environmental regulations, and occupational health and safety regulations which, when taken together with their previous investment history, may mean that these industries will encounter capacity bottlenecks somewhat before the rest of the economy, Aluminum and paper appear to be two such examples in the group of industries that the staff has studied, However, any such projections should be treated with extreme caution, since the intensity of any pressures that develop will be strongly affected by the particular pattern of the expansion in demand.

Implications for Government Policy

Given what appears to be the basic problem that set the stage for the shortages of 1973-74–an insufficiency of productive capacity— it might be imagined that the natural recommendation would be for a program of increased government incentives for capital formation, particularly in the basic industries. Certainly the decision made in the early 1950's to build up our industrial base had the effect of adding substantially to capacity in these industries. And there is no doubt in my mind that, if sufficient incentives were created, capacity expansion could be greatly stimulated.

This will not be the staff's recommendation, To be sure, the incentives of the 1950's stimulated capacity expansion, but they also helped produce an excess capacity condition that lasted well into the 1960's. In their own way they contributed as much to the long-range problems as did the price controls of a later era,

I do not mean to imply that decision by the Government to provide special incentives for capacity expansion in a given industry or group of industries is never justified, What I do say is that if such a policy is undertaken on a piecemeal basis with no account taken of its impact on other iridustries or on the long-run health of the industry being "helped," the result is no more likely to be effective, and, indeed, is quite as likely to be harmful, as some of the policies whose results are documented in our commodity studies,

The Commission staff likely will be recommending, therefore, that the Commission place its primary emphasis on suggesting means by which the uncertainties that result from the way the

Government currently forms and implements what might be called its "macroeconomic policies" can be minimized, This will directly improve the climate for investment, particularly in the basic materials industries where added uncertainty in any form is disruptive. It will also permit informed evaluation and effective implementation of any proposals that might be made to aid specific firms or industries.

The question of information appears to be central, It is difficult, if not impossible, for someone who was not involved in a specific policy decision to know what information was available to policy makers, how that information was used, and what additional information, had it been available, might have changed the decision, Nonetheless, the staff studies, contractor reports, and work undertaken at the request of the Commission staff by other Government agencies tell a consistent story to the effect that Government actions, whether undertaken with the benefit of full information or not, contributed greatly to the creation of the underlying conditions that resulted in the shortages of 1.973-74. The Government's apparent lack of awareness of its growing influence over virtually all aspects of decisionmaking in industry, and its failure to exercise this influence in a more coordinated, informed, consistent, and responsible manner contributed to the shortfall in capacity expansion. Its apparent lack of understanding of the impact of its policies on aggregate demand both in this country and overseas prevented it from being sufficiently alert to the possibility of the strong demand pressures that began to be felt in 1972. The apparent failure of its monitoring of basic industries caused it to be unaware both of the bottlenecks that were developing and of the seriousness and abruptness of the inventory buildup that occurred in late 1973. The ad hoc actions that were taken to increase supply, apparently without a full understanding of their long-range consequences, created other problems, particularly in agriculture. Consequently, the staff's recommendations will concentrate on improving the flow of information available to Government decision makers.

Detailed suggestions for institutional changes are now being prepared and will be presented to the Commission at the next two meetings. They will be designed to achieve four objectives:

1. Improve the quality (notice that I say "quality," not "quantity") of the information the Government generates with regard to materials;
2. Improve the ability of the Government to monitor the condition of major industries and industrial sectors:
3. Improve the quality of forecasts and situation reports that alert the Government and the general public to important

emerging trends and potential problems; and

4. Improve the quality of the Government's policy analysis so that the Government can better understand the impact of particular policies, how these policies interrelate, and how they combine to affect business incentives, particularly the incentive to invest.

I will not go into detail about what the staff will be proposing to the Commission in these areas because I do not believe it appropriate to do this before the Commission has had a chance to see the results of the staff's work. Suffice it to say that we will be presenting a broad range of options.

Let me now turn very briefly to the subject of economic stockpiling. This medicine has been proposed as a cure for an astonishingly wide range of diseases. Yet, as with any medicine, in actual use it is likely to be less effective than its more optimistic proponents would contend, and it is likely to have a number of unpleasant side effects.

The "diseases" for which this medicine has been must seriously "prescribed" are three: (1) to offset the impact of actual supply disruptions, (2) to provide a defense against price increases by cartels or by other sources of monopoly power, and (3) to stabilize the prices of key raw materials on a continuing basis. It is undeniable that each. of these objectives is laudable. Supply disruptions, or even just the threat of them, can create havoc in an economy that is being pressed to produce at close to its full potential, Private firms can indeed often take protective steps to limit the damages that such disruptions might cause, but these steps can themselves be quite destabilizing.

Although the cartel threat in minerals undoubtedly has been overplayed, and although the impact of price increases in any mineral where a cartel threat is remotely plausible would have considerably less impact on the economy than did the increase in petroleum prices, deterring such increases is a worthwhile goal– if it could indeed be done and at reasonable cost.

Price fluctuations such as we have observed in many basic commodities over the last several years are disruptive and lead materials users to take costly actions to offset them. Yet the record of attempts to stabilize materials prices does not hold out much hope that any scheme is likely to be both practical and reasonably inexpensive.

The Commission staff has examined each of these objectives in detail and has concluded that the first and, in certain cases, perhaps the second, appear practical. The Commission, after considering the staff's recommendations, has instructed us to prepare draft report language and draft legislation outlining in detail how a stockpiling agency designed to accomplish the first of the objectives just mentioned would be constituted and would operate in practice, We are now proceeding to do this with the help of the staffs of our congressional Commissioners,

Before I close, let me make one final observation. In talking with many of you from the materials community about the work of the Commission, I have heard disappointment expressed that we weren't getting into areas that might be of special interest to you. For example, some of you were hoping that the Commission would identify and perhaps "anoint" promising technologies to promote substitution or that we would single out specific problem industries for Government attention, but a Commission like ours cannot be all things to all people. Materials are indeed important, as you keep reminding me, but they are only a part of the entire economy, In my mind, the factors that produced the shortages of 1973-74 and that will produce any significant shortages that we are likely to see in our lifetimes are symptomatic of a much broader set of problems, These problems have to do with the way the Government conducts its business and, in particular, how it relates to basic industry. It is these problems that we are attempting to address, And if this Commission can cause public attention to focus on these problems and can make sensible, implementable suggestions to resolve them. then it will have accomplished much more to help the materials sector than it could have by making solemn-sounding pronouncements that are beyond our own technical and scientific competence.

ENERGY CONSERVATION IN THE CHEMICAL INDUSTRY

by
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Past Henniker Conferences have provided the objective basis for policy recommendations to the Congress. Hopefully, this conference also can be of great service to our legislators and our Nation by helping us rationally address our problems. As Herman Kahn said the other day, "Everything is very complicated, " (13) and my heart goes Out to our representatives, who last year had to cast their votes on 800 separate occasions on extremely complicated matters. In such an environment, good advice does seem important,

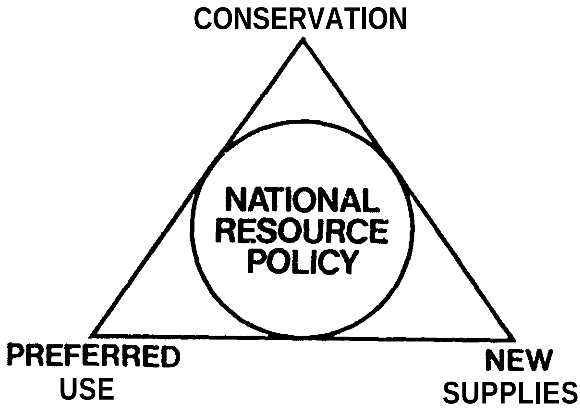
Conservation of energy is a necessary and important aspect of national energy policy. My address must be primarily practical rather than theoretical, for that's my background. It is our bicentennial year, so I hope you will take comfort with me from the words of John Dickenson at the first Continental Congress when he said, "Let experience be our guide, for reason may mislead us."

In that vein, my remarks will seek to describe the attitudes and policy position of the chemical industry on "energy" and energy conservation in particular; the nature of the political interface that currently exists in this area; the industry's and other views on the potentials for conservation; what industry is doing about it; and, last, what I believe are some sensible policy directives which the Congress might adopt to encourage better performance,

The Petrochemical Energy Group (PEG), is an ad hoc group of some 23 independent manufacturers of petrochemicals. By independent is meant they are not integrated back to oil and gas; they are not oil companies. As a basis for their efforts to influence public policy with respect to feedstocks for petrochemicals, they have developed an overall policy position, which I quote–

"The Petrochemical Energy Group (PEG), an organization of independent petrochemical companies, believes the U.S. energy program should consist of three different, but concurrent, approaches (figure 1):

FIGURE 1.—Approaches to U.S. Energy Program



- energy conservation,
- expansion of all domestic energy resources, and
- the preferred and best use of energy resources.

"For the short term there seems to be no way to meet the demand for petroleum and natural gas in the United States except through imports, The current decline in domestic oil and gas production, coupled with Government policies designed to make the United States independent of foreign energy supplies, suggests that some products now based on these hydrocarbons may not be manufactured or that some energy requirements may not be met, In a free market, this dilemma would be resolved by pricing petroleum and natural gas much higher–forcing markets which could not afford the increased costs to turn to other alternatives, However, many kinds of Government restrictions on the free market will probably keep the free market from functioning effectively.

"Thus the United States is probably facing a period of 'energy management' for some years to come, How this management will he achieved is a continuing debate. Whatever mechanism is chosen— taxes, rationing, or prohibition of certain uses–- the Nation must consciously protect its resources for their preferred uses. "

The PEG policy position accepts the fundamental purpose of Project Independence without endorsing its expression. That is, it is necessary to assure U.S. freedom of action in international affairs by establishing a secure resource base for energy. It goes without saying that similar concern exists with respect to other raw materials basic to an industrialized society.

It is a measure of the maturing congressional appreciation of the problems of the Nation that there are attempts to address these matters today, compared with the initial reaction of the legislators in 1973 and 1974 to divide up the shortage without increasing the supply,

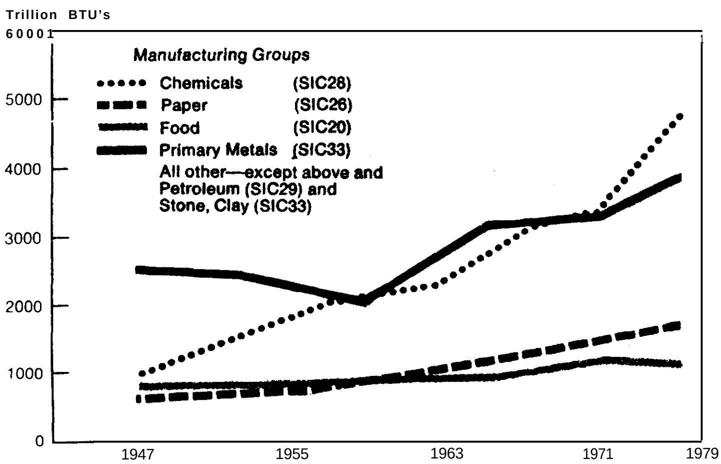
PEG's prime concern is the preferred use of resources doctrine–that is, to reserve the clean fuels which are also feedstocks for that superior use, and not to burn them as fuels. The distinction has been made between feedstocks and fuels effectively enough that the Federal Energy Administration and Federal Petroleum Congress do discriminate against synthetic natural gas plants based on naptha and LPG, for example, and a high priority for natural gas as a feedstock and process fuel is maintained in the FPC statement of priorities for natural gas use. Public policy on energy conservation generally distinguishes between fuel and feedstock uses, on the presumption that the conservation potential for feedstock is limited. That is a satisfactory working assumption for the short term, but it is probably not valid over a time span long enough to permit replacement of current processes by more efficient ones,

In early 1974 the PEG companies advised the Manufacturing Chemists Association (MCA), which comprises about 189 members producing over 90 percent of the U.S. chemicals (outside of fertilizers), that an industrywide approach to energy conservation should be initiated. Shortly thereafter, the Department of Commerce and the Federal Energy Administration asked 26 major chemical companies (both independent and integrated) in a series of workshops to define the subject matter further. The effort culminated on October 10, 1974 in a commitment to a 15 percent reduction in energy consumption per unit of output by 1980. My impression of the occasion is that the 15 percent number was a compromise reached under the threat of missing lunch, but represented a consensus among those companies who saw no way to achieve so high a result, and those who had visions of much better results than 15 percent. As additional information has been gained since then, both conservative and optimistic views are justified, depending on the different chemical processes involved. It is the mix of business which influences the average.

Other industries such as steel, aluminum, cement, petroleum, and paper undertook similar commitments at the same time, ranging from 5 percent to 15 percent. It is surely true that none of these industries has anything approaching the complexity of product mix that the chemical industry does, nor such a variety of processes or level of process complexity.

What is the level of energy consumption of these industries? In figure 2, note not only that the top six, of which four are shown, equal all other manufacturing, but also the rapid growth rate of chemicals versus others in the 1947-1975 period, particularly primary metals. This illustrates a long-term impact on the Nation's economic health, as well as a potential for apparent conservation as the manufacturing component of GNP increases in less basic industries, while the more basic industries grow relatively little. It is well known that new investment in U.S. industry lags well behind its proportion of existing world investment.

FIGURE 2.—Gross Energy Consumer by Manufacturing Groups



Source: Refcrence # 14.

To bring this history up to date, the voluntary energy conservation programs of Federal Energy Administration and Department of Commerce now include reports from some 32 industry associations, and probably 36 more are today planning to enter. The Manufacturing Chemists Association program report will this September include 107 companies of the MCA membership, with another 15 also involved but reporting through other industry associations (fig, 3). The industry also reports its total energy usage (fig. 4).

Under the Energy Policy and Conservation Act of 1975 (EPCA)–the voluntary programs may remain intact when the bill's provisions come into force on January 1, 1977, but there are many uncertainties. Efforts funded by FEA to satisfy the bill's

FIGURE 3. – Manufacturing Chemists Association

Energy Efficiency Table	1972	1975
production (10⁹ lbs)		**423**
Btu's (10^{12})	**3065'**	**2941 .***
Percent improvement Over Base Year (on gross Btu consumption)	**Base Year**	**4.0**
1980 Goal is **15 Percent**		
Energy Consumed to Meet Current OSHA and EPA Requirements (10^{12} Btu)		27.8
Energy Consumed to Meet OSHA and EPA Requirements (Percent of Current Consumption)		.9

Source "Voluntary Industrial Energy Conservation Progress Report, " April **1976.** Dept. of Comrnerce. FEA.

FIGURE 4, – Energy Consumed in Chemicals Processing (Calendar Year 1975)

The wide variety of fuels and the quantities consumed in the processing operation of the **107 reporting companies** are as shown below. The companies represent over 80 percent of the industry sales,

Distillate Fuel Oil. gallons	411 x 10^6
Residual Fuel Oil. gallons	1079 X 106
[.iquified Petroleum Gas (LPG). gallons	14 x 10^6
Natural Gas, scf	1305 x 10^9
Other Gas. scf	25 X 10^9
Coke. tons	354 x 10^3
Coal. tons	11.3 x 10^6
Purchased Steam. lbs	88.5 X 10^9
Purchased Electricity, kWh	**68.9 X 10^9**
Propane. gal Ions	**64 X 10^6**
Other Llquids. gallons	**50 X 106**

Source '"Voluntary Industrial Energy Conservation Progress Report, " April **1976. Dept. of Commerce.** FEA.

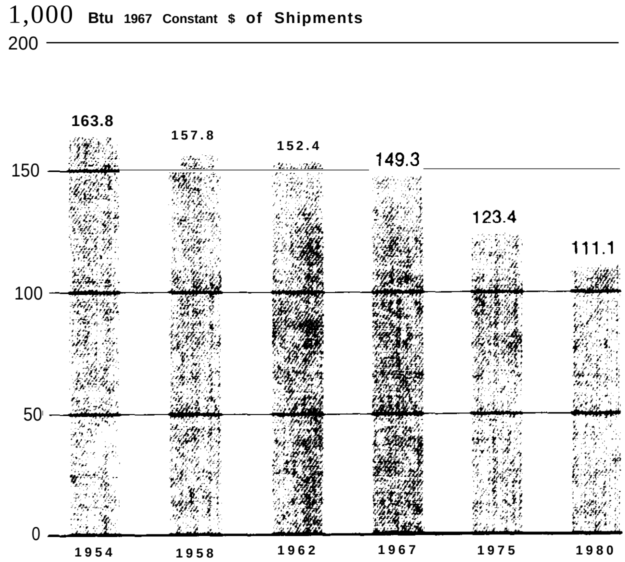
provisions include defining the top 50 companies in each two-digit, SIC code segment, and establishing by technical and economic analysis appropriate targets for energy conservation by such code for January 1, 1980. I will speak more to the question about potential savings in a moment. It is already apparent, however, that definition of the chemical industry by two-digit, SIC code raises more questions than it answers, and it is abundantly clear that taking the top 50 companies in each industry SIC using

I trillion Btu/year or more will yield a very spotty appraisal of energy intensive industry consumption.

Few people are pleased with EPCA, not particularly for its conservation provisions, but for many others, so we can expect a continuing flow of new bills covering various aspects of the energy situation. The picture is continually changing from the regulatory and legislative standpoint.

The definition of conservation currently in force in industry reporting is Btu's/unit of output (or, for the refining industry, per unit of input). This definition is not inconsistent with some economists' preferred definition on the macroscale of Btu's per unit of deflated GNP (Btu/$1976 or Btu/constant $ shipped), which suggests that through 1967, at least, manufacturing was increasingly efficient (fig. 2). The Conference Board has a forecast of continuing trend (fig. 5).

FIGURE 5.—Energy Utilization for Heat and Powcr per Unit Shipped



Source: Bureau ot the Census, *Census of Manufactures*; The Conference Board.

However, there are many more viewpoints to be heard from in the area of energy conservation. Denis Hayes, in WORLDWATCH PAPER No. 4, suggests the conflict between disciplines and jargons (11). I quote—

"Yet 'waste' can mean different things to different people. Waste signifies one thing to a physicist, and another to an economist; it has wildly differing meanings for philosophers, engineers, and politicians. In fact, all energy policy discussions bear this curse of Babel; they are plagued by ambiguous terminology and consequent misunderstandings. A new and eclectic field, energy policy, involves so many diverse disciplines that a common language and set of definitions could hardly be expected. But many conflicting claims might well be reconciled if only their respective proponents were talking about the same thing.

"Few energy economists, for example, have any background in thermodynamics. Few know that energy has a qualitative dimension, that the Second Law of Thermodynamics— which states that the quality of energy declines as it is used—is just as absolute as the First Law which states that the quantity of energy in the universe is constant. Most studies of energy use have dealt only with the quantitative dimension of energy. Most have considered the flow of energy units (Btu's, calories, or joules) used in a given process, but have not distinguished between the relative entropy levels (i. e., levels of organization and quality) of these quantities. Most have thus ignored the most important aspect of the energy flows they have been analyzing.

"While physicists thus argue that energy use in the United States is only 10 to 15 percent efficient, many economists believe that there is no significant waste in our present energy budget, By their own standards both camps are correct, The physicists failed to examine the economic cost of increasing the physical efficiency of energy use, Nor did they examine systemic alternatives (e.g. substituting van pools or public transit for automobiles). Theirs was a purely technical study of the efficiency of use of free energy in current technologies. Most economists, on the other hand, disregard the physical and technical phenomena their idealized marketplace purportedly represent. They take for granted that pricing mechanisms have assigned appropriate dollar values to all possible purchases, Since fuel buyers act in their own economic self-interest, and since the total economy seems to be operating reasonably efficiently, these economists argue that our current level of fuel consumption cannot be considered economically wasteful.

"If both perspectives are 'correct, ' both have shortcomings. In economic terms, technical opportunities tor conservation mean little if they are prohibitively expensive. On the other hand, the purely economic perspective may be even more deficient. Its guiding principle– that a dollar should be invested wherever it will bring the highest return —is sensible for many purposes, However, at present it almost completely disregards such 'externalities' as environmental quality, occupational safety and national security. Moreover, it_ ignores the needs of the next guy in line. On a planet with rapidly depleting, finite resources, future generations can't fend for themselves; the economic principle must be tempered by humanitarian constraints. But economics is an analytical tool, not a system of ethics.

"Combining the insights of both physicists and economists, this study considers energy to be 'wasted' whenever work is performed that could have been completed with less or lower quality energy and without incurring higher total social or economic costs. By this definition, the United States consumed about twice as much fuel in 1975 as was necessary, The major areas in which significant savings could be made are transportation, heating and cooling systems for buildings, water heating, the food system, electrical generation, industrial efficiency, waste recovery, recycling, and lighting."

So there are several definitions of conservation which can be applied, as well as standards of performance to use in evaluating results.

It does seem to the chemical industry that there is great merit in changing the dependence of the Nation on oil and gas toward coal, oil shale, oil sands, nuclear power, and such renewable energy sources as the solar, wind, and sea tides. That is the route to energy independence in supply which will be furthered by free market pricing of energy sources. The problem in the world, and in North America in particular, is not really lack of fossil resources for the foreseeable planning period (fig. 6), It is that regulated pricing of energy sources now inhibits development of coal, and later of oil shale and tar sands. About one-third of the reputed North American reserves are coal, with very questionable availability assigned to the oil shale and tar sands, which comprise all but some 8 percent of the balance.

While higher prices will create a better allocation of investment toward more available indigenous resources than oil and gas, it is also clearly the accelerator required to promote energy conservation, and it is an effective one, more so possibly to industry than to other sectors.

It needs to be stated that the profligacy in U.S. energy use which is so roundly criticized is clearly much more a function of lifestyle than industrial inefficiency. I find the Institute of Gas Technology data on correlation of spendable income and energy use interesting in this regard (fig. 7).

Other reports tend to support the view that to the American consumer convenience and comfort are and continue to be more important than vague concepts of national independence. The

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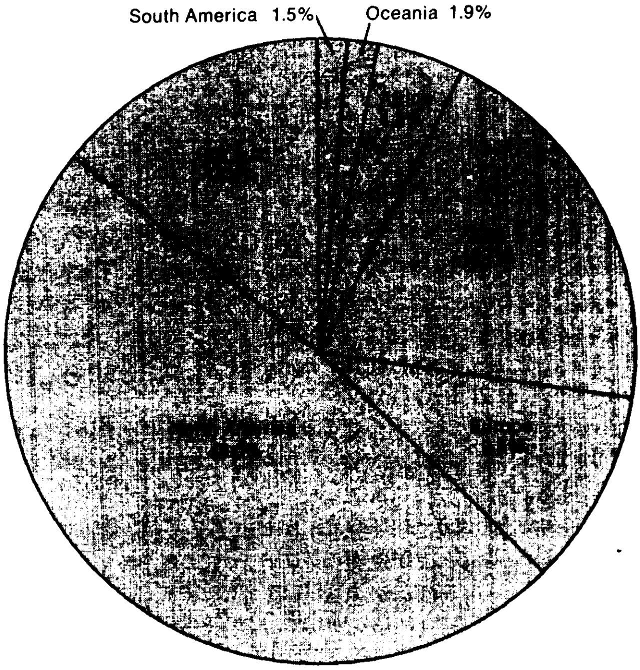
FIGURE 6.—Wor]d Recoverable Energy Reserves
(Quadrillion Btu)



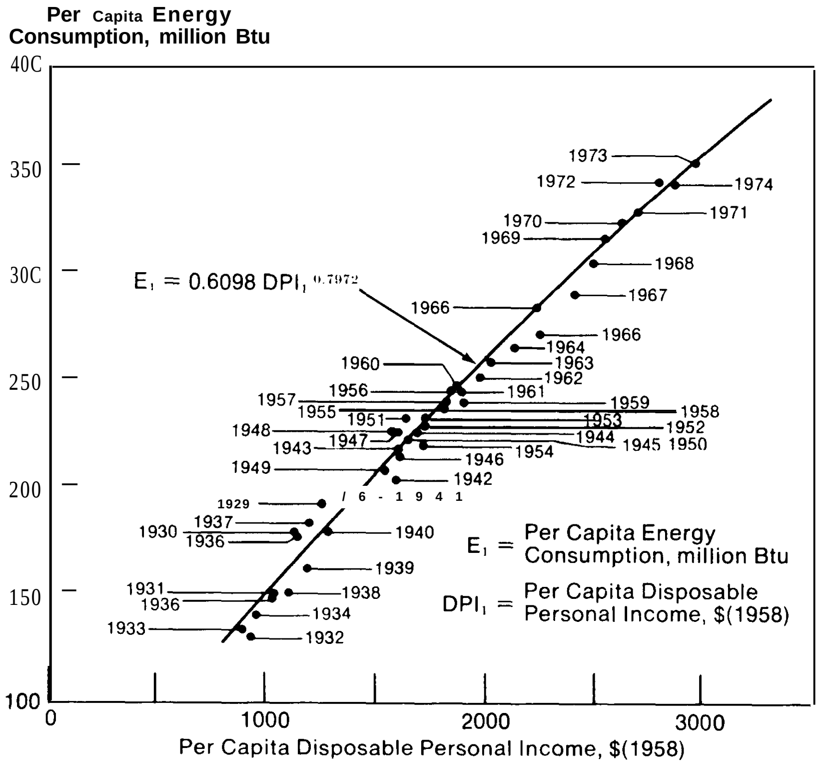
Source: Survey of Energy Resources, World Energy Conference, 1974.

American home is reported to use three times as much electricity in 1975 as it did in 1965, and gasoline use is up again in 1976, in what the New York Times calls a bicentennial driving binge. And why not? My own old 1972 Pontiac station wagon cost me 35cents/ mile to operate, inclusive of depreciation, insurance, and other costs, of which gasoline was 6cents. The economic incentive of gasoline price increases is minor relative to other costs.

Figure 8 illustrates the 13-year trend in net energy consumption by sector, and points out that the residential, commercial, and transportation sector outpaced the industrial in increasing use. FPC data on 25-year electrical use corroborates the data in figure 8, and incidentally illustrates the high-load factor of this customer class (fig. 9).

The trends in electricity consumption by sector reflect the realities of cost for this energy form versus other energy forms. It is at minimum three times as expensive a source of thermal

FIGURE 7.—Correlation of Annual Energy Consumption Per Capita with Disposable Personal Incorne Per Capita for the United States

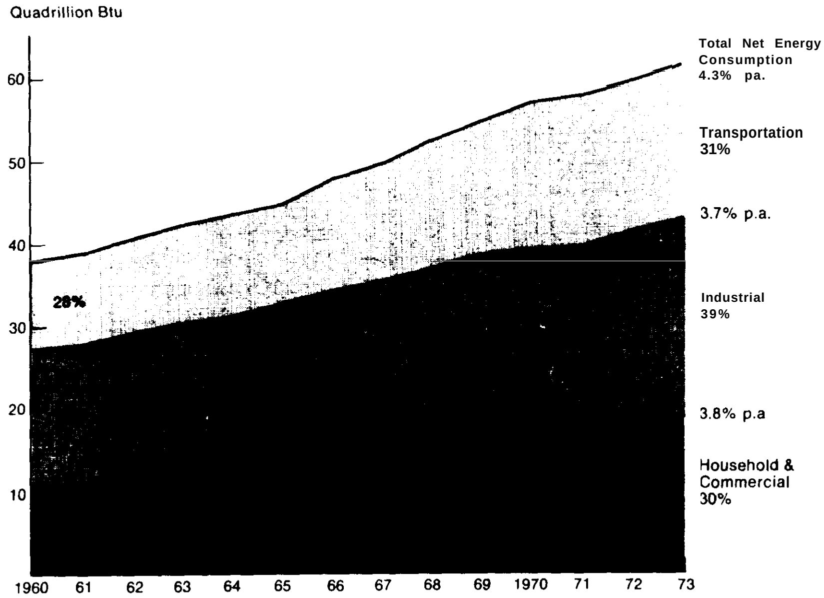


Source: Reference #8.

energy for the lowest priced user as the next cheapest alternative, and hence is and has been most efficiently used by industry. Of course, it is used in quantity only for electrochemical processes and mechanical application for which it is uniquely fitted. It is obvious from the recent congressional hearings on electric rate reform that the economic basis for charging the high-voltage, high-load factor users a lower rate per kWh than the low-voltage, low-factor users is not understood, Indeed, I was informed in those hearings that industry was "ripping off" the residential, and was wasteful of electricity because of low "promotional" rates to industry. Figure 10 was used by the Electricity Consumers Resource Council at the House Subcommittee on Energy and Power hearings in April 1976, in pointing out the illogic of that allegation,

Unfortunately some generally responsible consulting firms have reinforced this erroneous impression, The June 1976 report

FIGURE 8.—U.S. Net Energy Consumption, by Final Consuming Sector, 1960–73

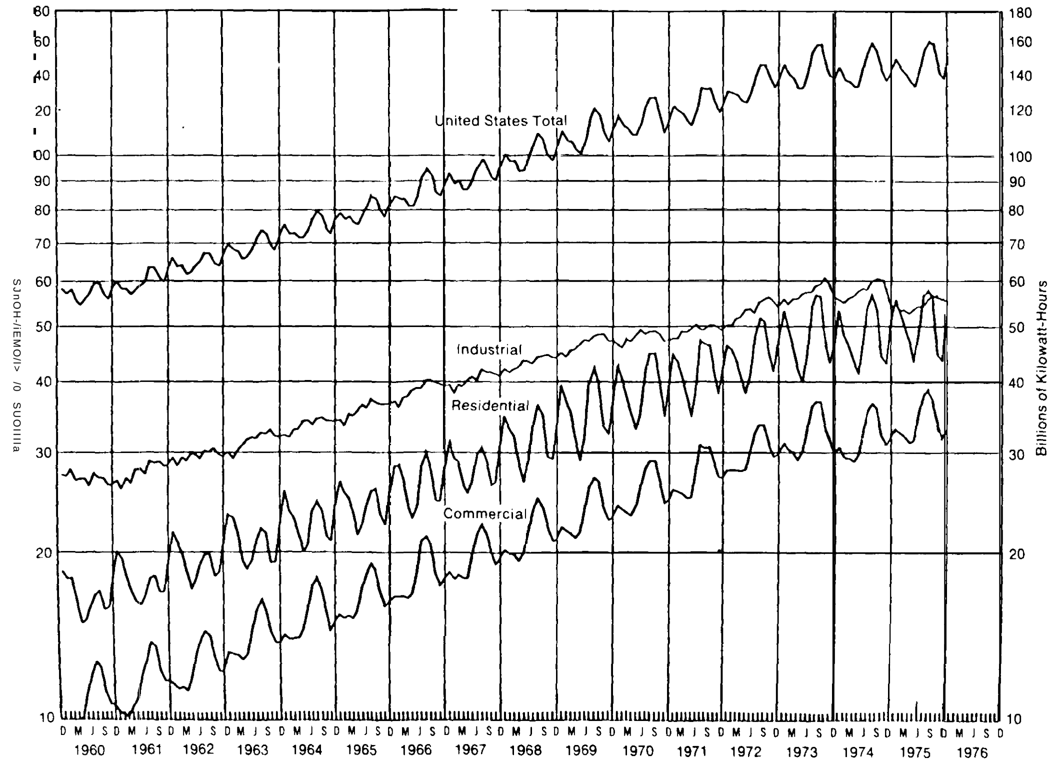


Source: U.S. Bureau of Mines, 1974.

by the Stanford Research Institute, "Electric Power–The Cost to Industry," (9) suggests that utilities price power such that industrial customers are in effect being subsidized, principally by the residential sector. Analysis of all rate-of-return studies made for utilities, public service commissions, and industrial users over the last 5 years by two major consultants in the field, indicates that in about 80 percent of the cases the industrial class provides a higher rate of return than does the residential class. In no case were rates below cost. It is ironic, of course, that almost universally the commercial class provides a higher return than either. As a policy, major industrial users would be pleased to see utilities so price electricity as to gain an equal rate of return from all classes.

To summarize, it seems there is reason to believe that, on the macroscale, increases in energy consumption have been a function of lifestyle and personal income, Further, the residential and commercial sectors have contributed more to the growth in

FIGURE 9.—Monthly Residential, Commercial, and ndus rial Sales of Electricity in the United States, 1960–1975



Source: Reference #20.

FIGURE 20.—Purchased Energy Costs at Several ELCON Member Plants $/Million Btu's [1975j

	GAS	OIL	ELECTRICITY
California	1.23	None	4.93
Maryland	1.61	2.44	7.32
North Carolina	.87	2.55	4.83
Texas	1.13	None	2.93
Texas	1.50	None	6.44

Source: Reference #6.

energy usage than has industry, particularly in electricity. There is reason to believe that industry, and the energy-intensive industries in particular, are more sensitive to price signals on a continuing basis than are the citizenry in general,

What potentials for savings in energy use exist? The literature of the last few years is not overly instructive. Various consultants, largely at the behest of the FEA, have sought to quantify the industrial savings potential by comparing the United States with supposedly similar societies such as Sweden and West Germany and by thermodynamic analysis,

Comparison of Sweden and West Germany with U.S. energy use was developed because the GNP/capita is similar, hence the relative energy use might suggest potential for savings. It is clear that there are gross differences between the societies in their energy use, but it is not certain that U.S. industrial use of energy is less efficient than in the countries compared **(11).** One finds that Swedish energy use per capita is 6 percent of the United States. However, Swedish industrial use per capita is slightly greater than in the United States, In the particular case of the chemical industry comparison between the countries, the report shows a U.S. use, measured in kWh per dollar shipped, of 73 percent of the Swedish use (fig. 11). The German study (fig. 12) does suggest materially lower energy consumption than in the United States per unit of industrial output.

Some of my colleagues in U.S. industry who have reviewed these reports and interviewed the London office of the consultant who did the German study criticize it on various grounds. In my opinion the outcome is not unlikely, in view of the generally more modern German steel, chemical, and refinery plants reconstructed after World War 11; the much higher level of processing of U.S. food; the imports of wood pulp by the paper industry in Germany; and the notably lower fuel costs enjoyed by the U.S. petrochemical industry on the Gulf Coast,

FIGURE 11 .—Energy Consumption in kWh/Capita for U.S. and Sweden in 1971

	United States kWh	Sweden kWh
Transportation	24.025	7.350
Commercial	9.600	7.375
Residential	13.500	14.150
Industry	28.900	29.450
Feedstocks	5.600	2.500
Utility Losses (actual)	14.200	3.700
Actual Consumption	95.825	64.500
Energy Embodied in Foreign Trade	1.800	-4.600
Net Consumption	97.625	59.900

Source: L. Schipper (Energy & Resources Group) and A. J. Lichtenberg (Chairman, Energy and Resources Group), University of California, Berkeley, Calif.

FIGURE 12.—Comparison of Industrial Energy Consumption in Relation to Value of Shipments for the United States and West Germany—1972

	10^3 Btu/$ of Shipments		
Industrial Sector	United States	West Germany	West Germany as Percent of United States
Food	11.9	8.3	70%
Paper	104.0	38.6	37
Chemicals	71.8	40.8	57
Petroleum and coal products	112.0	56.0	50
Stone, clay, glass, and concrete products	75.3	54.8	73
Primary metals	97.0	77.6	80
Total for six energy-intensive industries	61.2	42.4	69
Other manufacturing	9.4	7.1	76
Industry total	34.8	25.1	72

Source: "Comparison of Energy Consumption Between West Germany & the U.S." R. L. Goen & R. K. White, Stanford Research Institute—June 1975.

Going beyond comparisons, **A.** J. Appleby constructs **a** scenario of a nonfossil-fuel economy after the year 2000, with dramatically higher energy prices impelling **a** reordering of society and industrial organization to force conservation (17). For the year 2025 he would have industrial energy use overall at one-third of 1971 energy consumption per $1 of GNP, measuring energy use in tons equivalent of crude oil (fig. 13). He assumes an overall potential savings of 27.2 percent of primary energy use per GNP unit. Made up by a series of savings, these would include a reduction from the present industrial total of 33 percent

FIGURE 13.—Potential Energy Savings in the U.S. and EEC Economies

USA	% of total energy consumption	Present top/$1000 of GNP	Primary savings (%)	Method of saving	Secondary savings (%)	Method of saving	Final energy (% of current total)	Future top/ $1000 of GNP (1971)	Future total (%)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		15.0	0.23	39.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Electricity considered primary energy	9.6	0.15	25.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Waste heat use	14.6	0.21	36.0
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	0.59	100.0
[illegible]									
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		12.4	0.14	28.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		14.3	0.15	30.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		18.5	0.21	42.0
Total	100.0	[illegible]	[illegible]		[illegible]		45.2	0.50	100.0

Source: "Energy Costs and Society" by A. J. Appleby, ENERGY POLICY, June 1976.

in process steam and direct heat, with emphasis on retrieval of waste **heat from electric powerplants; cutting primary** metals demand for energy in half; reducing present inorganic chemical industry consumption by one third, and so forth.

His argument is based on the intolerable burden of future energy costs and capital demands which he sees placed on society by the generation of that energy. However, what kind of capital cost and technological development needed to replace current industrial, transportation, and housing to satisfy these ideals is not adequately understood, The measures required will be Draconian. This is a splendid example, I trust you will agree, of "Reason misleading us. "

"The FEA-funded studies by Battelle and Gordian Associates published thus far seem to me to be closing in on the subject of conservation potential without actually providing either a measure of potential or a rationale for approach. The thermodynamics studies at Battelle (16) cover seven energy-intensive industries, including four major plastics, and calculate the fuel requirements for the polymerization steps and the imputed thermodynamic efficiency of those steps (figs. 14 and 15).

FIGURE 14.–Fuel Use for PJastics per 'l'on of Product

	Total Industry Fuel Used(a)	Fuel for Polymerization(b) (10^6 Btu/ton of product)	Fuel Value of Monomer(c)
Low-density polyethylene	45.8	15.3	44.8
High-density polyethylene	37.2	13.2	45.7
Polystyrene	18.5	8.0	37.3
Polyvinylchloride	23.8	7.1	17.9

(a) Includes monomer production (but not fuel equivalent of feed stocks) are inefficiencies in steam and electrical generation.

(h) Fuel equivalent for steam and electricity required for polymerization process analyzed.

(c) Fuel equivalent of monomer feed stock. not included in Columns I and 2.

Source: Battelle Columbus Laboratories. "Evaluation of the Theoretical Potential for Energy Conservation in Seven Basic Industries," prepared for FEA **7/11/75.**

The Gordian Associates study (18) on these same plastics assigns the energy consumption from raw material acquisition to final product ex-reactor, and is therefore useful in focusing on which of these steps offers the biggest targets (fig. 16).

As time has elapsed, more sophisticated approaches involving direct participation by industrial groups have been initiated, and I

~FIGURE **15.–Plastics Production Efficiency**

Polymer	Polymerization Efficiency, Percent	Entire Industry Efficiency, Percent
Low-density polyethylene	67	45
High-density polyethylene	66	49
Polystyrene	79	64
Polyvinylchloride	62	37

Source: Battelle Columbus Laboratories. "Evaluation of the Theoretical Potential for Energy Conservation in Seven Basic Industries," prepared for FEA 7/li/75.

FIGURE 16, **–Percentage Breakdown by Operation of Total MMBtu of Primary Energy Consumption** for Production of Selected Plastic Products in the United States in 1970

Primary and Ancillary Production Operations	LDPE Resin	HDPE Resin	Poly-styrene Resin	Polyvinyl-chloride Resin
Natural Gas Processing	15.3	16.2	4.0	7.5
Production of Oxygen	—		—	1.4
Production of Ethylene	63.3	66.8	16.3	30.8
Production of Acetylene	—	—	—	9.4
Production of LDPE Resin	21.4		—	—
Production of HDPE Resin	—	17.0	—	—
Production of Aromatics	—		49.3	
Ethylbenzene by Superfractionation	—	—	3.1	—
Production of Styrene	—	—	20.5	—
Production of Polystyrene			6.8	—
Production of Chlorine		—	—	18.1
Production of Vinyl Chloride	—		—	12.7
Production of PVC	—	—	—	20.1
Total	100.0	100.0	100,0	100.0
Total Primary Energy Consumption, MMBtu/ton	93.49	86.64	117.42	82.92

Source: Energy Conservation Paper No. 9 prepared by Gordian Associates.

must say it is high time. It is not necessarily suggested that greater competence exists in the industrial groups than can be found in the consulting community, but much better access to current practice and the potential for technological advance can be expected. Probably most important, an evaluation of the reinvestment arising from anticipated growth rates of various product sectors can be expected to be applied, and this is certainly the most important influence on achieving conservation potential. In the chemical industry, we have, as a rule of thumb, anticipated twice as much energy efficiency improvement from new capital formation as from housekeeping and retrofit activities.

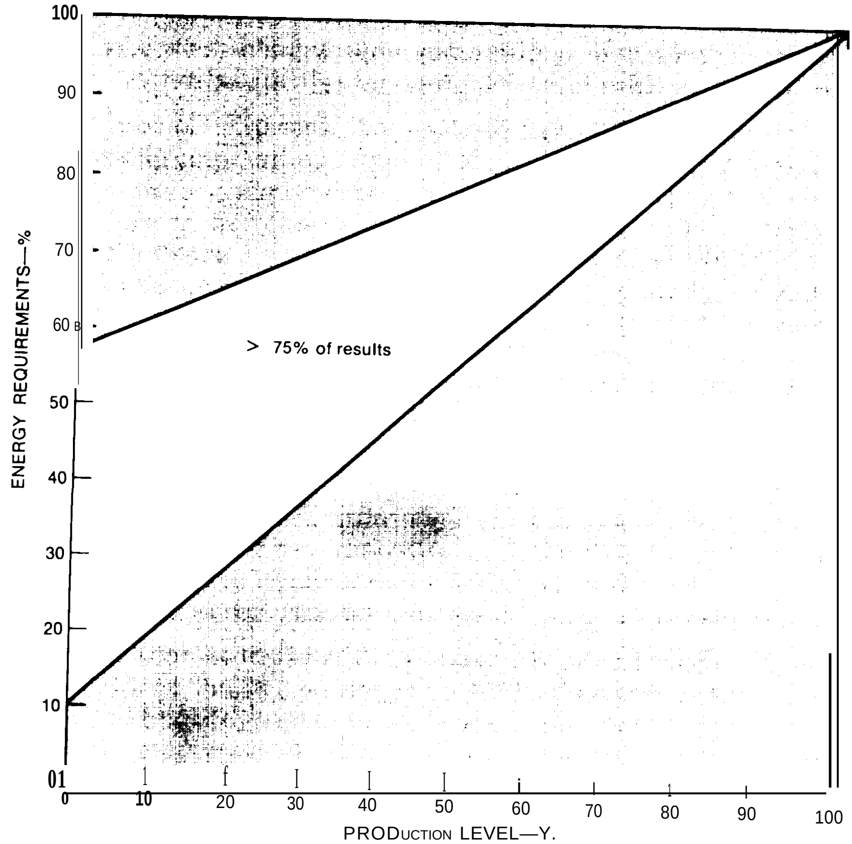
Under the auspices of the National Research Council, there is currently under way a study to appraise the appropriate future role of nuclear power among alternative energy systems, As an aspect of that study, a demand/conservation work panel is addressing the question of industrial energy conservation potential through the year 2010. The work statement of the group was reviewed recently with the Manufacturing Chemists Association task force, It seems to the MCA group that the study offers both theoretical and practical potential over that extended time span, tempered as it promised to be by realistic forecasts of population and economic growth, lifestyle changes, and technological advance,

The timetables currently governing the study would suggest that it should be finished in 1976, and will be in my opinion the first industry comment with adequate depth and scope to justify confidence in the forecast for the industry sector.

In the shorter term we have the FEA effort to define industry conservation targets for 1980, a program mandated by EPCA. The Battelle-Chem Systems study is likely to be published in September 1976. Under the urging of the MCA, an open communication by the chemical industry to consultants has been realized. Since the results have not been released yet by the FEA, and since they will be the subject of open hearings, it is impossible to offer comments on the results derived. The MCA Committee has organized a parallel study using industry experts in each SIC code area to develop an independent target number, properly weighted by the energy intensivity of the product sectors and the anticipated growth rates of each.

It becomes apparent in the MCA studies why the industry is reluctant to be bound to a high target at any time. Two technical reasons dominate, First, the extent of capacity utilization at any given moment has a profound effect on energy use per unit of output (fig. 17). Within the shaded portion lies 75 percent of the some 100 processes evaluated by the industry task force. You will note in these energy-intensive processes that at the origin the median energy requirement is 35 percent of full capacity energy. Or, on that median line, 30 percent of capacity required 50 percent of maximum energy utilization, The chemical industry operated at 74 percent of capacity in 1975, but the most energy inten -

FIGURE 17.—Energy Requirements Versus Production



Source: Manufacturing Chemists Association.

sive portions, such as olefins manufacture, ran at below 60 percent for a large part of the year.

Second, the SIC code approach mandated by law (and the only one seemingly feasible in light of currently available data) creates statistical problems for the chemical industry analysis. The problem is that SIC determination is by principal product shipped from each establishment, Given that, in the typical chemical complex, the sequential flow of intermediator to products is in several steps, these data shed little light on the effect of process steps involved. For example, my own company in its chemical operations produces 2-1/2 to 3 pounds of products and intermediates for each pound of product it sells. Less integrated operations will, of course, have fewer processing steps.

There is no question, however, that our own internal studies give great confidence that voluntary programs in the chemical industry will lead to savings greater than 15 percent by 1980 versus 1972, provided the economy justifies an economic utilization of capacity at that time. It is premature to publish specific predictions of savings for that time period. In plastics, synthetic rubber, fibers, BTX, and organic chemicals, increases in efficiency above 15 percent are considered feasible. On the other hand, the electrochemical and industrial gas sectors, dependent on electricity, offer much less savings potential overall, and along with the inorganic pigments and other inorganic serve to bring down the weighted average forecast.

It seems that energy intensivity declines markedly with each step in the value added. This has a most beneficial effect on management attention to energy conservation, since in the chemical industry the lowest value products have been most impacted by rising energy costs.

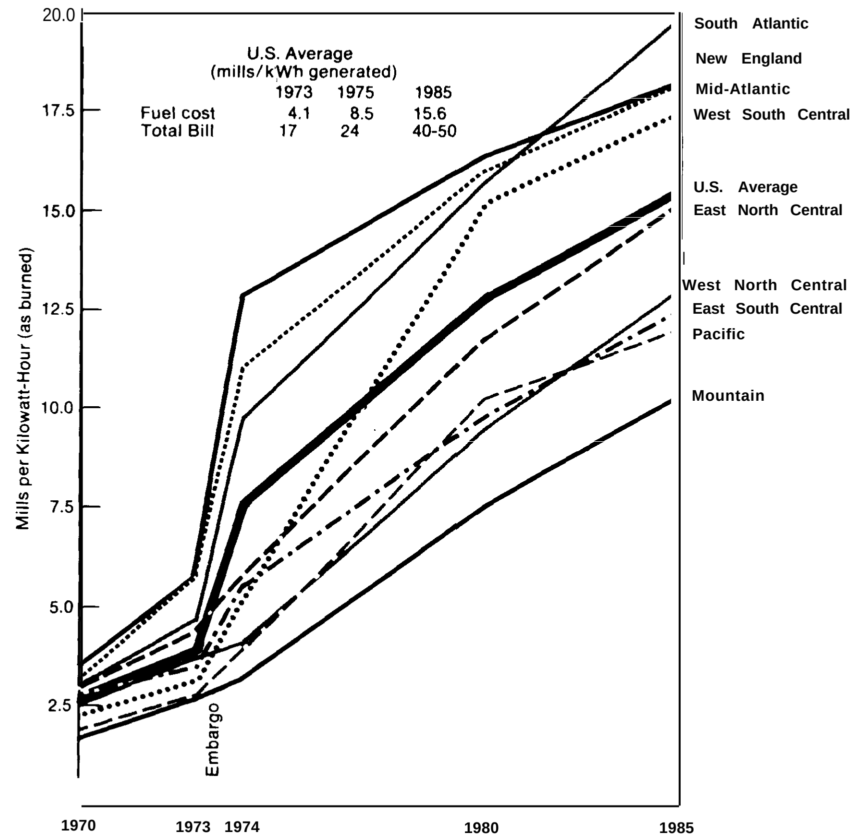
Which leads to the question, What is the impact on the chemical industry and how is it reacting in practical ways?

Lacking generalized data, I must resort here to particular examples. But I do believe the response has been very similar across the industry, in light of the reporting of some 100 companies in the industry. The conservation results reported to the MCA for transmittal to the Government indicate that the average savings per unit of output by the top 26 companies and the balance of the 100 are approximately the same.

The economic imperative created by energy dependence and sharply rising costs to save is enormous. Figure 18 displays recent fuel cost to utilities, and the total and projected U.S. average electricity costs. Since fuel cost is a major portion of purchased electricity charges for industrial users (about 70 percent in Texas Gulf Coast), the impact is greater on the industrial than the residential user for electricity. Unit electricity charges for a typical U.S. chemical company in 1975 are 240 percent of 1972. Intrastate natural gas prices are up eightfold. And oil costs are up fourfold. A basic petrochemical producer may have today 30 percent total energy product cost per dollar of sales. These relationships have directed management attention to savings of energy in many ways, with good effect and more zeal than any regulatory process can possibly command.

The industry conservation programs in my own company and others with which I am familiar have embodied all the paraphernalia required to systematically produce results. First, top management has uttered policy statements reflecting not commitments to Government agencies, but the economic necessity to be more efficient, Second, identified individuals in the organiza-

FIGURE 18.—Cost of Fuel Used for Electric Power Generation by Region, 1970-1985



Sources: Edison Electric Institute; Arthur D. Little, Inc., estimates.

tion structure have been given responsibility for results. Next, capital and expense moneys have been allocated consistent with economic and other guidelines.

Major energy-using processes are subjected to intensive audit, as are whole plants. Periodic reporting has been established, or better yet included in existing operations-improvement reporting systems, Strong internal and external employee and public relations programs have been instituted to encourage involvement and pride in results.

The published reports on the Monsanto Company represent a leading program. Under the "activity" method of reporting, they recognize a 19. I percent energy savings-per-unit output in the period of 1973-1975 inclusive, Since the production rate was low in 1975, the company purchased 15 percent less energy in 1975 than in 1974, but energy costs increased 24 percent, At the same production level as 1974, costs would have been up 45 percent.

The "activity" report concept anticipates the annual effect at reasonably high operating rates of projects instituted, and differs from the MCA report, which essentially reports the ratio of energy consumed, per pound of product produced, per calendar year, compared with the 1972 base year.

Monsanto uses a target energy cost to evaluate energy conservation investment, and that target is the energy cost in an outpost year 5 years after mechanical completion.

My own company's energy conservation savings are reported and managed through a longstanding Operations Improvement Program. That program, by the way, is given credit for our economic viability in the period 1960-1970, during which time the company's chemical price index in current dollars fell 36 percent.

Figure 19 portrays some recent history. It is noteworthy that since 1972 energy conservation savings as percent of total savings have gone from 15 percent to 37 percent of the total. About 30 engineers are dedicated to energy conservation work alone in the plants of this division,

FIGURE 19.–Energy Conservation Saving as Percent of Manufacturing Savings

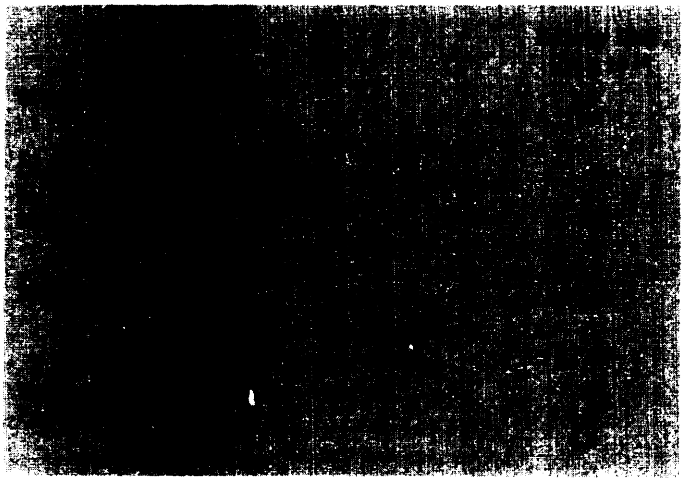
Year	Energy Conservation Savings $MM	Operations Improvement Program–Overall/ Savings (l)$MM	Energy Cons. Savings as% of Mfg. Total –(%
1972	6.2	41.1	1 5,1%
73	8.4	47.5	17.7
74	9.0	47.5	19.0
75	12.8	47,3	27.1
76 First Half Date	9.5	25.8	36.8%

(l)– Energy Conservation savings are included in the OIP overall savings. OIP focuses attentlon on:
- Energy Costs
- Raw Material Costs
- Period Costs
- Any other (:osts not in above

Source: Union Carbide Corporation

Research and development activities are increasingly directed to process development in less energy-intensive processes. Traditionally, about two-thirds of the equipment investment in chemical manufacturing is devoted to separation equipment, largely distillation columns. Since the early 1970's, research into new and less energy-intensive separation processes has been funded, The target is obviously large (fig. 20).

FIGURE **20.–Fuel** and Energy Use in the Chemical Mushy by Conversion Process



Source: Reference #21.

The principal deterrent to faster implementation of energy-upgrading projects is capital availability, A typical priority list for investment is, first, mandatory projects for employee safety; second, projects to meet environmental commitments; third, major expansion; and fourth, energy conservation.

Typically, paybacks for approved retrofit projects of an Operations Improvement Program or energy conservation nature are very great— less than a year at the present time. This reflects both lack of capital availability and the recognition that incremental investment in obsolete facilities may have very high returns, but the fundamental non-competitiveness of such facilities relative to all new ones embodying state-of-the-art technology is usually overriding. That trend is less obvious today, since all new facilities initiated will be completed at costs greater than 400 percent of those finished in 1971, but it is nonetheless fundamental in the long term.

The engineering guidelines currently in force indicate that there is economic justification in our operation for an investment of $100,000 to save 1590 barrels per year oil equivalent. The key assumptions are a forecast of energy price in an outpost year 5 years hence, and investment costs 2 years hence,

The discussion has concentrated so far on conservation measured as increasing energy efficiency. It is also true that conservation of declining fuel resources is a particular objective that prompts investment programs to diminish use of natural gas as fuel, The priority use of natural gas for residential use is explicit, and boiler use will be sacrificed. The current Texas Railroad Commission policy in that regard is clear, and while awkward for a number of individual plants and companies it is consistent with policies they have endorsed through industry groups such as PEG. My own company aims to reduce total natural gas use 65 percent by 1980 from 1972 levels, and I believe that is typical.

It is expected that if the new Federal Power Commission price , setting of $1.42 for interstate use is confirmed after litigation by consumers, then that will tend to promote conservation in interstate pipeline customers, as well as increased availability of gas to the pipeline. Intrastate prices in Texas and Louisiana already range from $1.50 to $2.00, and in our plans are expected to reach parity with oil in the early 1980's. A form value premium of 10 percent is very likely,

Such an economic spur to coal production is appropriate, and should suggest a more rational address to environmental costs and regulations, Environmental costs for coal should be internalized, and can in all probability be afforded if competing fuels reach more rational pricing.

It is perfectly apparent to the chemical industry that environmental obligations will have to be met fully in the areas where operations are principally located, such as Texas.

From a variety of industry sources, some forecasts of the energy efficiency of all new facilities embodying current technology at anticipated energy prices can be suggested. One source indicates that an all new olefins plant would use 35 percent less energy than a 1971 plant (22). Modifications of an existing plant would yield 15 percent. An all new refinery could achieve a 40 percent saving. Several categories of plastic plants will have 25 percent to 60 percent lower energy requirements than facilities built today (2). Realization of these potentials is obviously a function of increasing product demand for it is very difficult to justify additional new plants, no matter how economic they are, in an oversupplied market.

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A number of forecasters anticipate continued growth in the chemicals and plastics sectors at rates greater than GNP growth, albeit at half the levels realized in the 1960's. It is expected that engineering plastics will continue to replace metals on a utilized cost basis, particularly in transportation equipment. Continuing conservation potential exists there, Owens Corning Fiberglas has postulated a .79 gallon of gas saving per pound of weight reduction over the life of an automobile (100,000 miles). This sort of incentive will of course be reinforced by higher gasoline prices,

What Governmental and Regulator Policies are Appropriate to Energy Conservation ?

Beneficial results can be achieved in a number of ways, but the policy thrusts are relatively few, Seven are discussed as follows:

1. There should be more open invitation by the Congress and the energy agencies for industrial contribution to policymaking.
2. Voluntary industrial energy conservation programs should be maintained and encouraged. The economic incentives exist to prompt management attention and application of resources. The chemical industry's complexity surely calls for address within the infrastructure, not central regulation.
3, The prices of energy commodities, should be deregulated, and combined with windfall profit taxation modified by investment plow-back forgiveness for development of indigenous resources. The concept that "economic rents" created by deregulation is a social injustice does not recognize that present embedded investments are low compared with the dramatically higher requirements of new investments in energy product development and processing, Traditionally, these investments constituted about 12 percent of total industrial capital formation, but are about 25 percent today. Furthermore, the regulated low pricing of natural gas impedes the development of coal, exacerbates the misallocation of development resources, and keeps overall energy costs down, thus discouraging energy conservation investment in the United States compared to the rest of the world.
4. Capital and manpower are limited resources. Investment credit approaches are far superior to loans and loan guarantees, which impact on debt equity guidelines in many companies. A plan proposed by the Minnesota Energy Agency seems reasonable and could make many

marginal industrial energy conservation projects economically attractive. Briefly, the "Minnesota Plan" would give a tax credit of 25 percent for expenditures on plant and equipment related to achieving energy efficiency, plus a same year write-off if the company involved would certify that for every $4 of investment $1 annually of energy savings would result. The "break even" point for large and small corporations would range between 2 to 2.7 years. The Government would thus recover its cost for the program in 6 to 8.2 years,

5. Continuation and further development of Government-supported energy conservation education in smaller companies is appropriate. The EPIC manuals from the Department of Commerce get high marks from our people, and the industry seminars planned by FEA make sense, provided adequate technical content is achieved.
6. Industry-electric utility cooperation needs to be facilitated, The intrinsically wasteful thermal efficiency of electricity generation is improving in new coal-fired plants, to values like 8400 Btu/kWh from an average of over 10,000, but greater conservation potential exists in dual plants using waste heat. Industrial experience suggests that thermal efficiencies of 75 percent are practical.

   Specific areas include:

   (a) Off-peak and surplus power–some utilities offer lower cost power during off-peak hours or on an as-available basis;
   (b) Self-generation by industry with sale of surplus power to the utility or purchase of back-up power from utility;
   (c) Wheeling of power through utility-owned transmission facilities— this would involve purchase of power and self-generation outside of the serving utilities territory and wheeled over their lines;
   (d) Curtailable rate schedules–some utilities offer non-firm electric service at lower cost reflecting the higher utilization of generation facilities;
   (e) Dual-purpose industrial energy centers–these are a consortium of private industries which build and operate a central station for the production of both process steam and electrical energy;
   (f) Waste-heat recovery– this involves recovering waste heat from industrial processes and using it to generate power which is fed into the utility's distribution system, and

(g) Steam sales–purchase of process steam from electric utility. Steam sales for heating and process use are made by some utilities but the practice is not widespread,

7. A concentrated program should be started to demonstrate, and allow under law, coal mining and burning technology which is environmentally acceptable. The coal utilization in the United States today represents only 18 percent of primary energy supply, compared with 50 percent in 1950. But it is not generally recognized how narrow the market is—about 75 percent of all coal burned in the United States is consumed by 17 companies. Current strip-mining technology practiced in West German brown coal fields is noteworthy in its minimum environmental impact, and fluidized-bed coal combustion is near demonstration stage.

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THE ROLE OF MATERIALS AND STRUCTURES TECHNOLOGY IN DEFENSE–PART I

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Office of the Director of Defense Research and Engineering

Good morning, ladies and gentlemen. It is a pleasure to have the opportunity to be here this afternoon to discuss with you what I believe are some very important actions that the Department of Defense (DOD), materials and structures research and development community must take if we are to fulfill our mission. Hopefully, your deliberations at this conference will provide some guidance for these actions. Indeed, I could almost entitle this talk "Requirements Versus Realities."

The growing sophistication of DOD structural systems is requiring a much deeper understanding of the fundamental physics involved in evaluating the structural response of more complex materials and complicated geometrical configurations subjected to an ever-widening range of mechanical, thermal, and environmental loadings. When these thoughts are superimposed upon our technical and management philosophy which now emphasizes "design-to-cost" as well as reduced operation and maintenance, while at the same time insisting on some performance improvements, it is not difficult to realize that the demands on construction materials are becoming more and more severe and are placing both a premium on more extensive materials characterization and a deeper understanding of structural response and prevention of failure.

This situation is the primary motivation for the trend towards having to learn more and more about state-of-the art materials at the expense of developing new materials of construction. This is a fine philosophy as long as materials are available to do the required job. The basic problem is that an ever increasing number of situations are arising in which for one reason or another the materials we know about are not satisfactory. What I mean is that many applications are emerging where we are "up against the stops," or a required military capability cannot be satisfied because materials of construction either do not exist or have not been developed to do the job that is needed.

I will discuss some of these problem areas as I go along, but one fact is very clear: inflation and other factors over the past few years have steadily contributed to an erosion of the DOD materials and structures technology base. In the 1960s, the DOD technology base was able to provide support to the near-term needs of the military departments, while at the same time building a technological reserve for the future. Over the past few years that reserve has been used to important advantage, but it has not been replenished because of the pressing needs of increasing military capability. The realities of the fiscal situation are such that if we are to attain necessary military capabilities very deliberate management actions will have to be initiated to take better advantage of the U.S. national technology base.

I propose, therefore, to outline for you some personal perceptions of "technology requirements" and point out some areas where much work, including new ideas, is very badly needed in the light of present "realities," Figure 1 broadly illustrates the range of problem areas that we must address in the DOD technology base programs, I do not intend to address in detail all of the technologies listed here, but merely highlight a few which are of particular significance.

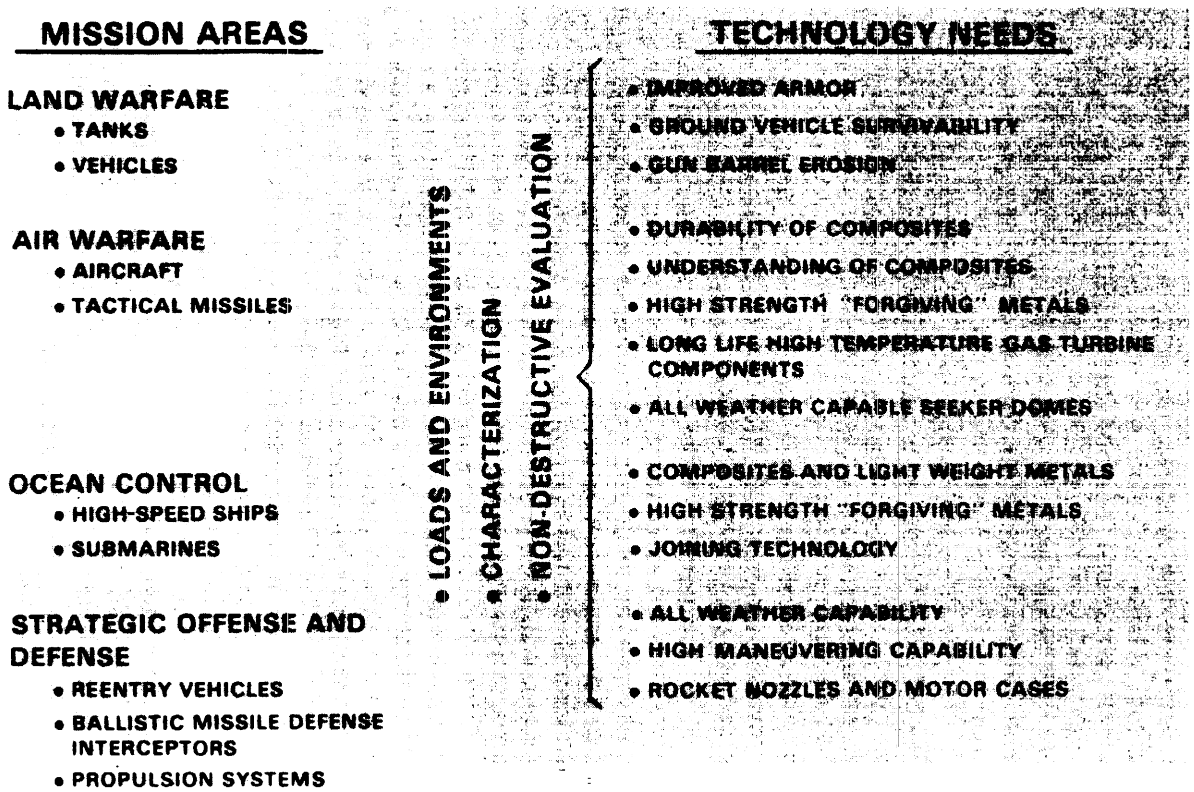
Technology

Before getting into the individual mission areas, however, I should point out that my intent in showing the loads and environment, materials characterization, and non-destructive evaluation as major program needs applicable across-the-board is very deliberate, I do not mean to imply that each of the mission areas suffers a major deficiency in these areas, but if there were any single set of program needs common to all mission areas, these are the ones. Without accurate definition of the structural and environmental loading on any given system, the designer must take a conservative route which leads to an over-designed or inefficient structure. Similarly for material characterization, if the measured properties scatter because of reproducibility problems, for example, the designer has no choice but to use the lower-most curve, These types of situations arise time and time again.

Now let me discuss the individual mission areas,

In the land warfare mission area one of our critical problems is that of survivability, The development of a materials solution to defeat the high velocity/high density penetrators is a very definite program need, This is a very complex problem involving not only materials development but also very extensive calculation schemes. This mission area also has very important program needs which address the problem of survivability of all types of ground vehicles, especially to mine field situations, The gun barrel erosion problem is one which has been with us a long time and will probably continue that way. As the need to increase projective velocity and accuracy increases, so do our gun barrel ero-.

FIGURE 1.—DOD Materials and Structures Techno ogy Requiremen s



sion problems. Materials and structures solutions to these problems, such as appropriate trade-offs between base materials and special coatings, are really not clear at this time.

The air warfare mission area also has many problem areas for which satisfactory solutions appear distant. All of the military departments are working on composite materials for use in aircraft. These materials are most promising for all types of aircraft structural components, particularly in areas where weight and size reductions are critical. When used effectively, they can result in structural weight savings up to 50 percent which can be traded for increased performance, combat survivability, or maintainability. But as with all things, we do not get something for nothing. Design with composite materials is a very difficult undertaking, as is meaningful, non-destructive evaluation during structural integrity investigations, Furthermore, they are not the solution to all problems. Military aircraft of the future will continue to depend on metallic materials for a variety of specific applications, The trend for the future will undoubtedly be towards the most effective use of each category of material.

Gas turbines perhaps provide a very good example to illustrate many of the points I have made so far. Before moving much further toward advancing this application, we need a better insight into the loads and environment inside military high-performance engines. We need a much better definition of the mechanical and the thermal loadings, especially in the very hot sections, While we seem to be moving in the direction of metal-matrix composites in the lower temperature compressor regions, the drive towards ever-increasing turbine inlet temperatures is putting severe demands on the high-temperature superalloy used in these regions. As a matter of fact, the evolutionary point has been reached where, for safety reasons, we must refurbish the hot sections of military aircraft gas turbines long before their estimated lifetime has been reached. This is a very expensive proposition from many points of view and reflects the quality of our materials and structures technology base.

The air warfare mission area also includes tactical missiles. A very important need is all-weather capability, While we have fairly large materials development programs addressing this need, I believe we are still a long way from providing the materials which will fully satisfy systems requirements.

The mission area of ocean control is primarily the responsibility of the Navy, We divide this mission area into high-speed surface ships and submarines. Each has its own particular combat environment, general performance envelope, design philosophy, and geometric configuration, For example, there is a major effort along a broad front to provide the Navy with higher speed ships, A common denominator of the various new types under consideration is the necessity to keep the weight low. Thus, the structural design and materials selection for high-speed ships approaches that of the aerospace vehicles. But the environment and loading are vastly different, leading one to inquire as to just how far it is possible to go in transferring aerospace technology to ocean control.

This brings me to the strategic offensive and defensive missile mission area. It is in this mission area where probably our most demanding program needs exist. Meeting existing requirements for all-weather capability, accuracy, reliability, and cost reduction all depend heavily upon our materials and structures technology. This mission area is in need of a great deal of emphasis.

Funding and Performers

Figure 2 shows the current and following fiscal years funding segregated by mission area. The recent Federal Council on Science and Technology Committee on Materials (COMAT) task force on the inventory and analysis of federally supported materials research and development revealed that the DOD materials R&D budget is less than 14 percent of the total supported by the US. Government. Because of the broad applicability of this technology area, it is not unreasonable to expect that a sizeable fraction of the work supported by other Federal agencies should, in some measure, be applicable to DOD needs. The question is "how do we take advantage of that work ?"

As far as military department performers involved in DOD materials and structures R&D, figure 3 indicates generally where and by whom the work is being done. The industrial and academic organizations listed are intended only to be representative and are by no means inclusive. The distribution of the funding shown at the bottom of the figure indicates that while the Army tends to do much of its work at in-house laboratories, the Air Force has a heavy contract program. The Navy is about 50 percent in-house and 50 percent on contract. An effort is being made to increase the amount of contract work of the Army and Navy over the next few years. This is an important step towards bringing in a broader range of new ideas into the DOD technology base.

Management

I would now like to discuss some aspects of what I term technology program management. Figure 4 illustrates some factors

FIGURE 2,—Funding Summary
DOD Materials and Structures Technology Base

&l+ 6.2+ 6.3A

MILITARY DEPARTMENTS +DARPA +DNA

MISSION AREA	FY 1976		FY 1977	
	MATERIALS	STRUCTURES	MATERIALS	STRUCTURES
RESEARCH	48.6	9.6	52.8	10.6
AIRCRAFT	36.8	21.4	34.9	28.9
MISSILES	23.2	4.5	19.5	5.4
ASTRONAUTICS	1.2	–	1.3	–
SHIPS, CRAFT, SUBMARINES	10.0	9.6	13.1	12.1
ORDNANCE, COMBAT VEHICLES	12.1	4.6	13.1	2.4
FACILITIES, OTHER EQUIPMENT	9.3	7.8	7.9	25.5
SUB-TOTALS	141.2	67.4	142.6	84.9
TOTALS	208.6		227.5	

which are having increasing influence on how we go about our business.

Over the past 3 to 4 years, there has been a steady growth of DOD/tri-service coordination for those mission areas having common materials/structures requirements. For example, there are formal and casual working groups in such areas as laser hardened materials and structures, tactical missiles, aircraft engines, reentry technology, and armor and penetrators. The military departments recognize that they must get together to exchange current information and to prepare integrated planning for future efforts if they are to keep up with requirements. In some cases workshops are called for, sometimes with industrial participants, to obtain additional ideas and inputs for future planning. These meetings prevent unwanted and unacceptable duplication of effort. They also focus more brainpower and experience to help solve existing technical problems. In addition to these specialized

FIGURE 3.—Implementation of the Military Department Materials and Structures Programs

ARMY			NAVY			AIR FORCE		
DARCOM		Army Research Office. Durham	Navy Commands (Sea, Air)		Office of Naval Research	Air Form Systems Command (AFSC)		Office of Scientific Research
DOD Labs	Industry	Univ.	DOD Labs	Industry	Univ.	DOD Labs	Industry	Univ.
AMMRC	U.S. Steel	Northwestern	NSRDC	Int'1 Nickel	Webb Inst.	AFML	Hughes	MIT
AVRADCOM	AVCO	Case Western	Annapolis	Union Carbide	Gee. Wash.	AFFDL	Boeing	Brooklyn Poly
HDDC	Norton	Lehigh	Carderock	Whittaker	U. Florida	AFWL	Gen'1 Dynamics	U. Calif.
ECOM	Philco-Ford	U. Calif.	NRL	Sikorsky	Penn State	AFAL	Northrop	Texas
MIRADCOM	TRW	Illinois	NSWC	Grumman	Ohio State	CRL	Lockheed	Yale
ARRADCOM	Corning	MIT	NWC	Lockheed	Georgia Tech		Fansteel	Wisconsin
BR L	Raytheon	Others	NADC	Battelle	Others		Dow Corning	USC
Watervliet	Honeywell			Others			Crucible	Others
Frankford	G.E.						Celanese	
Rodman Labs	Whittaker						Carborundum	
	Others						Others	

Army: $\frac{\text{In-House}}{\text{Out-of-House}} = 1.30$

Navy: $\frac{\text{In-House}}{\text{Out-of-House}} = 1.00$

Air Force: $\frac{\text{In-House}}{\text{Out-of-House}} = .40$

OVERALL $\frac{\text{In-House}}{\text{Out-of-House}} = 0.90$ “

FIGURE 4.—Materials and Structures Technology Program Management Trends

- **PLANNING AND COORDINATION**
  - **INCREASING ODDR&E/MILITARY DEPARTMENT PLANNING AND COORDINATION**
    - **LASER HARDENED MATERIALS AND STRUCTURES**
    - **TACTICAL MISSILES**
    - **REENTRY VEHICLE TECHNOLOGY**
    - **ARMOR AND PENETRATORS**
  - **INCREASING COORDINATION BETWEEN TECHNOLOGY BASE PROGRAMS AND MANUFACTURING TECHNOLOGY**
  - **INCREASING EMPHASIS ON [illegible]**
    - **IF TECHNOLOGY FULLY ACHIEVED WHAT ARE CAPABILITY/COST BENEFITS**
- **LIFE CYCLE COSTS WITH ACCEPTABLE MILITARY PERFORMANCE**
    - **ACQUISITION**
    - **O&M**
- **MATERIALS AVAILABILITY, CONSERVATION AND ENERGY REQUIREMENTS**
  - **INCREASING COORDINATION WITH OTHER FEDERAL AGENCIES**

working groups, formal materials and structures Technology Coordinating Papers (TCPS) have been and will continue to be prepared. The formality of these TCPS puts a necessary discipline in the system since they must be approved by high authorities responsible for materials and structure technology in defense.

These documents are prepared as a coordinated effort of the Army, Navy, Air Force, the Defense Advanced Research Projects Agency (DARPA), Defense Intelligence Agency (DIA), and Office of the Director of Defense Research and Engineering (ODDR& E). They describe and predict, in detail, the technical developments which the materials and structures technological communities who support the DOD must achieve in order that advanced weapon systems can be developed which will assure a credible U.S. military posture in the late 1970's and early and middle 1980's. These documents also identify areas where the greatest strengths and inadequacies lie, establish those categories in which critical materials and structures technology is needed, and recommend the level of effort to achieve required capabilities.

Unlike traditional descriptions of materials and structures technology programs, TCPS are organized in terms of military vehicles, weapons, and mission areas with each services' needs and objectives clearly identified, Each of these areas is analyzed with respect to principal systems, subsystems, and components to define and establish the pacing problems in materials and structures technology associated with each piece of hardware. In these documents we have tried to provide systems planners with the best judgments of the DOD materials and structures technology communities as to current technological status. The documents also address whether a specific technological area can be advanced at a faster rate than currently planned and, if so, at what cost.

As I am sure you can appreciate, these TCPS must be treated as internal Government documents because they contain financial and planning projections. Because of our sincere desire to share our assessment of the technology base with the industrial and academic sectors and thus develop a further, improved assessment, we have sponsored technology conferences which are based on the information contained in the TCPS. In the past, we have held separate conferences for materials and structures. The next one will be a structures TCP conference which will be held on November 16-18, 1976, at the Institute of Defense Analyses (IDA). This conference will update the information presented in 1974 at the last structures TCP conference.

We hope from these conferences that the industry sector will maintain a continuing insight into our many specific problem areas. An intangible, but most important, element of these conferences is the opportunity for representatives of those industrial and university organizations who have not been engaged in DOD research and development to meet Army, Navy, and Air Force officials and discuss mutual interests. The same opportunity would also exist for companies whose engineers and scientists have been involved in one or more segments of defense technology but have not participated in other related or unrelated areas. By this mechanism we hope that these conferences stimulate a continuing dialogue, After all, nobody has a monopoly on good ideas which can be stimulated by open discussion in an appropriate environment.

In a number of instances, we have found it necessary to engage in formal and informal coordination between ourselves and many other U.S. Government agencies and foreign countries. Figure 5 displays the coordination activities that are on-going between DOD and other Federal agencies. This, in a way, is a possible response to the first question posed to the panel; "How can DOD materials and structures research and development be made more productive in a world of declining real dollar funding?" The approach we have taken is less than satisfactory in that most of the relationships have been established in a specific known area and therefore relate to a specific problem. It would appear to be more beneficial if a realistically structured, Federal Government-wide coordination mechanism could be implemented so that all U.S. materials and structures technology areas are covered by an across-the-board formal organizational entity.

The question for the task group here then resolves itself to:

> Is greater coordination and interaction between the Department of Defense materials and structures technology base community and those participating in other Federal agency programs a feasible mechanism to increase productivity? If so, how should we go about achieving this?

An example of our cooperation with free-world, English-speaking foreign countries is the technical cooperation program (TCP) between the defense agencies of the United States, United Kingdom, Canada, Australia, and New Zealand. This is an extremely important aspect of our programs because, while their technology budgets are, in the absolute sense, less than those of the United States, they do provide an important different perspective on many problems.

FIGURE S.—coordination

WITHIN DOD

. **DOD Materials Shortages Steering Committee**

All Services, DARPA, Department of Commerce, Federal Preparedness Agency, NASA, General Services Administration, National Commission on Supplies and Shortages, Department of Interior, Office of Technology Assessment, etc.

. **National Commission on Supplies and Shortages**

- **Henniker IV Conference on Materials Policies**

FOREIGN

- **The Technical Cooperation Program (TTCP) Subgroup P (Materials Technology)**

All Sarvices and DIA

- **AGARD**

Materials Shortages

The possible shortage of critical materials is becoming more and more of a real problem. It forces DOD and contractors to examine carefully the question of materials substitution, redesign, recycling, or other alternatives at all stages of a given development. A great deal of attention is now being given to the question of shortages, and the situation may lead to some changes in DOD procurement techniques. To deal with this problem, the DOD Materials Shortages Steering Committee has been organized. Because the causes, effects, and resolution of potential problems extend much broader than the DOD, membership includes representatives from other Government departments and agencies. Figure 6 shows the current membership of this group. To date, the steering committee has held two major workshops involving representatives of Government and the materials industries (both producers and users). These workshops have contributed in defining and clarifying many very complex problems which could seriously impact DOD mission responsibilities. To assist in the deliberations of this conference, we have provided for each conference participant copies of the papers given at the workshop held in February 1976. We do not yet have any clear answers to the many problems we have encountered, but before that can happen we recognize that we must first have an understanding of the overall problem.

FIGURE 6.—Coordination

BETWEEN DOD AND OTHER FEDERAL AGENCIES AND ORGANIZATIONS

- **National Academy of Sciences (NAS)/National Materials Advisory Board (NMAB)**

  All Services, DARPA and NASA contribute to support

- **DOD/NASA Aeronautics and Astronautics Coordinating Board (AACB)/Supporting Research and Technology (SRT)**

  Materials and Structures Subpanel

- **Defense Materiel Standards and Specifications Board (DMSSB) – Materials Panel**

  All Services, DSA, Dept. of Commerce, Energy Research and Development Administration (ERDA), NASA, ANSI, ASTM, SAE participate

- **Federal Council on Science and Technology (FCST) – Committee on Materials (COMAT)**

  All Services, ARPA, Dept. of Commerce, Dept. of Interior, Energy Research and Development Administration (ERDA), Dept. of Transportation, HUD and HEW participate

- **Materials Intelligence Seminar (MIS) - Structures Intelligence Seminar (S1S)**

  All Services, DIA, and CIA participate

- **Industry Conferences**

  Jointly sponsored with Dept. of Commerce and Interior
  "Health of Industry," "Titanium, " "Technology Transfer"

- **ERDA Ceramic Gas Turbine Review Committee**

NASA

- **Carbon/Carbon Re-entry Shields**
- **Carbon/Carbon Rocket Nozzles**

Innovation

I would like now to discuss some aspects of creativity and the goals of materials and structures technology development. Admittedly, calling out the need for creative or innovative ideas is a little like renewing one's faith in motherhood. Such ideas are always good and desirable. Nevertheless, because of the technological barriers that are confronting us in so many areas, we must reexamine our technical approaches. Is there a better way to approach a given problem? Are we solving the right problem or are we overlooking something? Are there possible new concepts which could eliminate the problem altogether?

It is possible. even probable, that new ideas will not appear when requested. Creativity cannot be turned on like a faucet; it evolves in the mind. However, unless innovative ideas are invited and welcomed, they may never appear; or, if they do, may not be properly exploited, To be welcome, such ideas need be neither major breakthroughs, nor highly technical.

A case in point related to the non-destructive evaluation (NDE) of high-performance materials. Military requirements are emerging which require that the critical flaw size to be detected is approximately the same size as inherent materials defects. This evolution is placing ever-increasing demands on NDE detection capabilities and is approaching unreality in certain critical structural areas and in certain materials, Inspection costs are rising rapidly for these components as are the costs associated with the higher reject rates, Even more serious is the situation in which an undetected flaw might cause a catastrophic failure of a component because of our marginal ability to detect the smaller and smaIler critical flaws.

We may be traveling down the wrong path in developing high-strength metals which require increasingly higher resolution NDE. We should perhaps consider paying more attention to imparting some "forgiveness" into the materials of construction. For metals, compositing with high-strength fibers may be a good approach. Extensive work on organic-matrix composites has demonstrated significant flaw tolerance and dramatic increases in fatigue life. If these important attributes can be demonstrated for metal-matrix composites, a very important development for future military equipment could result.

While there is increasing interest in the use of ceramic materials for high-temperature structural use, they are certainly not "forgiving" materials; consequently, the reliability problem is quite severe. Compositing, however, may be one promising approach. Ceramic composites have been used in high-temperature windows but not really as a true load-carrying component. Another, and more basic, approach is to impart more ductility to ceramics.

Impact load characterizations and effects are becoming highly important. Particle impacts, such as the weather effects on all aeronautical vehicles, bird impacts on gas turbine engine fan blades, and ballistic impacts on armor are all phenomena which are only semi-empirically understood. It is vital that we understand, in a much better fashion, both how the loads arise (for example, how are atmospheric water and ice characterized?), and how to determine and simulate the material behavior under such loads,

Many similar problems exist for which more basic understanding is needed, But for the sake of time I will not elaborate upon them.

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Conclusion

Let me conclude these remarks by commenting on a matter of concern to me and my DOD colleagues involved with materials and structures. In many areas the technology base so essential to future systems development is severely depleted. Future military requirements are almost certain to involve even more stringent design conditions. At the same time, high reliability at lower cost will continue to be emphasized. These needs can be met only through a revitalized technology base. Unfortunately, the missions of other Government organizations are such that their technology base is not directly useful to DOD. We do use a great deal of what they develop and depend on them heavily to sustain the overall U.S. technology base, And without it I am sure we would be in even worse trouble. Nevertheless, the DOD has its own special requirements, and it will take special efforts to meet and maintain its needs. The overall question I therefore place before this audience is “How can the DOD do a better job of implementing the transfer of materials and structures technology between Federal agencies, industry, and academia so that it can replenish the technological reserve which has been depleted over the past few years?”

We in the DOD are working very hard to keep ourselves as far up on the “power curve” as we can. We recognize that we are running into “road blocks” in many areas and must work our way around them. I will continue to press for greater creativity and innovation in our programs as the best pathways around these road blocks, Let me emphasize again that dollars cannot produce good ideas. The ideas and thoughts that emerge from other programs could prove extremely valuable, and the military departments will welcome them.

As I said earlier, we cannot by ourselves solve the problems I have outlined. We need the help of other U.S. and free-world programs, The strength of the U.S. national defense effort is very much dependent on the collective, sustained efforts of the overall U.S. materials and structures technology community. My perception of the world situation is that we had better “get on with it” or the technological balance is sure to shift the other way. And we cannot allow this to happen.

Thank you.

THE ROLE OF MATERIALS AND STRUCTURES TECHNOLOGY IN DEFENSE-PART II

by Morris Steinberg
Director, Technology Applications
Lockheed Aircraft Corporation

In a recent report to Congress, the General Accounting Office (GAO) assessed Federal materials research and development and made three recommendations aimed at modernizing the materials policy formulation process and the management of Federal materials R&D activity:

1, Establish an institution to analyze materials issues and provide policy guidance,
2. Establish a comprehensive unclassified information system for materials R&D built on existing information in the Smithsonian Science Information Exchange, and
3. The Science Exchange should include in its information systems materials R&-D information developed outside the Federal Govern merit.'

In reviewing the Federal materials R&D the GAO study highlighted three aspects of past and present Federal materials R&D (table 1). First, program funding in constant dollars is actually decreasing. Second, Federal R&D effort is highly fragmented. Third, data are incomplete and have been poorly gathered over the last 15 years, and collection is sporadic and insufficient for policymaking.

TABLE 1. –Highlights of GAO Review of Federal Materials R&D

- **Program funding in constant dollars** ❇▲ ❁❃▼◆❁●●I ❄❉❃❒❉❁▲❇■❊✎
  1962-1972 = $185 million to **$331** million
  (real growth only **6%** in constant dollars)
- Federal R&D effort is highly fragmented.
  1) **No** overall Federal materials R&D program.
  2) Large number of specific mission-oriented R&D activities.
  (Fy 1974–23 agencies–90 **subdivisionals sponsoring materials R&D)**

Source: "Federal Materials Research and Development" Modernizing Institutions and Management. " GAO, DEC, 2. **IW5**

I Requested by Senators]ohn Tunney and William Brock to (1) analyze Federal Funding for Materials R&D **and (2) evaluate** the effectiveness of Federal Materials R&D. "Federal Materials Research and Development: Modernizing Institutions and Management," GAO Dec. **2, 1975.**

It would seem to me that these findings and recommendations could be deliberated this week by this assembly of experts and could help provide a mechanism to aid in formulating the means for establishing and implementing such a plan,

But specifically, I am here with Jerry Persh of Office of the Director of Defense Research and Engineering and Max Williams of the University of Pittsburgh to address the questions of the role of materials in defense (table 2), From the DOD point of view, could these recommendations of the GAO be sufficient to assess the DOD materials R&D and to determine weakness in the program and disseminate information more readily? What about the very large body of classified materials R&D and materials data that is an integral part of DOD weapons systems? Would a more complete DOD system be more relevant, or can the recommendations made by the GAO satisfy DOD's major needs?

TABLE 2.–Questions for the Role of Materials in Defense

1, Can R&D be made more productive in a world of declining real dollar funding?
2. Can the design team approach significantly increase cost effectiveness?
3, Would DOD funds allocated to basic science–not mission oriented–be more effective in furthering the long range, materials-associated needs of DOD rather than depending on NSF funding for basic research?
4. How can centers of excellence for areas such as casting, welding, etc., involving individuals from industry, academia and Government be more effective in advancing and disseminating technology?
5. Is the trend toward reductions in DOD's manpower and resources in its materials and structures divisions severely reducing its effectiveness?
6. What is the best way to expedite the development of materials and technologies that limit the development of new systems and weapons?
7. How can R&D programs of DOD be better coordinated to more effectively develop new materials and technology?

The policy questions posed by Jerry Persh (table 3), should also be examined in light of the GAO study.

DOD Materials and Structures Technology and Industry Support

For many years the DOD Materials and Structures Technology programs were the main support in the United States, underlying in the area of high performance materials the basic research and development effort underway.

TABLE 3. –Policy Questions

- Role of Federally supported industrial materials and structures R&D in the U.S. National Technology Base,
- Role of company sponsored R&D
- Should (or can) industry make a greater effort to coordinate itself (or depend on the Government to perform this role)
- How to assess U.S. National Technology Base in materials and structures (with consideration to U.S. competitive base in industry).
- What are weaknesses, or strengths. of the way the "system" operates?

With the advent of NASA, the growth in NSF and the recent formation of ERDA (absorbing the old AEC), the proportion of U.S. materials and structures R&D supported by the DOD has been in general decline since about 1968 in relation to other Federal programs. The potential military relevance (PMR) clause in Public Law 91-441 and in ASPR 15-205.3 and 15-203.35 helped accelerate this decline.

The needs of the DOD, and industry supporting the DOD in the area of materials and structures technology, have increased, as pointed out by Jerry Persh. The dilemma, then, is how to generate the necessary technology base to insure that it will be adequate to support our military hardware programs, not only with a declining DOD manpower and financial base, but with serious challenges being made to the Independent Research and Development (IR&D) programs of the defense industry in support of DOD objectives.

The subject of IR&D is debated yearly in the Congress. The major attitudes are to either eliminate it or excessively control it, and the new requirement for potential military relationships in Public Law 91-441 have exerted a constraint on industry's desire to continue to generate the technology base necessary to support DOD objectives for future weapons systems.

In the face of these constraints, the last decade in DOD weapons systems development has encompassed a more fundamental approach to structural response of complex materials systems for weapons systems which includes:

- "Design-to-a-cost" philosophy,
- New concepts in structural integrity, and
- Minimum life cycle costs consistent with enhanced safety and improved performance.

For example, in the last 5 years new concepts in fracture mechanics have been introduced into the characterization of materials and into the structural integrity program of aircraft and missiles for determining operating stress levels and prediction of the life of structures, and very importantly, for determining proper inspection intervals of aircraft.

This technology has found widespread use in aerospace applications and now has created a high level of interest for surface ship needs in both the Navy and Coast Guard where high-strength, heat-treatable steels are being used to achieve higher performance. Here, older technology of determining structural integrity is suddenly no longer adequate. For example, in the case of the application of high-strength, low-alloy, heat-treatable steels applied to ship construction, recent attention to notch toughness as a material parameter for ship construction has focused attention on the inability of producing welds that satisfy current charpy V-notch (CVN) energy requirements and the multiplicity of required test specimens and notch locations for different plate thicknesses required for low-temperature (less than +32°F) applications. Metallurgical studies are needed to determine whether a solution to this problem is economically feasible in view of the severe restrictions placed on production weld fabrication in the shipyard to satisfy present requirements for critical low-temperature weld joints with present-day steels.

Finally, there is no doubt that high-performance Naval and Coast Guard surface ships of the future probably will employ materials with intermediate to high, strength-to-weight ratios. Because some of these materials are susceptible to rapid fracture resulting from small flaws, sub-critical crack growth aspects of material behavior, such as stress corrosion cracking and fatigue, would he incorporated in the design process (as in aircraft) preferably as part of an overall fracture control plan to insure safety, reliability, and economics. This fracture control plan is a methodology for avoiding failure by fracture over the design life and includes considerations of the elements identified in table 4, At the heart of this plan would be the application of fracture mechanics considerations that assumes an initial flow which can

TABLE 4.– Elements of Fracture Control Plan

- Load and Environmental Definitions
- Structural Design
- Material Properties Selection and Quality Control
- Fabrication Processes
- Inspection and Maintenance

Source: Ref. NMAB-327.

propagate and lead to fracture and the necessary fracture control steps that will prevent this from happening.

This need and the problems described focus on the requirement for new processes, new non-destructive inspection (NDI) procedures, and the need for the generation and the maintenance of a materials properties data base that is much more detailed and sophisticated than is available at present. I would like to use this point as one example where policy is needed and where this assembly may be able to generate some meaningful recommendations to the DOD in one aspect of materials policy.

Materials Standards and a Properties Data Base

Jerry Persh has alluded to the problem of declining manpower and resources in the DOD in the past few years which has steadily contributed to an erosion of the DOD materials and structures technology base. This is especially true in the area of materials and process specifications which serves as the backbone of hardware procurement for the DOD, where over a 50 percent decline has taken place in the last 10 years.

The DOD has been fortunate in having more than 4,000 materials and process specifications available and maintained to ensure that the standardization effort in the DOD is consistent with the procurement of military hardware which meets the performance, reliability, and Iife expectancy of the using services. However, because of the declining manpower and financial resources being allocated to the generation and maintenance of these specifications and standards, and with the increasing sophistication of the newer weapon systems, the ability of the services to fill the needs of standardization in this area is declining. With this growing sophistication in weapon systems and the need for greater performance has been an increasing demand for enhanced structural integrity, minimum acquisitions cost and low life cycle costs.

A second problem is the data base of meaningful properties on which to base specifications and accomplish engineering design. There is a need for:

1. A better means of generating materials property data,
2. A proper format to display data being generated on major DOD programs so all meaningful data are available. and
3. A long-term program of R&D to develop property data on new materials and composites to enhance the transition of materials and process technology to the newer weapon systems.

The newer requirements place severe demands on materials of construction and require more extensive materials characteriza-

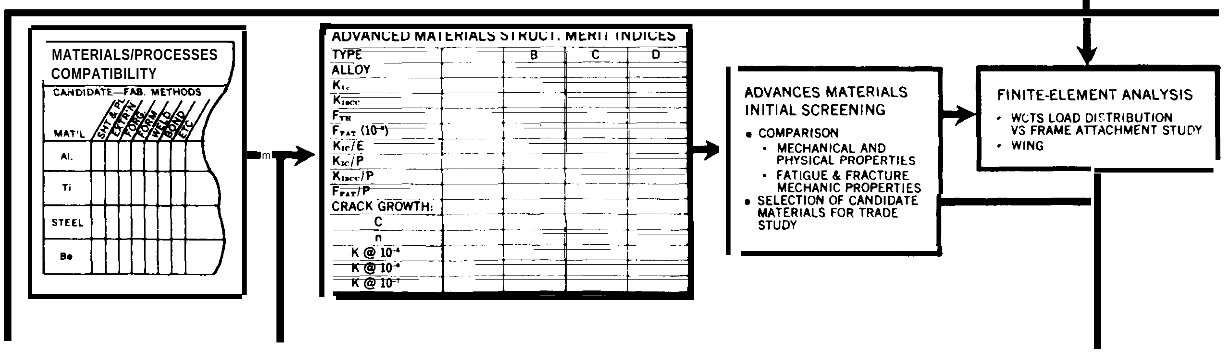
TABLE 5.

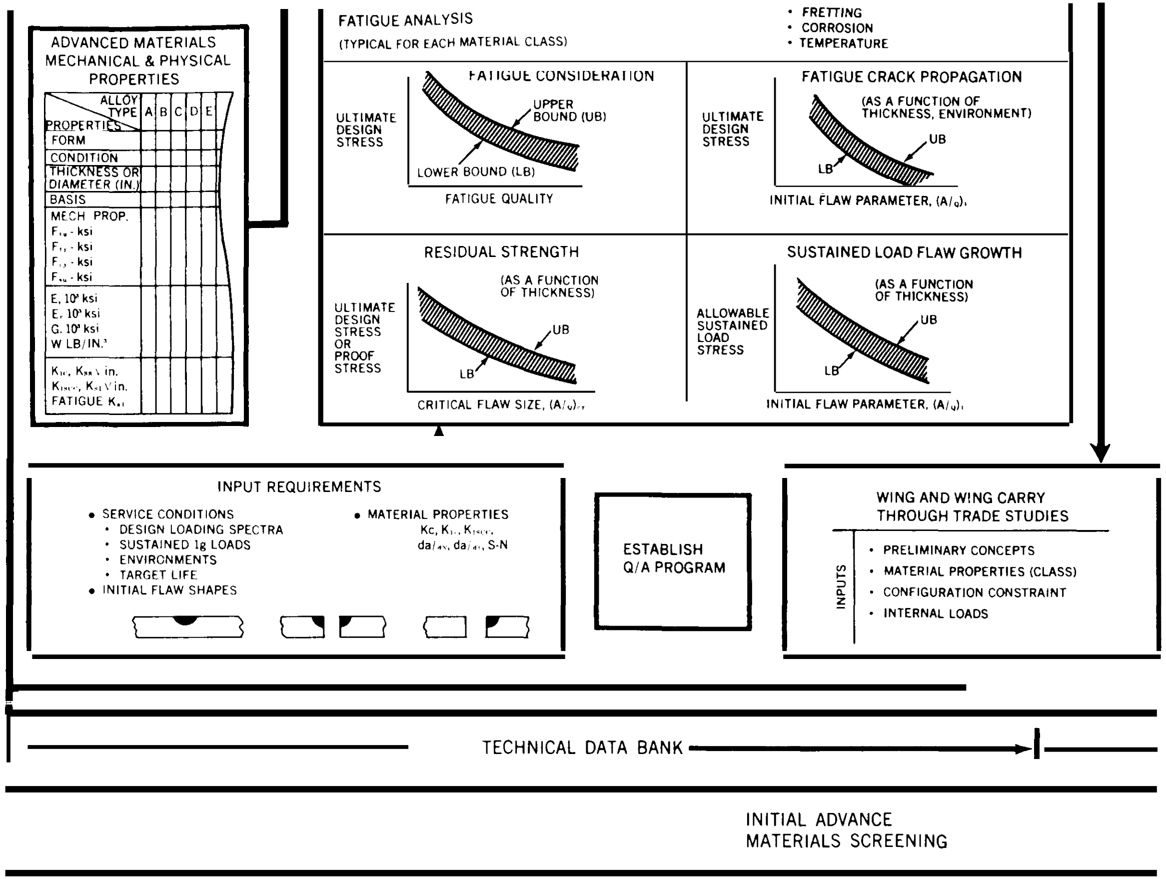
MATERIAL TESTING

DETERMINE:
- C CANDIDATE MATERIALS
- AMOUNT OF TEST MATERIAL REQUIRED
- AREAS WHERE INSUFFICIENT DATA EXISTS
- CRITICAL PROCESS STEPS

DEFINE:
- SPECIFIC TEST VARIABLES FOR CANDIDATE MATERIALS
- DATA REQUIREMENTS FOR DESIGN
- TYPES OF ENVIRONMENTS
- s PROPOSED TEST PLAN

PRELIMINARY DESIGN




ADVANCED MATERIALS MECHANICAL & PHYSICAL PROPERTIES
ALLOY TYPE
A
B
C
D
E
PROPERTIES
FORM
CONDITION
THICKNESS OR DIAMETER (IN.)
BASIS
MECH PROP.
E, 10³ ksi
G. 10³ ksi
W LB/IN.³
FATIGUE ANALYSIS
(TYPICAL FOR EACH MATERIAL CLASS)
• FRETTING
• CORROSION
• TEMPERATURE
FATIGUE CONSIDERATION
ULTIMATE DESIGN STRESS
UPPER BOUND (UB)
LOWER BOUND (LB)
FATIGUE QUALITY
FATIGUE CRACK PROPAGATION
(AS A FUNCTION OF THICKNESS, ENVIRONMENT)
UB
LB
INITIAL FLAW PARAMETER
RESIDUAL STRENGTH
(AS A FUNCTION OF THICKNESS)
ULTIMATE DESIGN STRESS OR PROOF STRESS
CRITICAL FLAW SIZE
SUSTAINED LOAD FLAW GROWTH
ALLOWABLE SUSTAINED LOAD STRESS
INPUT REQUIREMENTS
• SERVICE CONDITIONS
• DESIGN LOADING SPECTRA
• SUSTAINED 1g LOADS
• ENVIRONMENTS
• TARGET LIFE
• INITIAL FLAW SHAPES
• MATERIAL PROPERTIES
S-N
ESTABLISH Q/A PROGRAM
WING AND WING CARRY THROUGH TRADE STUDIES
INPUTS
• PRELIMINARY CONCEPTS
• MATERIAL PROPERTIES (CLASS)
• CONFIGURATION CONSTRAINT
• INTERNAL LOADS
TECHNICAL DATA BANK
INITIAL ADVANCE MATERIALS SCREENING

tion and a deeper understanding of structural response for prevention of failure.

Perhaps an insight into the use of the materials and process specifications and the materials properties data base in modern preliminary design in the preliminary design of a lighter aircraft, as shown in the chart of table 5, can indicate the importance of the specifications and materials properties data base.

The materials-testing requirements shown at the top of the chart would be accomplished on the candidate materials of interest in the forms necessary to generate the data needed, shown in the tables under "preliminary design, " In many cases if the data are not available, this test program for materials characterization could cost several millions of dollars for only a selected few mill forms of one material. The materials / process capability (specifications) would be evaluated, and if needed new specifications would be written or old ones modified or revised. The mechanical properties needed are illustrated in the tables given, as well as the method used in rating the materials.

The inputs required to ensure structural integrity for fracture mechanics and fatigue analysis under the proposed conditions are also detailed. The advanced screening and analysis then is made consistent with the requirements imposed by stress analysis, and mode studies are then accomplished against the initial conceptual design. All of these data make up the initial technical data bank. From this discussion it is evident that new approaches to these problems are needed. The questions that need answering are:

1. How can the DOD best use the resources of the voluntary standards organization, i.e., SAE, ASTM, AWS, AS ME, etc., to help update and prepare specifications in the materials and process field so that they are available and timely for new weapon systems production?
2. How do other agencies of the Federal Government prepare and update their specifications? Did the DOD and other agencies, i.e. NASA, ERDA, etc., coordinate their act iv i ties ?
3, Should there be a national standards system supported by the Federal Government of which the DOD would be a part ?
4. What effect will proposed legislation such as the Voluntary Standards and Certification Act of 1976, which among those proposed is the development of a uniform national standardization process, have if passed?

As to the materials properties data base problem, industry and the military spend large amounts of resources to characterize materials properties, Too often the data are scattered throughout development contract reports without organization, and there is no uniform method or requirement as to how these data should be analyzed, collected, and disseminated. There is a major need for Government and industry to get together to do this to save manpower and resources and to determine what data are really lacking so that the declining DOD resources in this area can be made more effective. The major policy question is then how best to' accomplish this.

Problems Limiting Development of New Systems and Weapons

There is no doubt that one of the most promising materials concepts for efficient structures in the newer weapon systems will be the use of high-stiffness, high-strength filamentary composites. I would like to use this structural concept as my second example to highlight the question of what is the best way to expedite the development of materials and technologies that limit the development of new systems and weapons, and to point out the problems of the transfer of this technology from R&D to production.

An example of some lessons learned in a major application of composites to a new strategic missile program can perhaps highlight the problem, may help this group in formulating some new ideas on how to do it better and more efficiently, and may even help detail ideas on how the DOD can better coordinate its R&D programs to insure more rapid application to weapon systems.

The Technology Transfer Problem With Composites

During the past 15 years, military aerospace interest in applying composites has been motivated by the desire for "more efficient" aerospace structures that can be lighter, stiffer, and stronger, together with the hope that they will be more durable and cost less. These have been the evaluation and selection criteria for the development and acceptance of composites. *

Certain benefits have accrued to the application of composite materials in the last 15 years (shown in table 6). Although significant progress has been made, problems remain which affect the further development and use of composite materials in military aircraft (table 7).

Perhaps as much as $500 million or more has been spent in this development, If the commercial aircraft applications are considered, perhaps another $100 million has been spent, and the

" Summary of "The Influence on Advanced Composites–An Assessment of the Future", june 11-12,]975.

TABLE 6. – Benefits Accrued and Progress Made Composites Structures Development *

1. Simultaneous development of materials, design, and manufacturing technologies rather than a sequential approach.
2. Early achievement of production applications, such as F-14 and F-15 empennage components,
3. Development of basic technologies at user facilities rather than exclusively at universities and Government laboratories.
4. Clear demonstration of an initial goal of potential weight savings on a substitute basis.
5. Development of competitive material sources on a commercial basis,

'Conference on Advanced Composites–June 11-12.1975

TABLE 7. –Problems Remaining in Composites Materials Affecting Further Development and Use in Military Aircraft

1. Overselling composites through 100% usage for structural components.
2. Cost of material (e.g. tape) does not reduce as rapidly as projected,
3, The nonuniformity of materials is a normal occurrence.
4. Some programs experience "start' '-''false start" and '*stop'- ''go" syndromes.
5. Program delays due to Government inter-laboratory conflicts on responsibilities and goals.
6. Conflicts within a company between experienced metal designers and new composite design specialists.
7. Lack of confidence in small statistical samples of components.
8. Marginal cost tradeoffs and unclear cost-benefits.
9, No realistic definition of a successful "Goal" has been established.
10. New vehicle totally dependent on composites for its success is not like! y.
11. Misconception that all aerospace companies progress uniformly and share equally on developments.

Source: Conference on Advanced Composites-]une 11-12. 1975,

programs of both DOD and NASA indicate another $2OO million may be spent in the next 5 years. With this major expenditure over this length of time (2o years before major commitments to production), we might ask why so long a time and so much money, or, more importantly, have our resources been properly spent in pursuit of these deserving objectives?

Perhaps the qualification of composites for full scale application poses problems that from a cost and time point of view make the application of composites on an ongoing program difficult to accomplish. When this is coupled with the need to develop not only structural concept verification but also NDI acceptance criteria with a minimum data base, the confidence level for application then is not too high.

In order to assure structural integrity, the qualification testing (hot and wet fatigue testing as one example) does much to inhibit their use. One might ask what sort of a policy should best be pursued to stimulate more rapid applications? Should the DOD impose all of the requirements that seem much more difficult to satisfy than with metallic structures? Or should the DOD adopt the posture of the FAA in application to commercial aircraft where industry and the agency (FAA) together determine the optimum procedures for certificating end use based on the best judgment of the producers of the structure and a consensus of all interested industry members before "rule making" is applied?

In the field of composite application, systems performance can sometimes be the major driving force for commitment to development and production, It also can require a coordinated design team approach from the time of preliminary design to first lot production to insure cost-effective commitment to production and use. An example of this is the present application of graphite/epoxy composites in the Trident C-4 missile structure.

In reviewing the various means of fabricating missile structures to reduce weight and increase the range, graphite/epoxy materials provided a high, strength-to-weight ratio material that could be utilized in current production. The equipment segment of the C-4 Trident was chosen as the optimum structure to be designed from graphite/epoxy material since a weight reduction in this segment provides the greatest increase in the mission performance. Since the development phases of the C-4 program were followed very closely by the production program, it was essential to select a material satisfactory for design and producing components with high reliability and at a reasonable cost. For these reasons, the graphite/epoxy was selected as the advanced composite material that would provide the best opportunity for meeting these objectives.

In the initial materials evaluation, the graphite/epoxy tape produced satisfactory components; however, the manhours required to layup the complex shapes using the tape was excessive. and the orientation of the tape, gaps, voids and other discrepancies was difficult to control. A combination engineering/manufacturing development program with graphite/epoxy fabric showed that the fabric could meet all of the engineering requirements and result in an overall reduction in fabrication cost. Therefore, the graphite/epoxy fabric was adopted as the prime candidate for the graphite components.

Working closely with design, structures and materials, and process engineering, manufacturing concepts were established that would produce reliable, repetitive components at minimum cost. For many components, the autoclave cure method was found to be the optimum process, while other components were found to be produced more efficiently using matched dies on the silicone rubber mold technique for obtaining pressure. A close working relationship between engineering and manufacturing permitted the design, process, and acceptance criteria to be reviewed for each part; and changes were made, when possible, to permit ease of manufacturing. To ensure a repetitive high quality structural component, each initial production part is process verified to measure mechanical properties, to confirm process and document control, arid to substantiate adequacy of the tooling, Then, after successful completion of process verification, no changes are made in processes, controls, tooling, or other variables that could effect the integrity of the composite component.

The use of graphite fabric, cut-out templates, matched dies, establishment and control of the cure cycle, tooling aids to assist layup, and no modification of the manufacturing and process cycles after the fabrication of the initial production parts were some of the factors that greatly assisted in maintaining a low manufacturing cost for the composite parts. Although the initial development cost of the composite parts was higher than initially predicted, the learning curve drops rapidly as the production process is established. The close initial coordination between engineering and manufacturing in designing and manufacturing toward one composite concept pays off rapidly in the lower repetitive cost of the production parts.

In the course of this development, a number of key lessons were learned in the application of composites structures that indicate the unforeseen problems that can arise in the course of the introduction of a new structural materials concept to production, These include:

1. Composites pay off when everything works;
2. Serial production development does not work;
3. The use of woven cloth pays off big in certain applications:
4. There is a tendency for engineering to over-design for conservative reasons when the data base is not complete;
5. Structural analysis techniques are quite good for composites;

6. Tooling developments are tougher than expected:
7. Metal tolerances do not apply;
8. Training requirements can be grossly underestimated:
9. The QA accept/reject criteria can be a quagmire; and
10. The selection of the proper manufacturing manager can be quite critical.

My last example has to do with materials research and materials needs, particularly long range needs of the DOD and the policy as to who does it, and the way the R&D programs can best be coordinated for the developments of new materials and technology, It is not only in filamentary composites that we look for enhanced structural efficiency and durability, Future aircraft, for example, are still expected to use aluminum alloys as the principal material of construction, even though there may be increased use of composites in competition with aluminum and continued use of steels and titanium for special design applications.

Aluminum Alloys

The principal trend in aluminum alloy development for airframes has aimed at improved corrosion and stress corrosion resistance and increased fracture toughness. Improvements in these characteristics have generally been accompanied by a reduction in strength properties. This trend is clearly illustrated in figure 1 which indicates that the 7178-T6 composition remains the highest strength aluminum alloy available today. It was first used extensively 25 years ago; however, unfavorable stress corrosion and exfoliation experiences have limited its application during the past 10 years. Therefore, a high-priority need exists for a replacement material for 7178 which provides strength properties equal to or greater than 7178, with greatly improved toughness and corrosion-resistance characteristics. Such a product could be used to provide the following benefits in typical applications on a transport aircraft as well as high performance fighter aircraft.

Aluminum alloys with improved fatigue and stiffness are also of great interest and would obviously translate into similar weight reductions when used in airframe applications designed to fatigue and stiffness criteria. Ongoing research and developments in aluminum alloys that hold great interest for potential applications in airframe design include A1-Mg-Li alloys, powder metallurgy processing, controlled solidification process, and retrogressive aging (table 8).

FIGURE I.—Aluminum Alloy Developments

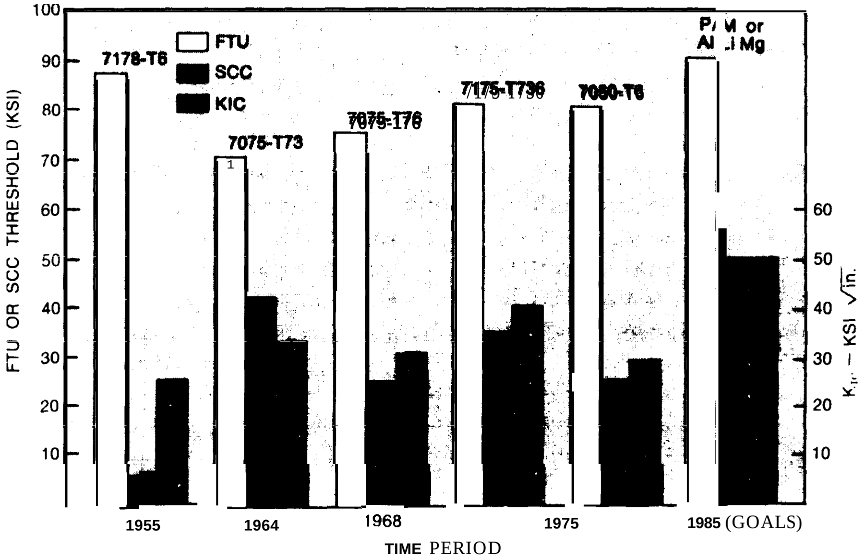


TABLE 8.—Potential Weight Reduction in Cargo Aircraft With Advanced Aluminum Alloys

Product and Application	Material Now Used	Potential Weight Reduction with an Advanced Alloy	Approx. (lbs.) Reduction in Annual Fuel Consumption*
Misc. Forgings (2000 lbs.)	7075-T73	300	42,000
Extrusions (5000 lbs.) Horizontal Stabilizer & Beam Caps	7075-T76	400	56,000
Fuselage Floor Supports (3000 lbs.)	7075-T76	150	21,000
Fuselage Skin (900 lbs.)	7075-T76	80	11,000
Upper Wing Skin (6000 lbs.)	7075-T76	540	70,000

* Per aircraft, 3000 hours utilization per year.

Airframe Needs for Steel Alloys

Another perspective of alloy needs can be gained by a review of service problems with materials used in current aircraft construction. Failures experienced with current aluminum, titanium, and steel materials most often result from residual stress, stress corrosion, cracking in mechanical fastened joints, misprocessing, poor surface condition, corrosion or poor detail design which introduces stress concentrations such as sharp corners, abrupt stiffness changes, etc. Obviously, most of these problem sources cannot be directly remedied by providing the aircraft designer with an improved alloy which has optimized only for metallurgical features concerning micro-constituents, morphology, atomic bonds, aging kinetics, and defect densities.

The state of the art in high-strength steels is a case in point. Virtually all large aircraft for the past 20 years have used, and will continue to use, high-heat treat (260 KSI rein), low-alloy steels, primarily of the 4340 or 300M grades. The reasons are these steels offer the best combination of structural-strength and fatigue-strength efficiency at moderate costs. Successful use of these steels is achieved through precise design practices and controls, and very careful attention to all stages of processing and fabrication. Experience with thousands of HHT steel parts has evolved empirically-derived limits on sustained stress levels to avoid stress corrosion cracking (SCC). As shown in figure 2, sustained stresses in short transverse grain may typically be limited to only 25 percent of yield strength to avoid SCC. Clearly, steels capable of much higher thresholds would be very welcome to the aircraft designer, Similarly, fracture toughness related properties of KI_c and KI_{scc} of commonly used low alloy-steels show considerable room for improvement. (figure 3). This latter figure also indicates the trends in alloy development which certainly are in the proper direction.

The past 20 years have seen numerous unsuccessful attempts at “alloy design” to obtain new improved high-strength steels to replace the currently used low-alloy steels. One reason for this lack of success has been the failure to adequately consider the importance of the “engineering end of the classification scale” wherein 300 M- and 4340-type materials provide capability for readily attaining consistent, high integrity in large parts through highly developed melting, forging, heat treatment, and other practices. Too often laboratory alloy developments have been prematurely touted for their “significant breakthroughs” in SCC and/or KI_c properties, only to find this improvement has been attained at the expense of such a drastic sacrifice in processing and producibility that it precludes the alloy ever reaching pro-

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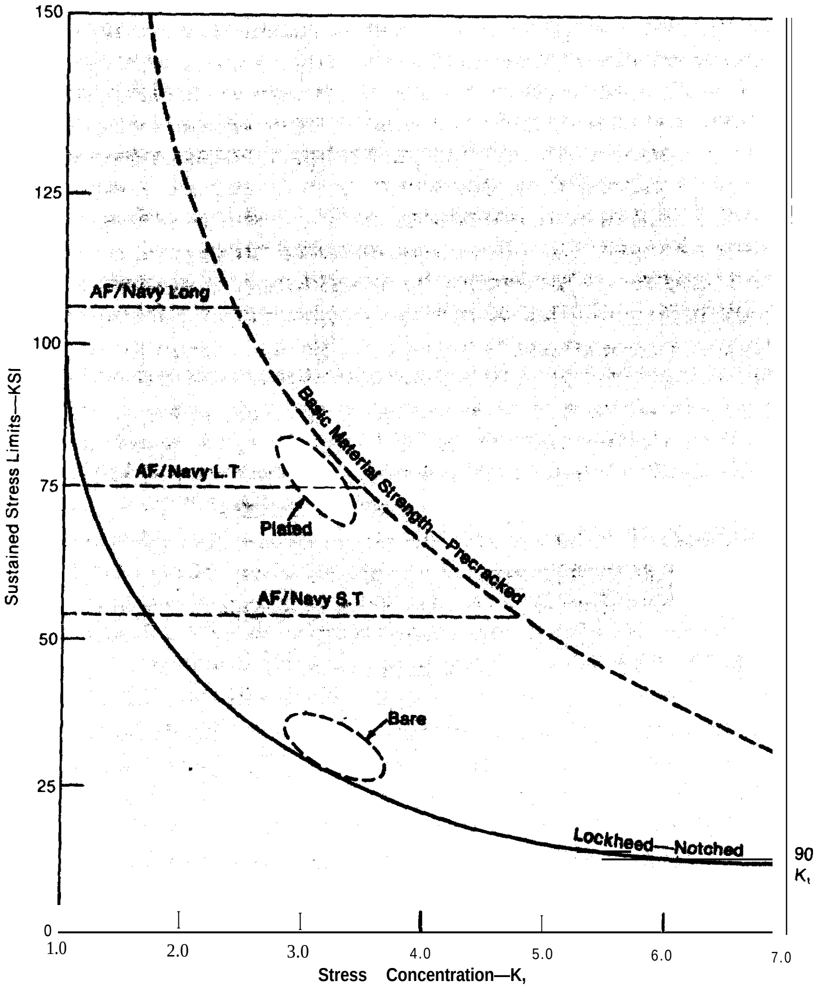
FIGURE 2.

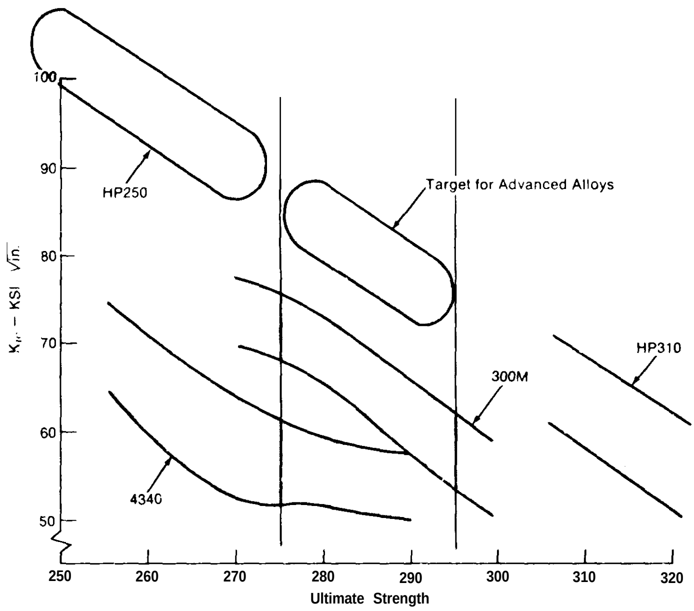


duction status, The aircraft industry is extremely interested in alloy development of improved damage tolerance and more stress corrosion-resistant, high-strength steels; therefore, we urge those engaged in such alloy development to include producibility criteria in their development parameters so that processability of new materials at least approaches that of current alloys, as indi~ cated in figure 3.

Current R&D Trends and Airframe Titanium Alloy Needs

Improvement in present alloys is being sought through using cleaner master alloys and improved melting procedures. Higher

FIGURE 3.–Fracture Toughness Versus Strength for Steel Alloys

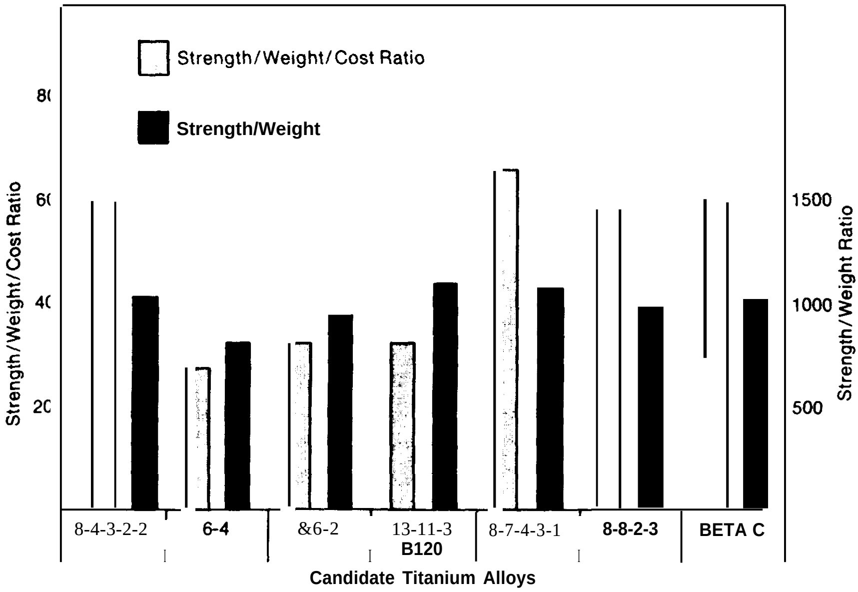


strength alloys are being investigated through interstitial hardening of beta and alpha-beta alloys and by developing alloys with modulated microstructure,

The raw material cost of an aluminum fighter is 2 percent of the fly-away cost; for 100 percent titanium, the raw material cost is 5 percent of the fly-away cost. If titanium raw material costs were halved, the fly-away cost of an all-titanium fighter aircraft would change by only 3 percent. It is apparent that raw material cost of titanium is not of major importance, and that the cost of fabrication is the significant factor. Improved cold-formable and age-hardenable beta alloys have made their appearance. Further improved performance is expected from alloys now in development. These new developments are expected to expand the use of titanium through Iowering fabrication costs and increasing the utilization ratio, as depicted in figure 4.

It is not only in supersonic aircraft that titanium can be used to advantage in airframes. The use of titanium will increase with the trend to larger cargo aircraft. The longer sections and spars of the larger aircraft have rigidity requirements beyond the capacity of aluminum alloys. Titanium alloys with elastic modulus values from 50 to 80 percent higher than aluminum alloys. and possessing increased strength and corrosion resistance represent optimum materials for airframe construction.

Figure 4.



The strength of conventionally heat-treated, alpha-beta alloys and beta alloys is being substantially increased to the 250-ksi level by texture hardening and thermo-mechanical treatments, and by producing modulated microstructure in current commercial alloys. Finally, deep-hardenable, alpha-beta alloys are being explored as replacements for high-strength steels in landing gears.

All of these potentials with advanced metallic materials of construction for high-performance structures require considerable amounts of R&D for the understanding and control of microstructural features, heat treatments, alloy composition, etc., to achieve these improvements. Besides improvement in alloy chemistry and microstructure, we are in dire need of better test methods to develop economical test methods for evaluating crack growth-resistance behavior of materials.

The policy question, then, with these examples is how best to marshall our national resources to achieve these aims. Are our present methods of utilizing university, industry, and Government facilities too fragmented and too remote to be able to work to the solutions of these problems effectively? How can industry, which is prevented from joint or cooperative efforts, somehow optimize its nonproprietary R&D in materials more expeditiously? How can information generated on the many R&D programs be assembled, analyzed, and presented as a materials data base for use by designers in a more efficient and economical manner? Can the DOD lead in marshaling this R&D? If not the DOD, then who in the Federal Government can? The analyses and solutions to these problems with some pragmatic recommendations by this fourth Henniker Conference will do much in assuring its success.

THE ROLE OF MATERIALS AND STRUCTURES TECHNOLOGY IN DEFENSE–PART III

by M, L, Williams
Professor of Engineering, Universit y of Pittsburgh

The first two parts of this presentation dealing with aspects of national materials policy upon operations in the Department of Defense were given by Mr. J. Persh, primarily from the point of view of the DOD, and by Dr. M. A, Steinberg representing industry, This third part completes the triumvirate by expressing at least one academician's viewpoint. There seem to be essentially three relevant parameters of immediate concern: technical, economic, and institutional.

From the Government point of view, one might inquire as to how to get the DOD job accomplished within a zero-growth budget atmosphere. Mr. Persh has first described the technical dimensions of this problem by enumerating various pacing problem areas in which materials policy has an important impact: gun barrel erosion, penetrators, mine fields, composite materials, and all weather capability especially in tactical missiles. He has also observed that there are three areas in the overall design cycle, i.e., loads/environment, material characterization, and non-destructive examination, which the materials engineer must recognize as common threads to be understood and technologically supported by the materials community if its contributions to the overall design process are to be optimized,

Turning to economic-related issues, Mr. Persh has outlined the principal dilemma facing Office of the Director of Defense Research and Engineering as it attempts to provide advice. Because military systems are being pushed more and more toward the limits of technology, it appears more conservative to support relatively predictable improvements in the state-of-the-art rather than riskier investments in newer technologies and advanced materials. Generally speaking, there are inadequate funds to do both well, Furthermore, legislative pressures tend to demand short-term resuIts. Once the short-term payoff approach is adopted, however, there is the real danger of a rapidly accelerating erosion of the broad technology base which increasingly inhibits innovation, Ostensibly the Advanced Projects Research Agency was set up to help resolve this dilemma, but one point for discussion might be its degree of success in terms of return on investment, The other important economic matter is that of critical material shortages, a subject to be dealt with by one of the other panels, Institutional mechanisms referred to by Mr. Persh deal mainly with those improving technology transfer, and include intra-service, inter-service, inter-agency, and inter-governmental exchanges. In addition, he has mentioned the technology coordinating conferences in materials and structures at which public elements of DOD policy, plans, and concerns can be shared with industry and universities, In passing, it may be noted that the 1974 structures conference attracted only a half-dozen academicians: presumably a better representation can be obtained in 1976. And finally, one of his optimistic, key statements stressing the importance of creativity and innovations bears repeating: “Dollars can not produce good ideas. Progress [is] idea rather than funding limited,”

As to lndustry, it frequently seems to me that too many persons are inclined to forget that its major purpose is to operate with reasonable stability over the long term at a fair profit. Furthermore, since most of our upgraded life-style has emanated from that profit, it is not inherently bad.

Dr. Steinberg has made two primary technical points I should like to emphasize, First, materials scientists have been known to succeed beautifully in achieving announced “break throughs, ” e.g., improved fracture toughness, but frequently succeed prematurely in the systems sense because too much “producibility” has simultaneously been lost, One inference could be that an effort should be made to ensure that the vistas of the materials scientist are broad enough to embrace an appreciation of the entire design cycle— from the atom to the end product and its uses. The second point, which impinges somewhat upon institutional barriers, is that there is plenty of information in the data bank, but there is a serious difficulty with technology transfer. There are really two facets to this subject, One is a “people-problem” in terms of the NIH [not-invented-here) syndrome. The other is legalistic in terms of anti-trust barriers which prevent industrial collaboration, even though as Henry C, Wallich, formerly a Yale professor of economics and now a member of the Federal Reserve Board, wrote in Newsweek, “. . . we might give some thought to whether a law enacted in 1890 to protect a nation against exploitation by robber barons still meets the needs of a nation now hard-pressed by its competitors around the world.’” As Dr. Steinberg says of the materials data base consolidation, “There is an avowed need for the Government and industry to get together . . . for the avowed purpose of saving manpower and resources. , . . The major policy question is then

1 As quoted in **“Dialogue** on Technology No. 6“. CouId Inc.., 1976.

how best to accomplish this." Presumably, the current trade association mechanism is inadequate as is the utilization efficiency of our present set of data and information centers. Salient points of a more economic nature are the relatively low raw materials cost (in aircraft) of I-4 percent flyaway cost compared with the much higher cost of processing and fabrication.

Nevertheless, the national research emphasis on such unpopular subjects is, to say the least, low.

While it is not particularly emphasized as a critical economic matter to industry, Dr. Steinberg calls attention to the growing capital requirement in industry. The mature industries, including mining and natural resource conversion in particular, seem due for major injections of capital as our formerly ample supplies, internally and externally, dwindle. Such industries must somehow be assured that major capital investments can be protected, e.g., conversion of alumina ores to replace embargoed bauxite. Here one must carefully distinguish between subsidies, which usually imply Federal controls, and contingency insurance-retaining free enterprise and market checks and balances.

Finally, in addressing institutional barriers, Dr. Steinberg calls for a better way of doing business then specifying products to death, with little room for flexibility to change with product improvements at minimun cost. One may note optimistically the new DOD procurement policy that is being attempted. As reported in the WalJ Street Journal (July 28, 1976) the emphasis is to be on meeting the end use requirement–any way you can! – without excessively detailed component specifications. Such apparent flying in the face of "normal specifications" could increase the present product liability suits, especially. if applied in the civil sector, yet this kind of management innovation would seem to fall within the "new idea" category advocated by Mr. Persh,

A View From Academia

While I have taken the liberty of editorializing rather extensively on my colleagues' previous remarks concerning the DOD and industrial involvement with the materials community, there are a few points that are peculiar to universities and the way their collaboration with the agencies of the Federal Establishment is effected. With few exceptions, the association is at the basic ("6.0") or applied ("6.1") research levels represented approximately by the science and engineering schools respectively, Especially since the Mansfield Amendment, a rough division might be that science schools tend to be supported by the National Science Foundation ("6.0") and engineering schools by more mission oriented agencies ("6.1") such as DOD, NASA, and ERDA. To the extent that academic research investigators are prepared to understand that relevance is required, the academic engineering community can make an important contribution to DOD and specifically to materials research—without compromising the individual professor's freedom of inquiry. The simplest resolution of any concern is a declination to bid.

Quality work comes from quality staff who work with quality students. This latter group is especially critical because the materials engineering constituency is not nearly as strong as are other more publicized and popular disciplines. In these days when high school students are frequently too influenced by TV and the news media, it is small wonder that there appears to be a relatively low registration of U. S. citizens in materials options. Considering materials graduates, e.g., metals, ceramics, polymers, and natural resource specialists as a national human resource, one would prefer that a substantial number of our trained engineers remain in this country to solve our future materials problems. Some new public relations initiatives in this area would seem fruitful.

The second major "technical" point I would like to make relates to the importance of choosing "good" teaching or research areas to study. After the fundamentals, schools must fight against the tendency to stagnate in classical areas, although the real problem of appearing to respond to industrial or Government "needs"—which may also have stagnated—while simultaneously being progressive is serious enough to deserve continuing attention. Two cases in point. The first relates to the aforementioned deficiency in most engineering schools in materials processing. It frequently appears that other than materials disciplines, e.g., computer science, are more concerned with manufacturing technology and CAD/CAM. The other example derives from the long-standing opinion in most U.S. chemistry departments that polymer science is not particularly academically suitable. As a result it is not surprising that polymer engineering and polymer processing suffers[2] in the United States compared with similar development in Japan, Germany, and the United Kingdom. In the latter country, incidentally, notwithstanding the economic downturn, something like £10 million has been authorized by the Scientific Research Council (SRC) for polymer engineering in the U.K. universities over the next 10 years.

Third, I agree with the implied conclusions of my colleagues that a more integrated understanding by materials engineers of

[2] "Polymer Engineering and its Relevance to National Materials Development", F. R. Eirlch and M. L Williams, Washington. D. C., 1973, Library of Congress 73-8!9413,

the overall design process would be very beneficial. One would hope that it would lead to more selective work, at least among those with engineering rather than scientific inclinations. A better bridge between the microscopic and macroscopic views would be enlightening, For example, in rubber elasticity theory, one can show that the materials scientist's parameter of cross link density of the molecular chain is directly proportional to the mechanical engineer's (longtime) Young's modulus of elasticity. While most micro-macro associations are not as simple, such associations are of immense value in permitting improved interdisciplinary thought processes,'

From the economic standpoint, the most important financial matter to universities is reasonably long term research stability, e.g., 3 years **as a** minimum. Such consideration is by no means unknown in DOD because of the major investment in Interdisciplinary Materials Laboratories (IDL) over the years. They were effective in producing materials scientists, although I have heard some adverse criticism regarding the lack of engineering impact and balance among a wider interpretation of what the materials field embraces, Some changes in the IDL program are being effected under the current NSF responsibility for this program, In terms of Federal research funding (1974-75), the top 25 engineering colleges spent approximately $200 million. With their combined staffs of about 5000 faculty members, the average research support per faculty member was approximately $40,000, Before leaving this subject, it may be noted that R&D expenditures in 1975 by industry totaled $26 billion plus $9 billion in Government laboratories or about 2 percent of the GNP as reported by Business Week (June 28, 1976) (table 1). According to NSF, the distribution in percent was basic research (3.5), applied research (20.0), product development (76,5). The average R&D expense per employee varied between $500 and $2,000 per year which corresponds to 1-4 percent of sales,

As a final point of economics, equipment grants are very important, especially for equipment used in sophisticated materials research and related automatic data acquisition and processing systems. To the best of my knowledge, NSF is the only major agency with a special equipment grant program for universities,

It is tempting to close my remarks by expanding upon the subject of institutional barriers. Much has been said already of the importance of technology transfer and the mandatory need to make it work. International competition demands it, whether one

3 "The Engineering of Polymers for Mechanical Behavior", F, N. Kelley and M, L. Williams, Rubber Chemistry and Technology, 42,4.1175-1185, September 1969.

TABVLE 1.– Industrial R&Dl Expenditures*

	R&D $/ employee	R&D $	% Sales	'% Profit	Sales
Aerospace	$1.324	.$ 825.3	3.2	136.0	$26.023M
Rockwell	252	31.0	0.6	30.5	4.943
IJnlted Tech	2,344	323.7	8.3	275.5	3.878
Boeing	2,589	188.0	5.1	246.6	3,717
Lockheed	916	52.8	1.6	16.6	3.387
Chemical	$1.579	1,317.4	2.6	39.4	$51.056M
DuPont	2,538	335.7	4.6	123.5	7.222
IJnlon Carbide	1.123	120.2	2.1	31.5	5.665
Dow	3,153	167.4	3.4	27.2	4,888
Electrical	$1 .038	1.345.1	3.0	81.5	$44,692M
Instruments	1,990	695.6	5.4	68.6	1')~f5f3
General Machinery Mfg	673	288.1	1 7	405	16.531
Metals. Mining	698	204.2	1.2	33.3	13.241
Natural Resources. 011, Coal	1 .008	715.2	0.4	8.3	169,250
Steel	294	105.9	0.6	10.9	17.043
Telecommunications	630	735.3	1.9	19.9	36,877
AT&T	661	619.4	2.1	19.7	29,272

● Source: (Business Week, June 28, 1976)

speaks from a Government, industrial, or academic platform. Suffice it to close for now with an observation made by Etzioni in a recent Science editorial (July 30, 1976). He distinguished between collegial and positional meetings and the need to recognize the difference, In short, the former can be a rather unstructured meeting of the community for information exchange, accompanied by considerable sociability, The latter is one at which a policy or a position is to be developed, It must be carefully structured as to its participants so that the subject matter stays on course, even to establishing a ruthless chairman.

On behalf of the three of us, we are pleased to have been here. to have had an opportunity to present our views in this positional meeting, We hope your policy recommendations will eventually evolve by the end of this week, without the complete absence of the collegial sociability.

UTILITY OF ORGANIC RENEWABLE RESOURCES

by Ingemar Falkehag
Westvaco Research Center

At this time, U.S. consumption of energy, mostly from fossil carbon sources, is about equal to the net annual storage of solar energy in the U.S. biomass system. The latter is estimated at about 5 billion tons of biomass per year, which in dry form corresponds to a heat value of about 80 Q Btu. We are indeed at an interesting point in our cultural history, and policies on how we govern the carbon system, including the photosynthesized resources, are pertinent. We are facing some deep philosophical questions on how we in the future should manage our organic materials, land, nutrient, and water systems. How long can we continue a fossil-carbon-based industrial development? Will we ultimately have to come "back" to the solar energy driven carbon system on which we were almost totally dependent only 100 years ago?

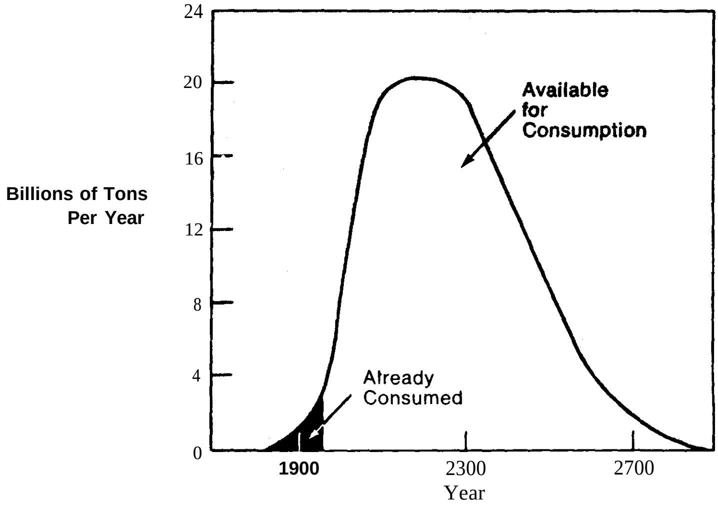
I would like to quote a Zen proverb: "For the man who is ignorant, trees are trees, waters are waters, and mountains are mountains. When that man gains understanding, then trees are not trees, waters are not waters, mountains are not mountains. And when, **at** last, he attains wisdom, then once again, trees are trees, waters are waters, and mountains are mountains,"

Will we be wise in shifting back to solar energy and renewable organic resources to meet human needs for not only food, but also fuels and materials? Maybe we have to within the next 100 years. In assessing this, I will contend that most of our "problems" are systemic in nature—we truly cannot see the forest for the trees, As Morowitz has put it, "We are confronting an entropy crisis more than just an energy crisis, "

This conference deals with materials, and I will discuss energy only in the context of energetic of materials. It should be pointed out that about 94 percent of the fossil oil resources today are used for fuel purposes. Of the **6** percent going to the petrochemical industry, probably only one third actually ends up as a material. The energy intensity in production of synthetic organic materials is on the average about 3 tons of oil per ton of product. The competition for some oil fractions and for gas is likely to intensify, and we might see a certain conversion to coal in the petrochemical industry within the next 10 years (figure 1),

It is through the energy flow (subsidy) in the form of solar energy stored in fossil carbon reserves that we have been able to carry out what we refer to as the industrial revolution during the

FIGIJRE 1.—Fossil Carbon Consumption Scenario



last 100 years. This is a short time span in the history of humans and the biosystem, as King Hubbert and others have pointed out. (1,2,3) (figure 2).

One of the major concerns in the extended transfer of carbon from the fossil sources to the biospheric systems relates to the impact of additional CO_2 generation, half of which is raising the CO_2 level in the atmosphere and half of which is absorbed by the ocean and the biosystem (figure 3), It is estimated that the stock of biomass on earth has increased by 15 billion tons the last century, mostly as a result of the higher CO_2 level. The increased absorption of heat radiation by CO_2 should result in a warming trend of the climate which might be an ultimate concern in relation to how much carbon is handled in the biosystems (4,5) (table 1). However, because of the sun's cyclic activity, we experience a cooling off in the northern hemisphere which might be expected to cause droughts and crop failures in the 1990's. The stock of biomass, mostly forests, can be considered as a food reserve, and policies on future uses of lignocellulosic materials should consider the requirements for adaptation during such discontinuities in the food producing system. The climatic effects of CO_2 in the atmosphere might only be of concern around year 2020, but probably earlier in the Southern Hemisphere.

At this point it appears highly desirable to increase photosynthesis, and net and gross bioproductivity, The management of these processes and the alternative uses of the biomass will be the subject of debate during coming years. The shift in value

FIGURE 2.—The History of Fossil Carbon

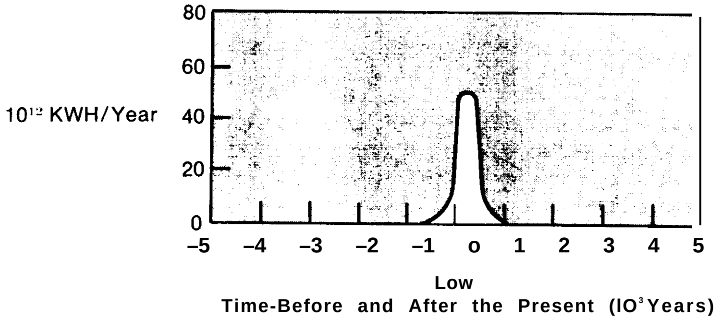
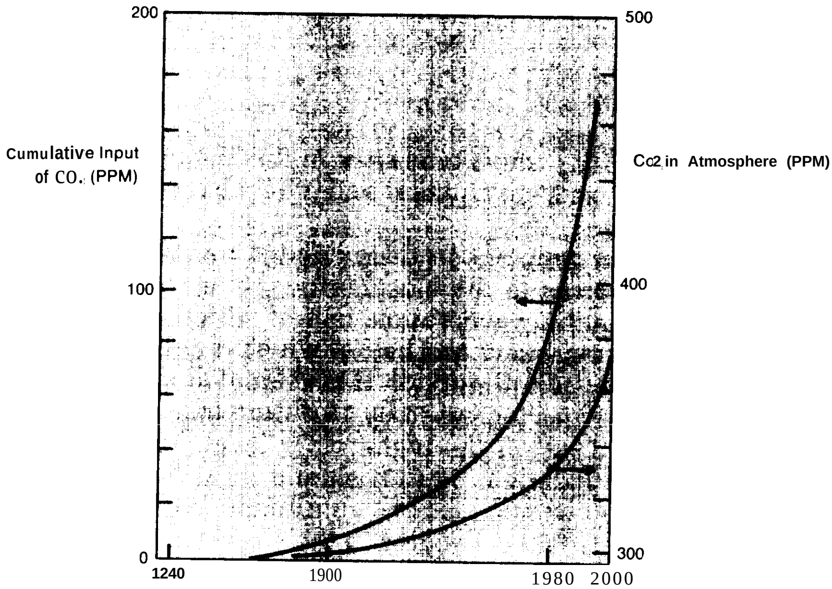


FIGURE 3.—Carbon Dioxide in Atmosphere (BOLIN)



system from "man over nature" to "man in or with nature" plays an important role.

Systems View and Time Frame

It is my view that in assessing the extended roles of renewable resources we should not only address the operational or tactical questions of how to alleviate immediate shortages and pressures, but it is imperative that we act in resonance with strategic and

TABLE 1.—Carbon in the Biosphere (BRODA, 12)

FORM	TONS x 10^{12}
Carbonate in Sediment	18,000
Organic Carbon in Sediment	6,800
CO_2 in Atmosphere	0.65
Living Matter on Land	0.08
Dead Organic Matter on Land	0.7
CO_2 in Ocean	35.4
Living Matter in Ocean	0.008
Dead Organic , Matter in Ocean	2.7

normative considerations. As a communication tool, I will use the planning model proposed by Ozbekhan (6). I will attempt to address the various levels discussed in that model as they might relate to renewable resources, but emphasize the normative view and my perception of reality (figure 4).

It is apparent that the assessment will require an interdisciplinary effort and a general systems approach with consideration for hierarchal levels (7), the complexity and desirable diversity and adaptability of natural systems, the cyclic nature of materials and energy flow patterns in renewable systems, purposeful goal seeking and evolutionary processes, etc. The vertical and horizontal integration we talk about in industry is used all the time in nature to improve survivability.

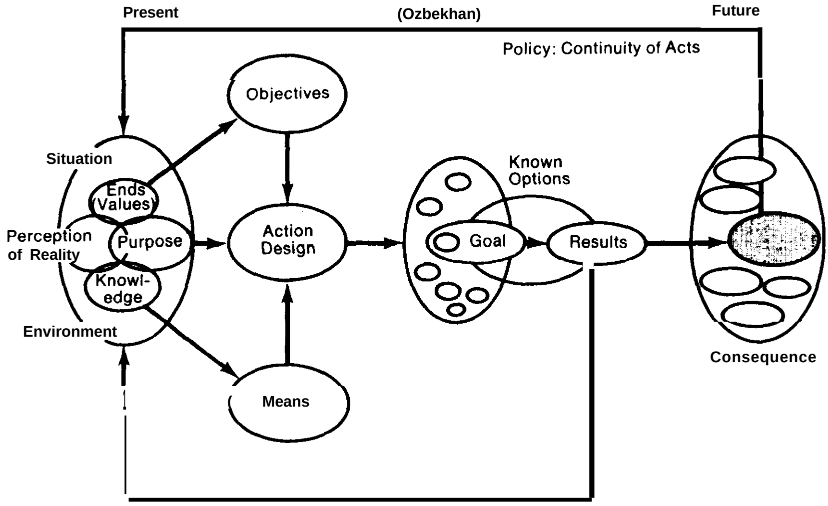
Two questions immediately come up in considering renewabIe resources for new and extended uses,

1. Is it technically feasible to produce the major petrochemicals and polymers from renewable resources?
2. Are there, in the United States, enough renewable resources available for a shift from oil as a raw material without adversely affecting food, lumber, and paper production?

The answer to these questions today appears to be yes.

The substitution for oil and gas in polymer and organic materials production is not a matter of technical feasibility and resource availability but rather a matter of driving forces, constraints, and uncertainties affecting a change. The energetic in producing a product from alternative raw materials varies and can be in favor of renewable resources. Optimum plant size, logistics, labor intensity, and the cost and availability of capital enter into the economic picture. The environmental and social

FIGURE 4,



costs in relation to alternatives have to be assessed. Traditional economics does not account for "renewability," Georgescu-Roegen (8) has discussed the need to account for the "entropic loss" with "non-renewable resources," "The economics of scale" is being challenged by Schumacher (9) and others, and such terms as "appropriate technology" are increasingly heard, Some of these emerging concepts are more applicable to renewable resources than to fossil carbon sources, The competitiveness of natural rubber compared with the synthetic product is a case in point.

The assessment of renewable resources uses thus has to include not only aspects of what we call economics, but also environmental, social, and political factors. As Sarkanen (10) has pointed out, "The area should be looked at as a whole, rather than having separate groups of parochial researchers concentrate on forest residues, waste products from the pulping industry, agricultural residues, or marine resources, This calls for a broader interdisciplinary endeavor than is possible in the framework of existing Government agencies. " I want to amplify and extend on that statement and add a warning about the simplistic, "plug-in" approach of producing "petrochemicals from wood," It is likely that we will continue to see integrated systems similar to the present lumber-board-paper-tall, oil-energy system. We should stay at highest possible systemic levels. The energy farm as a single output system is justifiable only if markets and needs for higher value materials than energy do not exist. An immediate issue is how we can upgrade renewable resources that today are "wasted" or used for energy production.

Renewability

The Board on Agriculture and Renewable Resources of the National Academy of Sciences organized the CORRIM program, CORRIM defines as "renewable" a material that can be restored when the initial stock has been exhausted, The dynamic nature of the concept of renewability is recognized, A "renewability ratio" is defined as the ratio of replenishment rate to depletion rate. "Renewable resource" is used as a synonym for a resource of biological origin, while "nonrenewable resource" is used as a synonym for a resource of geological origin.

A carbon atom in a biological material might have its origin in oil or coal or even in a mineral like calcium carbonate. The energy source that causes the "renewing" is the sun for the phototrophs (autotrophs), the plants, and the photosynthesizing bacteria. Electromagnetic radiation and gravitational forces give the energy flow in biology that has driven evolution, and produced our biomass stock and fossil carbon sources. The enormous bioproductivity of the salt water marsh (Spartina alterniflora) is possible because of solar radiation and tidal pulsation. We have in that case a sun- and moon-powered system. The water splitting by light quanta resulting in C02 reduction starts the process. In fact, our primary concern should be with the process of renewing our resources,

"Solar resources" or "phototrophic resources" through a "solar processes" or "photosynthesis" could be the emerging concepts and terms.

We have a classical matter-energy and structure-process issue. Renewable resources can be looked upon as a temporarily "frozen" solar energy process.

ERDA's Solar Energy Division has a great task ahead, and I hope it will extend the present "Fuels from Biomass" philosophy.

Present Organic Materials System in the United States

The use intensity of new supply of materials has been discussed by Radcliffe (10). The per capita consumption of synthetic polymers (derived from fossil sources) constitutes only 6 percent of the total organic materials consumption, and thus renewable materials today are consumed at a rate 16 times greater than nonrenewable organic materials (table 2),

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TABLE 2.—Use Intensity of New Supply of Materials in the U.S. (RADCLIFFE)

	LBS PER CAPITA FOR 1974
NONRENEWABLE RESOURCES	
Nonmetallic Minerals	18,900
Metals	1,340
Synthetic Polymers	180
RENEWABLE RESOURCES	
Wood and Wood Products(1971)	2,222
Fibers (Other than wood)	29
Natural Rubber	6
Leather	14

The increase in rate of materials and energy consumption follow each other closely, As pointed out by Keyfitz, (11) the growth attributable to affluence is greater than the population growth (figure 5).

Published data (10,13,14,15,16,17,53) on the production of renewable organic resources and various uses and non-uses vary considerably, but an attempt has been made in table 3 to differentiate between food-feed, materials, energy, and residuals or unused material. The latter group will generally be referred to as “waste.” Some figures are estimated and several resources have not been listed. The noncommercial timber stock is estimated to over 1 billion tons but this may not be the annual out-take. The recoverable quantity of the residuals depends on economics and environmental considerations.

The various traditional uses of wood products for structural. and fiber applications are shown in table 4. The wood requirements are indicated according to one scenario for 1985 and 2000. CORRIM (13) also dealt with three other scenarios with assumptions of lower rate of population growth and higher rate of growth of prices for nonrenewable resources.

Some projections by the American Paper Institute for paper and paperboard (13) are shown in table 5. Substitutions are discussed in the CORRIM report and will also be dealt with under the Reference Materials System.

It seems likely that the consumption of renewable resources for the traditional materials (lumber, plywood, particle board, flakeboard, fiber board, insulating board, paper, paperboard, hardboards, etc.) will at least double by year 2000. (10) The pri-

FIGURE 5.—U.S. Energy Consumption

Growth Attributed to Population vs. Affluence (K EYFITZ)

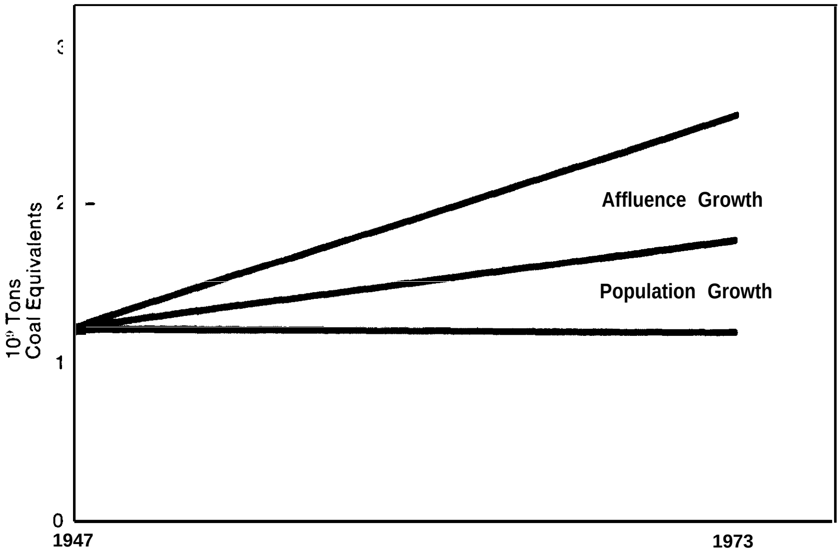


TABLE S.–Organic Materials Production and Use in the U.S. [Approximate Figures, 1972-1974)

	Tons x 106/Year				
	Food-Feed	Mate-rials	Energy	Resid-uals	Total
Synthetic Polymers	—	18	(36)		
Lumber & Rigid Panels	—	119	16	25	160
Paper & Paperboard	—	57	30	—	87
Forest Residues	—	—		150	
"Noncommercial Timber"	—	—		100	
Municipal Waste	—	—	—	100	
Bushes, Shrubs, Foliage	—	—	—	>50	
Hardwoods on Pine Sites	—	—	—	>50	
Cotton	—	3	—	13	
Fats & Oils	6	3	—	—	
Soybeans & Peanuts	40	—	—	65	
Grain Crops	250	2	—	300	
Forage	240	—	—		
Sugar Crops	10	0.2	5	6	
Animal Wastes	—	—	—	360	
Approximate totals	550	200	50	1,200	2,000
Total Net Biomass Production					5,000

TABLE 4. Projected Demand for Roundwood and By-Products for Manufacture of Wood-Based Commodities According to One Scenario~13~

Commodity	Wood Requirement 1970 MM 0.D. tons From Roundwood	From By-Product	1985 MM O.D. tons From Roundwood	From By-Product	'2000 MM 0.D. tons From Round wood	From By-Product
Structural						
1. Softwood lumber	73.41	2.6	80.4	3.5	64.6	4.0
2. Softwood plywood	15.08	—	17.7	—	14.6	—
3. Hardwood lumber	24.51	—	34.5	1.4	42.2	1.4
4, Hardwood plywood	2.28	—	3.1	—	3.1	—
5. Particleboard	—	2.4	—	5.3	—	8.5
6. Med. densitty fiberboard	18	.2	0.4	0.4	0.6	0.6
7 1nsulation board	—	1.2	—	1.9	—	2.2
8 Wet-formed hardboard	—	1.1	—	1.9	—	2.9
9. Structural flakeboard No. 1	—	—	3.0[1]	—	5.1[1]	—
10. Structural flakeboard No. 2 (RCW)	---	---	3.0	—	5.1	—
11. Laminated-veneer i umber	—	—	2.32	—	4 4[3]	—
Fibrous						
12. Paper and paperboard	61.30	24.5	104.2	38.2	154.9	45.1
13. Miscellaneous-industrial and fuelwood	16.62	—	11.3	—	12.2	—
Total	193.38	31.9	259.9	52.6	306.8	64.7

1. Yielding flakeboard cores equivalent to veneer from 5.9 MM tons of veneer logs in 1985 and 9.7 MM tons in 2000. These equivalents have consequently been subtracted from projected roundwood demand for softwood plywood.
2. Of which 1,5 MM 0.D, tons is converted to finished softwood lumber and 0.8 MM O.D. tons is converted to finished hardwood lumber.
3. Of which 2.8 MM O.D. tons is converted to finished softwood lumber and 1.8 MM O.D. tons is converted to finished hardwood lumber.

TABLE 5.–Production of Total Paper and Paperboard (Corrim)

10^3 Short Tons	1972	1985F	2000F
Newsprint	3,436	5,350	8,400
Groundwood	1.329	2.020	3,300
Other Printing & Writing	10.958	18.115	29,300
Packaging & Industrial Converting	5.695	7.895	12.000
Tissue	3,977	5,935	9,000
(TOTAL PAPER)	(25.396)	(39,315)	(62.000)
Solid Wood Pulp Paperboard	20.965	32.040	48,330
Recycled Paperboard (incl. Wet Machine Board)	7,686	11,875	18,530
(TOTAL PAPERBOARD)	(28.503)	(43.780)	(66.700)
(TOTAL WET MACHINE BOARD)	(148)	(135)	(160)
Construction Paper and Board excl. Hardboard	3.444	5.130	8.000
Construct Ion Paper and Board incl. Hard board	5,352	8,015	12.500
TOTAL PAPER AND BOARD excl. Hardboard	57,491	88.360	136.860
TOTAL PAPER AND BOARD including Hardboard	59.398	91.245	141,360

F– Forecast trend by American Paper Institute
Real GNP trend 1972 to 2000 – 2.580 X 28 years 3.5% per year average.

Real GNP: for 1972 $ 792.5 billion
for 1985 $1.222.0 billion
for 2ooo $2.000.o billion

mary needs of the forests-products industries relate to reducticn in energy intensive processes, and improved environmental control processes, The CORRIM (13) discusses future needs in the conventional structural and fiber uses of wood, and they will not be dealt with extensively in this paper in spite of their obvious importance.

Bioproduction Potential and Potentially Available Renewable Resources

Human activities in the United States interfere with about 25 percent of the net biomass production through various forms of harvesting, but probably only about 15 percent leaves the land. Some of this “used” biomass (food, feed, and materials) is again returned to the soil.

Various forms of management techniques such as fertilization, pest control, irrigation, genetic plant selection, thinning, etc., can improve productivity considerably; the recommendation for increased productivity made for agriculture (19) can in principle be applied also to forestry and biomass plantations.

The 500 million acres of commercial forest land has a net annual productivity of less than 1 ton per acre. The biological potential (10) of 400-500 million tons per year can probably be increased by at least 50 percent. Whole-tree utilization concepts (18) are being adopted, and intensive, short rotation forestry of hardwoods can give yields of up to 4 tons per acre a year, A primary concern in the use of these intensive techniques relates to the tolerable removal or organics and nutrients from the soil (2o) and other environmental impacts (21,18).

In addition to the commercial forest land, there are 250 million acres of noncommercial forests of which 20 million acres are assigned as parks, wilderness areas, etc. The forests totally occupy about one-third of the US. land area. The use of non-forest, non-agricultural land for biomass production should be the subject of assessment.

Intensive biomass production on land or in water can, under optimum conditions, give yields of up to 30-50 tons per acre a year for C4 plants (22,16).

It appears that production of lignocellulosic materials can remain complementary with food production and that, depending on population growth rate and international developments, adequate quantities of non-food biomass will be available for materials, including synthetic polymers, if necessary. The statement by Marvel at the centennial ACS “Symposium on Macromolecules and Future Social Needs” that this would not be possible (23) is typical of the views of many polymer chemists. However, it is not likely that the use of biomass for energy can increase to any major extent.

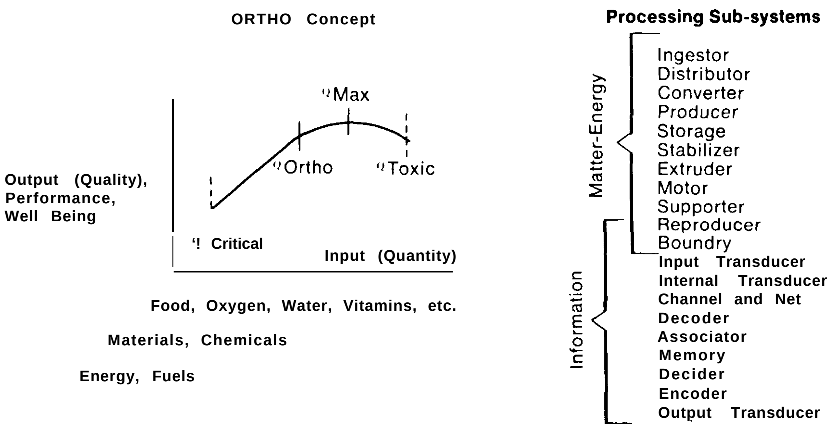
With a time frame of more than 30 years and with continuation of present growth rate increases, major stresses are likely to occur in the organic materials and land use systems. It seems plausible that new patterns of materials use will have to develop before that time. It is now appropriate to see how we can harmonize our use patterns with the production capacity of the photosynthetic system. It is now up to materials policy analysts to set some of the guidelines for the future, The multiple interdependencies make this a very complex task.

Natural Products and Systems

What is nature then capable of producing qualitatively, and how can the biosynthesized materials meet shifting human needs? Have our materials requirements in terms of performance, as achieved through the marvelous developments in polymers and composite materials, deviated so much from the properties-performances of natural materials that we must increasingly rely on the "feedstock approach" of using renewable resources as another carbon raw material source, comparable with coal, shale oil, lignite, and peat?

As a thought experiment, we can look at the materials-energy system as part of an earth metabolic system (24), and for the purpose of discussion one can consider analogs based on biological systems, Figure 6 shows some of the subsystems of an organism (7) and its functional characteristics. The food, oxygen, water, vitamins, trace metals, etc., participating in anabolic and catabolic processes in organisms can be viewed as the analogs of materials, chemicals, and fuels in the larger (external) metabolic system, This is obviously a much too simplified system but can be used as a conceptual framework for discussion of such questions as "throughput," energy-materials intensity, substitution, etc. Information can be viewed as an input or output depending on the level of abstraction.

FIGURE 6.—Internal and External Human Metabolic System



If we allow ourselves to adopt Pauling's (25) orthoconcept as applied to medicine, we can develop an idealized picture of what would be "correct" ("ortho" is Greek for "right" or "correct"), in terms of materials-energy input for the optimum performance (as opposed to the maximum performance) or well-being of the organism (individual, group, society) and its subsystems.

Obviously the shape and "height" of the curve as well as "critical" and "toxic" levels of an input will vary dependent on the nature of the input (which can be subject to substitution). The optimum rate of use of a material, product durability, utility and reuse, materials loss and recycling, etc., are concepts increasingly considered in the so-called materials cycle. The evaluation of "ortho points" for various materials and social systems can be the subject of normative assessments that might affect policies. The Symington (54) statement in relation to a national materials policy is of interest in this context.

We can also look at the biomaterials cycle and flow involving humans in a more dynamic manner and distinguish among a) production-conversion (biological and by man), b) use, and c) post-handling degradation (55) The "loss" of renewable resources to the environment is not of critical importance as we have a renewing energy system available. In the long term, however, it will be critical for "depletable" (nonrenewable) resources (figure 7).

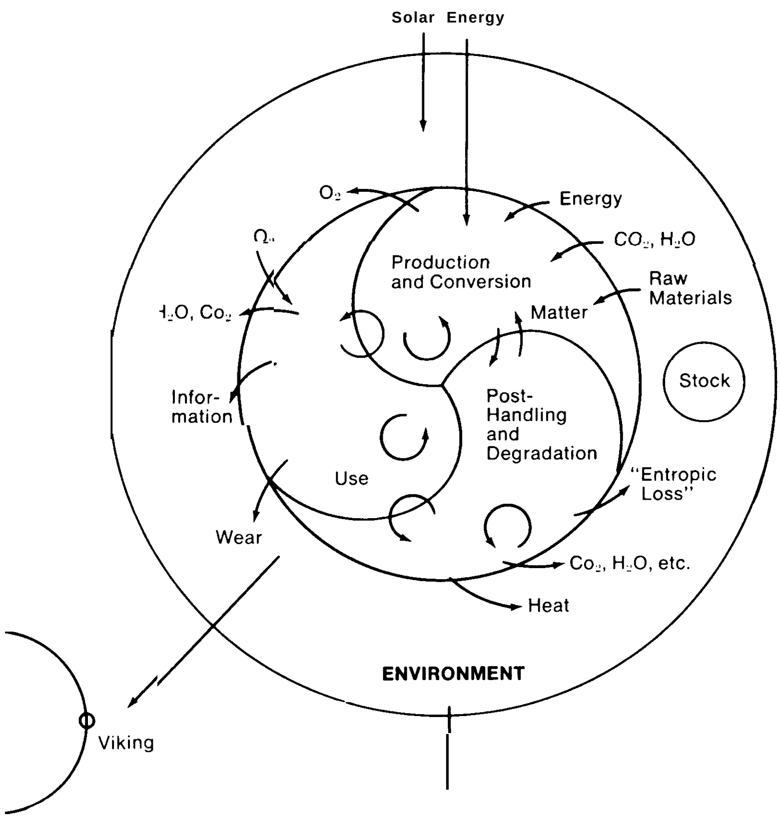
If we distinguish among bioproduction, conversion, and consumption, we can look at the capability of the solar energy-driven production system to produce molecules and structures at various free energy levels which have to be modified to meet the thermodynamic requirements of the human consumption system. (16) The symbiotic relationship between the earth and humankind has recently been discussed by Dubos (56) (figure 8).

The hierarchal levels of the natural materials system is shown in table 6. Only a single example is given at each level. (In the oral-visual version of this paper a series of slides is shown, indicating the systemic levels from an ecosystem to the molecular structure of cellulose, a hemicellulose, and lignin.) The manner in which we go down the systems scale is of course a primary question. The "cost" of going down the scale to meet a social need can be expressed in energetic terms.

The broad groups of plant types and the chemistry of their components are shown in tables 7 and 8. The lignocellulosic plants, which constitute by far the greatest stock of biomass on earth (2,1012 tons), are not digestible by man but can be made digestible for ruminants. The foliage is, however, directly digestible by various animals and could be a source of protein for man if adequate collection and separation processes were developed (18). The foliage can constitute up to 7 percent of the weight of the plant and for hardwoods can contain up to 8 percent of protein (half as much as alfalfa). The "starchy," the sugar, and the protein (legumes) type plants have generally more than 50 percent ligno-cellulosic material in the roots, stem, and branches. It is, of course, often the seeds we eat.

From a chemical point of view, we can group the materials into carbohydrates, phenolics, proteins, lipids, and special biomolecules, such as chlorophyll, vitamins, etc. The component

FIGURE 7.—Biomaterials Cycle



RECYCLING	MATERIALS LIFETIME
REUSE	FLOW
MULTIPLE USE	LOSS
EXTENDED USE	STANDARD
SHARING	ENERGETIC
USEFULNESS	UTILITY

roles can be as building stones and adhesives, energy sources synthesizers, environmental protectors (stress adjusters), etc., participating in both anabolic and catabolic processes (7).

We often hear about cellulose as being the major polymer on earth. In terms of volume and weight, this is true, but in terms of storage of solar energy, lignin is the dominating biomaterial. Trees have 35-45 percent cellulose and 20-30 percent lignin, but lignin has almost twice as high enthalpic level (heat of combustion) as cellulose, Presumably nature has a purpose in this (table 9).

FIGURE 8.—Plant—Human Symbiosis

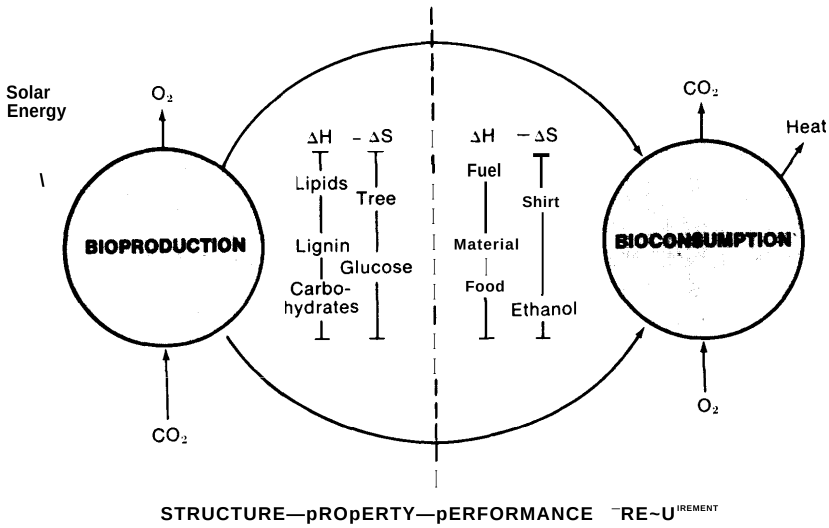


TABLE 6.– Hierarchal Material System Levels

Biosphere	
Autotrophs	Heterotrophs
Forest	Human Society
Tree	Supply System
Stern	Transportation
Wood	Pallet & Goods
Fiber	Box
Cellulose Fiber & Fibril	Carton (Paper)
Microfibril & Protofibril	Film Barrier
Cellulose Molecule	Polyethylene
Glucose	Ethylene
Ethanol	

TABLE 7. –Plant Types and Components

1. LIGNOCELLULOSICS:	Trees, straw, woody tissues in various plants. Contain Cellulose, Hemicelluloses, Lignin, Lipids
2. STARCHY PLANTS:	Corn, Wheat. Potatoes (seeds)
3. SUGAR PLANTS:	Cane. Beet
4, PROTEIN PLANTS:	Legumes, Foilage rich plants
5. ISOPRENOID PRODUCERS:	Rubber Plant. Guayule

TABLE 8. – Chemistry of Plant Components

CARBOHYDRATES:	Cellulose
	Hemicelluloses: Hexosans
	Pentosans
	Starch
	Sucrose
	Pectin Etc.
PHENOLICS:	Lignin
	Flavanoids
	Aromatic Aminoacids
PROTEINS AND PEPTIDES	
LIPIDS AND HYDROCARBONS:	Fatty Acids
	Rosin Acids
	Sterols
	Fatty Alcohols
	Rubber
CHLOROPHYLL, VITAMINS. TRACE ELEMENTS ETC.	

TABLE 9.—Heats of Combustion for Some Plants Components

		ΔHc (25°C)	
	COMPOUNDS	BTU/LB	CAL/gM
State of Reduction ↑	α — Pinene	19,600	10,900
	Oleic Acid	17,000	9,500
	Lignin	12,700	7,100
	Cellulose	7,500	4,200
	CO_2	0	0

$$\text{COMPOUND} + O_2 \xrightarrow{\Delta Hc} CO_2 + H_2O$$

Some of the “functions” of lignin can be described as (27):

- Response to stresses:
  - Mechanical,
  - Biochemical (degradation),
  - Physical-chemical (water), and
  - Chemical (02, 03, UV-light, fire);
- Energy storage; and
- Contributions to soil (humus) properties.

Cellulose and hemicelluloses have relatively simple composite materials functions in wood, while the protein and chlorophyll have very complex functions. The lipids might act as surfactant, hydrophobizing (sizing) agents and agents for control of insects, fungi, diseases, etc. A better understanding of the functional roles of plant components and means of affecting their biosynthesis should have high priority as a research area. We know a considerable amount about the organic chemistry of plant components, but much less about the biosynthesis and the manner in which the molecular, macromolecular, and morphological structural features relate to processes and property-performance-requirement characteristics of the plant.

The free energy in various plant components is there for a purpose. We can simply use the enthalpic value and burn the biomass for energy, or we can attempt to use renewable resources at highest possible systems level (see table 6). We should not increase entropy and destroy a composite material, a fiber, or a macromolecule when we don’t have to in order to meet our need. The manner in which we manipulate the biomass and make cross levels transformations and changes at the molecular level by changing carbon-hydrogen-oxygen balances can be the framework for important research policy recommendations. To a certain extent, these questions can be approached through thermodynamic tools (28,30). Work on natural products in this area is badly lacking, as the petrochemical interests have controlled thermodynamics research. Non-equilibrium thermodynamics (29) and systems opening and closure (31) can be particularly important for living systems and evolutionary processes.

From the point of view of materials science, the research field is open. We don’t know much about the composite materials contributions of the various components in wood. The interplay of natural products at various systems levels with synthetic polymers and inorganic materials has room for many innovations. A definition of materials performance requirements is often the bottleneck. Table 10 shows some material system types, many of which are already used for natural products.

TABLE 10. –Materials Systems

Type	Examples
Uniform. Amorphous	Lignin-Phenol Resin
Partially Crystalline	Rayon (Cellulose)
Laminated Sheets	Plywood
Fiber Network	Paper
Bonding Agent	Rosin Adhesive
Fiber Reinforcement	Wood
Particle Reinforcement	Lignin-Rubber Composite
Polyblend	Wood Middle Lamella
Coating	Starch
Powder Compaction	

A better understanding of structure-process relationships at various hierarchal levels (32) is much needed. In fact, general systems science could contribute considerably to the renewable materials understanding, Workshops by NSF (33,34) could put more emphasis on renewable polymers and materials. Although we are in the space age, we need to get down to the earth (even soil) in materials research,

Let me show you one example of where a renewable resource (lignin) can substitute for a nonrenewable material (carbon black). Adequate (but slightly different) properties in the reinforcement of rubber can be achieved with a lignin replacing HAF or ISAF carbon black (table 11). Lignin as a reinforcing filler (below 100 Å) is not like carbon black in its properties, and hypotheses on filler parameters' effect on materials properties, cannot be extrapolated (27).

The abrasion resistance with a lignin-reinforced rubber does not appear to be governed by the failure properties but rather by the visco-elastic properties of the cured rubber. Lignin is a macromolecular material with lower modulus and hardness than carbon black. The modulus of the reinforcing particle has been shown to affect the reinforcement properties, and work of the type done by Morton at the University of Akron can thus be highly relevant for renewable resource composites.

The shift from carbon black to lignin in the rubber industry is primarily controlled by institutional factors, lack of economic incentive, and concern for pulp mill impacts by recovery of a large fraction of the lignin which has to be replaced with another fuel source with present recovery systems. The quantity of lignin burned annually in U.S. kraft pulp mills is about 16 million tons.

TABLE 11. –Physical Properties of Lignin and Carbon Black Reinforced Styrene-Butadiene Rubber at 68 Parts Lignin per 100 Parts Rubber (Oil-Extended SBR)

	Lignin A	Lignin B	HAF	ISAF
Modulus (psi)	520	650	610	730
Tensile Strength (psi)	3165	3380	2500	2930
Elongation (%)	720	630	720	750
Tear Resistance (ppi)	355	300	320	335
Hardness (Shore A)	54	54	56	61
Corrected Pico Abrasion	86	85	91	II-4

Biosynthetic Pathways

Before discussing the "feedstock approach" of producing chemicals from renewable resources, it might be useful to look at the photochemistry and biosynthetic pathways of making chemicals, an area justifiably emphasized by Calvin (35) for many years. Solar energy can be used for both heat and quantum collection. In the latter category are photosynthesis, photochemistry, and photoelectric processes,

The primary and most important step in photosynthesis does not have to do with carbon but is rather the split of H20 leading to oxygen and highly reduced products which can affect the C02-reduction. The carbohydrate synthesizing cycles are then the starting point for synthesis of proteins, lipids, and phenolics.

A conscious human effort to design photosynthetic systems (plants, bacteria, or nonlive systems) to produce food, materials, and energy for internal as well as external metabolic systems might be as important an evolutionary event as the domestication of plants and animals in what we call agriculture. Philosophical questions of maintaining (increasing) diversity and complexity to safeguard adaptability get into the picture in considering the further "domestication of biosynthetic pathways."

Practical examples of controlling the production of specific chemicals are the natural rubber and naval stores industries. Termite-resistant, resin-loaded pine beams were once produced in the South, Ongoing efforts to triple the production of rosin and turpentine by chemical stressing of pines is being actively studied by the Forest Service and is funded by ERDA (36). Ecological impact is of major concern in this project, and the bioenergetics in relation to endproduct value has to be researched.

Zaborsky (16) has proposed a long range strategy of bioconversion using regulated plants or microbes or isolated cellular components for the selective production of small active moIecules. The argument would be that photosynthesized macromolecules and plant components cannot be made to meet material needs and that fragmentation processes are expensive, consume energy, and require complex separation processes as multiple (water-soluble) products are formed. An exception of easy separation is methane from anaerobic digestion. If we need other hydrocarbons, we can, as Ehrensvard (37) has proposed, achieve an enzymatic "instant fossilization, " but this would be quite expensive. If we would calculate the net energy of producing the oil we pump from the ground, we might get indications of what the "cost" will be when we have run out of it,

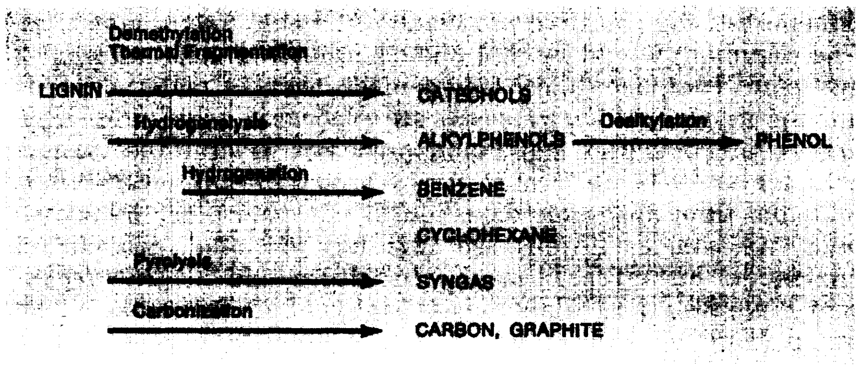
However, the photosynthetic system can be used to produce chemicals by:

1. Modifying productivity of existing organisms,
2. Affecting the selective component synthesis with existing organisms,
3. Interference with biosynthetic pathways as, for example, to catch an intermediate,
4. Biosynthetic production of complex molecules with needed properties, and
5. "Photosynthetic feed stock" approach by production of small molecules such as H_2, O_2, H_2O_2, CH_4, CH_3OH, CH_2O, CO, NH_3, C_2H_2O, C_2H_5OH.

The Chemical Feedstock Approach

Various recent assessments (10,13,14,38) indicate that abundant biomass resources are potentially available for chemical conversion and that conversion of lignocellulosic material to glucose, ethanol, syngas, methanol, furfural, and phenol are technically possible, although in most cases demonstration work is required and optimization has to be achieved (figures 9 & 10). The economics at present energy and wood cost do not yet appear to justify production of bulk chemicals from wood or waste, but considerable uncertainties still exist on actual costs. If renewable resource-derived chemicals or substitutes are less energy intensive than fossil carbon-derived chemicals, a substitution might be justified at a certain oil (or coal) cost. Uncertainties about coal conversion processes add to the difficulties in decisionmaking. More information about differences in conversion costs, labor, and social costs are needed and justify extensive Federal funding for research, development, and demonstration projects. The two major types of feedstock chemicals are the

FIGURE 9.—Lignin Fragmentation



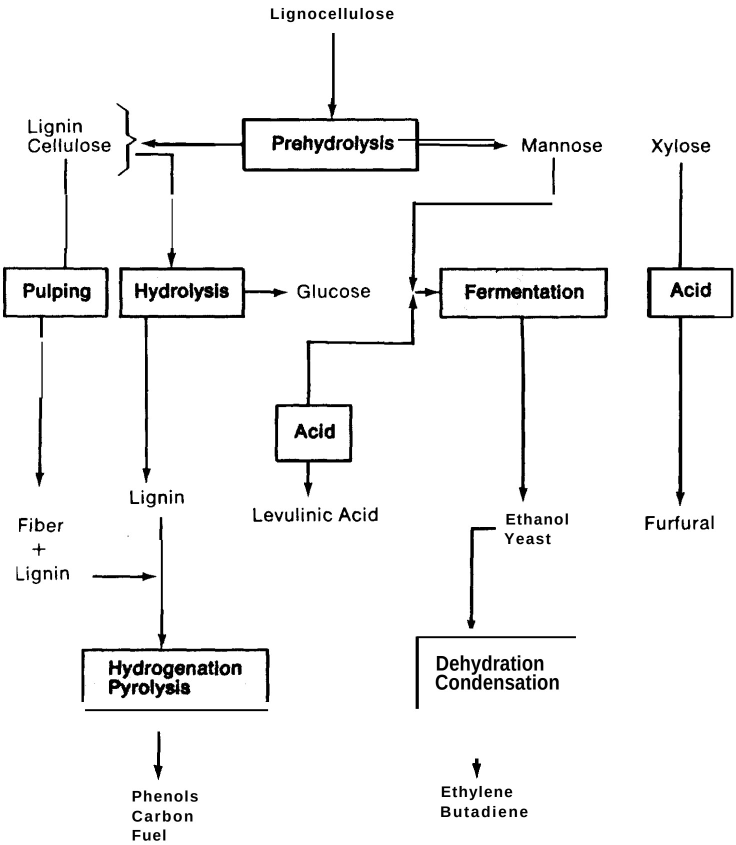
olefins and the aromatics. Carbohydrates are most conducive to conversion to the former while lignin can be a source of aromatics. Coal will probably be a more economic source for aromatics than for olefins.

The Forest Service study (14) financed by NSF is the most recent U.S. assessment. It concludes that petrochemical feedstock replacement through wood residue conversion would not significantly impact national petroleum consumption, No single chemical could be economically produced today. However, an integrated plant producing ethanol, furfural, and phenol could be economical at today's energy and wood prices. Dr. Zerbe of the Forest Service is manager of this project which should be well funded and complemented with technology assessment activities (figure 11).

Reference Materials System

As earlier pointed out, all of these assessments have to consider multiple interactions in the energy-materials sytem. The concepts of net energy and energetic in materials production can usefully be applied. Berry (39) has discussed the thermodynamics and energetic of alternative materials in packaging, transportation, etc. Hoffman and his group at Brookhaven National Laboratory (26) have developed guidelines for a reference materials system similar to the energy reference system (figure 12). This can be an extremely useful tool towards providing a framework for materials policy. Hoffman's input to the systems group in the CORRIM study (13) has led to a preliminary trajectory for the renewable resource system with a quantitative materials flow and some inputs of the energy requirement

FIGURE —Schematic Flow Chart of a Sample Lignocellulosic Chemical Plant (CORRIM)



at the various steps from the growing and harvesting to the final use,

The technique can also include inputs of labor, capital, and environmental activities and might be particularly useful in studying the effects of perturbations in the various parameters, A comparison of the energetic in producing a 1 gallon milk container from plastic versus paper is illustrative. Measured by the criterion of energy, paper is most favorable. Further research in this area is very much justified.

U.S. Materials Studies Related to Renewable Resources

During 1973, four studies (40,41,42,43) were released, all emphasizing timber and conventional uses of wood:

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FIGURE 11.—Multiple Product Waste Hardwood Facility Ethanol, Furfural, and Phenol

Basis of Projection

Wood Waste (hardwood)	1500 T/ D.O.D.	Ethanol 25 mm GPY 190 Proof
Investment Estimate	$100 mm	Furfural 75 mm lb/yr
Phenol Recovery	20% of Lignin in Residue	Phenol 52 mm lb/yr
Furfural Recovery	7.2% Of Wood Waste	

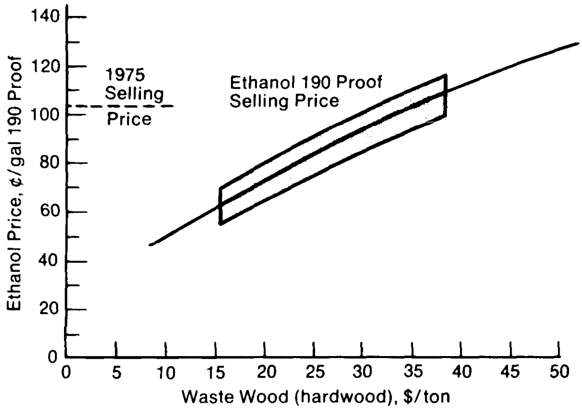
Production Costs Investment
- Depreciation 8
- Maintenance 4
- Taxes and Insurance 2

Labor
- Operators $20,000/yr
- Foremen 25,000/yr
- Management 30,000/yr

Profit 20 "/0 of Investment (10% after taxes)

Overhead 100°/0 of Labor

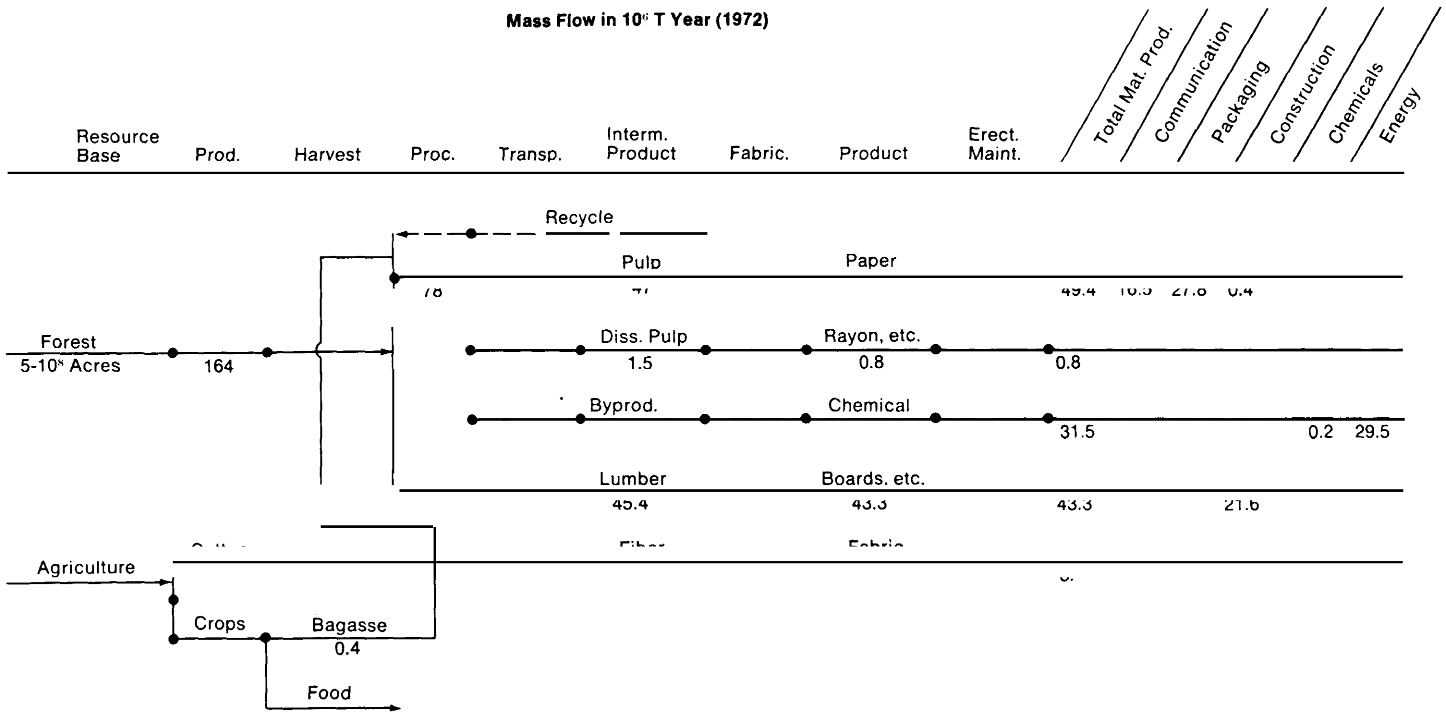
Credit 1975 Selling Price
- Furfural at 80% of $0.37
- Phenol at 80% of $0.27



- **USDA-Forest Service: "The Outlook for Timber in the United States;"**
- **National Commission on Materials Policy: "Timber—The Renewable Material;"**
- **Report of the President's Advisory Panel on Timber and the Environment; and**
- **National Commission on Materials Policy: "Material Needs and the Environment Today and Tomorrow."**

The 1974 summary report of the National Academy of Sciences Committee on the Survey of Materials Science and Engineering (COSMAT), "Materials and Man's Needs," had a strong (and by wood scientists welcome) recommendation on renewable resources: "that studies be undertaken on the feasibility of using renewable resources, including organic wastes, as a raw material base for synthetic polymers." The COSMAT report recognized the low level of materials R&D on renewable resources and recommended an increase. It did not identify any applied or basic research problems for renewable resources but rather emphasized high-performance composite materials, biomaterials, energy, environment, recycling, etc. It was amazingly ignorant about the Iignocellulosic system. It defined pulping liquors as

FIGURE 12.—Aggregate Reference Materials System



waste, when in reality the organics are used for fuel value and the inorganic are recovered. It claimed that lignin "has not responded to scientific attack" and that new hope lies in methods "such as high resolution electron microscopy "-a poor definition of the materials research problems in the eyes of lignin scientists. It did make a meaningful conclusion that lignin might be employed as bonding agent in wood products. This is still a valid research objective. (In **1976,** there is to this writer's knowledge no academic polymer-material scientist in the United States doing research on lignin — indeed amazing considering that lignin energetically is the most important macromolecular material in our biosphere.)

The National Academy of Sciences–National Academy of Engineering report, "National Materials Policy," published in 1975, made recommendations on increased timber yield and referred to renewable resources under "waste utilization and materials conversion" advising on "research into development of feedstocks for polymer production."

The National Academy of Sciences Board on Agriculture and Renewable Resources formed the Committee on Renewable Resources for Industrial Materials on September, 1974, and will soon be ready to publish the general report. Several parts of the study were reviewed in the February 20 issue of Science. One panel dealt exclusively with the conversion of lignocellulosics to energy and chemicals, recommending accelerated R&D efforts both with the "macromolecular" and "feed stock" approaches (see earlier discussions).

CORRIM recommended as a top priority that an "advisory office for policy issues related to the use of renewable materials" be established under the Office of Science and Technology Policy in the Executive Office of the President, Studies should be undertaken to evaluate the Nation's materials supply systems, the capacity to develop and advance new technology, and the manpower and training needs in the field of renewable resources. It is concluded that the biological productivity of commercial forest land can be doubled within half a century through application of proven silvicultural practices, CORRIM recommends major efforts by USDA in this area. Deficiencies in the research and educational systems are being recognized. CORRIM recommends that NSF create and maintain university centers of research in renewable resources and that cooperative industry, university, and Forest Product Laboratory studies be encouraged,

The Technical Association of the Pulp and Paper Industry, Wood Chemistry Committee, represents an active group of wood chemists in the United States and has taken a strong stand in favor of "wood chemicals" and increased research effort and funding by Federal agencies. The Committee organized, jointly with Syracuse University, an international symposium "Wood Chemicals–A Future Challenge" now published as a special volume of Journal of Applied Polymer Science (17). It is now planning another international conference in Madison in June 1977 (jointly with the Forest Biology Committee). The conference will bring together various international assessment studies of renewable resources conversion to chemicals, food, and materials,

The NSF-Forest Service study on "The Feasibility of Utilizing Forest Residues for Energy and Chemicals "(14) is through its first phase and will now go into a systems definition and analysis phase. This program should lead to a demonstration of the technical and economic feasibility of processes for producing feedstock chemicals, like ethanol, furfural, and phenol, from lignocellulosic materials, The emphasis is on products that can be used within the forest industry. Of particular significance can be the part of the program related to adhesives for reconstituted wood products. Furfural and phenol can of course be involved, but adhesives end-objectives can also consider the use of lignin in macromolecular form, and a good material science effort will be required.

The Washington Center for Metropolitan Studies organized a well attended and publicized conference on "Capturing the Sun through Bioconversion" with a large number of papers and panel inputs which will be published. The emphasis on technology assessment and a participative, multidisciplinary format can make such activities very valuable, By unifying around biomass concepts and solar energy conversions, a much needed bridging between forestry, agriculture, and intensive biomass production advocates may come about.

The Battelle Columbus Laboratories have an ERDA-sponsored program on Fuels from Sugar Crops and have organized a Tutorial Conference, October **13-15, 1976.**

Institutions

Just as we are emphasizing "renewable resources" rather than "processes of renewal" and the energy-materials flows, it seems that institutions are mostly looked upon as structures with well-determined processes. This might be well so long as we have a homeostatic system with agreed upon ends and purposes. Forest Service has performed excellent statistical surveys of wood supply according to the merchantable bole concept, but it was not prepared to survey the total bioproductivity (net and gross) in various ecosystem. The two futures conferences (46,47) of the paper industry during 1973 both emphasized technical trends and needs, and employed as primary forecasting tools trend extrapolation and "surprise free futures" concepts. However, there is emerging a consensus that the research and educational system in relation to renewable resources and the forest industry should be revitalized, The technological initiative now comes largely from Scandinavia whose industry can compete in spite of twice as high wood cost, A wood chemistry or paper technology conference in this country will generally have more than half of the papers coming from Europe. The international orientation typical of wood science (necessary to reach a "critical mass") has many positive aspects to it, however.

The emphasis on structure shows up in the names of institutes and departments (wood, cellulose, forest products, paper, etc.), although a recent trend has been to include "environmental science" and thus a more interdisciplinary outlook. The wood chemistry research during recent years had, to perhaps 80 percent, been oriented towards oxygen bleaching-pulping for paper making (mostly justified because of beneficial environmental attributes). Some wood chemists had a professional identity problem which was accentuated when the American Chemical Society excluded "wood" from the division now called "Cellulose, Fiber, and Textile." In response to this, the TAPPI Wood Chemistry Committee became an active force with conferences, such as the Wood Chemicals Symposium in Syracuse, 1975, and an effort to affect NSF-RANN and other agencies. Wood Technology departments at universities might in a halfhearted way apply material science concepts, but material science or polymer departments will rarely work with wood, lignocellulosic components, or renewable resources in general.

NSF, RANN, and ERDA show a flexible attitude in defining the place for research on renewable resources and the processes for generating and converting these resources. ERDA deals with "Solar Energy" and "Bioconversion" and has listed in its scope "petrochemical substitutes," but emphasizes "fuel from biomass." NSF should formulate its policies in relation to renewable materials,

If we are truly approaching a state where we will view our photosynthesized resources in a new way with regard to generation, conversions, and end-uses, we might not be able to rely on trend extrapolation; and we might in fact as scientists confront a major paradigm shift (48), Harman (49) at Stanford Research Institute has compared a "transformation perspective" with the "Kahn post-industrial perspective." Henderson (50), Beer (51), and others have applied the "metalanguage-metasy stem" thinking about institutional change and concepts of managed, rather than exploited, resources, Emerging understanding of self-organizing systems (3o), systems opening and closure (31), homeorhetic vs. homeostatic systems, and the evolutionary view of Jantsch (52) could be of particular relevance in dealing with questions of our interdependencies with the photosynthesizing systems and the resulting products: food, "renewable resources," and other bioproducts.

It could be a major task for OTA to assess the technical, social, economical, and ecological implications of a major shift in our management of the phototroph system and renewable resource generation and utilization. NSF should study the educational and science policy implications of such a shift.

In summary, we might talk about renewable resources through renewable organizations and institutions.

Implications for Scientists and Engineers

The "renewable resource" and "materials renewal" issues involve major uncertainties and high complexity (multiple interdependencies) with regard to the extended and "new" uses. The time frame for change is important in the nonconventional uses of renewable resources, Considerations about the total biomass system and the mutualities between forestry and agriculture add to the need for interdisciplinary and systems-oriented views of the pattern of change.

The existing areas of renewable resource use confronts such needs as:

1. Safeguarding raw material supply,
2. Less capital-intensive technology,
3. Less energy-intensive processes,
4. Improved environmental control,
5. Less dependency on depletable resources, and
6. Better utilization of all resources.

The extended or new uses of renewable resources raise challenges in many areas in relation to the production, conversion, and uses of renewable resources. Most traditional institutions are not very well oriented towards handling some of the tasks ahead, and this is particularly true in the materials science and engineering areas.

The "age of substitutability" has been used to describe our present materials situation. The extent to which we can rely on trend extrapolation or will have to prepare for a major (paradigm) shift in our view of organic raw materials uses is still up for discussion,

The implications of a transformation in the renewable resource system should, however, be the subject of well organized assessments, incorporating technological, economic, social, environmental, and educational concerns.

Some examples of research, development and demonstration activities at three planning levels are outlined below:

A. Bioproduction

1.. Normative level (ends)

Develop an awareness about the functional roles of the components in phototrophs, the ability to direct the selective production of valuable components, and the manner in which plant components, macromolecules and chemicals can best be integrated (symbiotically) with the human needs system, using the biosynthesized product at highest possible systems level.

2. Strategic level (objectives)

Develop joint forestry-agriculture programs in such areas as biological nitrogen fixation, water management, genetic selection of plants (for optimum production of a combination of plant components for food, materials, chemicals and fuel), nutrient flows, and tolerable biomass removal from ecosystem, etc.

3. Operational level (goals)

Survey the existing biomass systems with regard to type, quantity of different plants, economics of harvesting and transportation to potential use sites, etc.

B. Harvesting, collection, transportation, processing, conversion, and fabrication, etc., to needed products

1. Normative level

Assess alternative socioeconomic systems for ecologically acceptable transformations of photosynthesized materials to end products meeting human needs in an adaptable manner (according to shifting priorities).

2. Strategic level

Develop a Reference Materials System enabling the assessment of the benefits and constraints in choosing alternative raw material sources for functional end products.

3, Operational level

Demonstrate technical feasibility and economics of integrated production of ethanol, furfural, and phenol from wood.

C. Product development and use

1. Normative level

Determine the structure-property -performance relationships for materials components and systems derivable from renewable resources, assess future organic materials requirements and substitutions, and develop approaches for optimization (according to "ortho philosophy") of the use of renewable resources to meet materials needs in manners compatible with food and other needs.

2. Strategic level

   Develop relevant composites and polyblends using renewable resource materials and macromolecules in combination with synthetic polymers (when necessary for performance) and inorganic materials.

3. Operational level

   Assess the feasibility of using modified lignins as adhesives for reconstituted wood products.

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IV. Task Force Reports

TERMS OF REFERENCE AND SUMMARIES OF REPORTS

The following pages present the terms of reference and summarize the task force findings for each task. The terms of reference give a more complete description of the topic, the rationale behind the choice of topic, and a series of questions to be addressed by the task force.

Each "terms of reference" is followed by a summary of the two task force reports on that topic, The summaries are presented in outline form and state the major points of agreement and disagreement between the two task force reports as well as some general comments on the subject made in each report.

The purpose of this section is to provide an easy reference to the principal ideas contributed during the conference on the five subject areas of importance in the consideration of a national materials policy.

Assistance in preparing this section was provided by Ms. Elaine B, Carlson, Research Assistant, Science Policy Research Division, C.R,S,

TASK ONE: MATERIALS ASSESSMENTS FOR CONGRESS: STRESSES ON THE TOTAL MATERIALS CYCLE

A. TERMS OF REFERENCE

Future stresses on the Total Materials Cycle are expected to influence the costs and flow rates of materials through the cycle. Identifying the stresses and responses to avert or relieve them is essential in order to insure a healthy economy. A basic question arises: can the magnitudes of the anticipated adverse impacts of the stresses be ranked, thus setting priorities for developing effective responses to relieve the stresses?

Rationale

Many factors affect the prices and supplies of materials, and we have relied primarily on the marketplace to provide materials at what are loosely termed "reasonable" prices, There are growing concerns about new, and quite different, stresses on the total materials cycle that may not be dealt with by relying entirely on market adjustments. Some of these stresses are foreign in origin; others are domestic. The quadrupling of bauxite taxes is an example of the former; the increased costs associated with meeting new environmental regulations, the latter. The coupling of energy and material flows is yet another source of stress which has both foreign and domestic origin.

Identifying the stresses, their relative magnitudes, anticipated impacts, and possible responses to averting or relieving them, is essential in order to maintain a smooth flow (but most probably a redistributed flow) of materials through the materials cycle, and hence a healthy economy. Both Government and private sector roles must be properly balanced in considering these responses.

What is being requested is the development of a list of stresses and possible responses, a ranking of the relative importance of the stresses, the potential effectiveness of the responses, and suggestions of how a balance between Government and private-sector roles might be achieved.

Questions

Stresses on the Materials Cycle

1. From a final list of stresses to be prepared by the Task Force, which are expected to be most important and for which materials? Can this ranking be made other than

qualitatively? Which are the "principal" stresses and which the "component" stresses?

2. What are the expected impacts (e.g., economic, social, institutional, etc.) ?
3, What are the controlling factors that determine when the impacts of these stresses might be expected to be felt: o-5 years, 5-10 years, 10-20 years?

Responses to Relieve Stresses

1, From a final list of responses to be prepared by the Task Force, and for those stresses for which a time period for expected impacts has been generally agreed upon, which responses might be expected to be most effective and why?
2, What are the expected impacts of these responses?
3. What are the relative roles of Government and the private sector in applying these responses to deal with the stresses on the materials cycle? For example, can one distinguish areas of direct as opposed to indirect as opposed to no governmental action?
4. What motivations are available for swift Government and private actions in applying the responses to relieve the stresses ?

B. SUMMARY OF TASK FORCE REPORTS

Task One

Group A	Group B
Points of Agreement	
Major stresses on the materials cycle are the followlng:	Major stresses on the materials cycle are the following:
–the increasing per capita demand for materials largely attributable to rising standards of living;	–lack of availability of competitive domestic resources;
—environmental, occupational health and safety impacts and regulations:	— Federal legislative and regulatory constraints including environmental controls and health and safety laws;
— Internal dlfflcultles In foreign countries and actions by foreign governments affecting supplies of imported materials; and	— uncertainty of foreign supply; and
— the declining long-term trend in materials investment	–financing difficulties –poor Investment climate.

Comments

The stresses on the materials cycle cannot be relieved within the next 5-10 years. For the foreseeable future most industrialized nations will be importing an increasing amount of materials from foreign sources.

An early warning system of changes in the international environment or local unrest endangering the flow of imported materials should be given more detailed study.

Part of the response to the stresses of uncertainty in foreign supply should be the establishment of a stockpiling policy.

There is a lack of public understanding in the subject of materials— industry and Government should formulate education programs involving the public, industry. and Government concerning the environment and land use in resource development,

TASK TWO: GOVERNMENT, SUPPLIES AND SHORTAGES

A. TERMS OF REFERENCE

Looked at with the benefit of 2 years' hindsight, what does the 1973-74 period tell us about the possibilities for and the limitations to effective action by the Federal Government to secure reliable supplies and prevent shortages of key raw materials?

Rationale

During 1973 and 1974 a series of severe shortages arose which caused hardship and dislocation throughout the economy. These shortages, and the perceived inability of the Government to do anything to alleviate them, were in large part responsible for the creation of the National Commission on Supplies and Shortages.

The shortages themselves largely disappeared with the coming of the sharp recession in late 1974. However, as the economy has begun to turn upward again, fears have been expressed that the problems of 1973-74 may recur or even worsen.

Major contributing factors to the shortages of 1973-74 were the direct and indirect effects of the action of OPEC, In the aftermath of the events of 1973, third world materials producers began to talk openly about emulating the oil cartel. The growing dependence of the United States on imported raw materials and the increasing interdependence and vulnerability of the industrialized countries lent creditability to this threat in spite of the fact that economic analyses almost uniformly tended to downplay its importance. This concern about our possible vulnerability to supply cutoffs, plus a belief by some that large swings in raw materials prices were both undesirable and could be prevented, led to the serious discussion of materials strategies employing stockpiling in various forms.

A parallel concern that surfaced in a particularly graphic manner during the early 1970's was the question of the long-term availability of basic resources. Again, subsequent analyses have tended to downplay the seriousness of the problem, but not all are convinced. Even those who contend that resources will be adequate in the foreseeable future tend to disagree about the degree of governmental involvement that will be required to achieve what GoeIler and Weinberg recently referred to as "The Age of Substitutability," In particular, some have pointed to the troubles that occurred in 1973 and 1974 as proof of the need for a more overt planning capability for the Government.

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Questions

1, During 1973-74 it was widely believed that the shortages we were then experiencing were the first sign that we were entering into an "Age of Scarcity" during which such shortages would become commonplace. There are new strong indications that the shortages observed during 1973-74 had little or nothing to do with an underlying scarcity of raw materials. Was there a misperception of the basic problem? What lessons for future Government policy can be learned from the 1973-74 experience?
2. Participants at preceding Henniker conferences apparently have agreed that total self-sufficiency in raw materials, while perhaps technically feasible, is not a desirable goal for the United States. How should the proper degree of self-sufficiency be determined? What policies are required to attain this level?
3. The Office of Technology Assessment has recently completed a major study of materials information systems, This study identifies weaknesses in the current system, discusses possible changes, and outlines institutional alternatives for implementing these changes. In the light of OTA'S results, what, if any, changes in Government materials information systems are both feasible and desirable?
4. OTA has also just finished a study of economic stockpiling, Among the possible stockpiling objectives which are identified are: stockpiling to offset the effects of supply disruptions of key imported materials; stockpiling to deter price-enhancing actions by producer nations; and stockpiling to stabilize the prices of important raw materials. This study estimates the benefits and costs of alternate stockpiling policies, suggests a methodology for implementing and operating a stockpile, and outlines institutional alternatives for congressional consideration. In your opinion, is stockpiling for any of these purposes both feasible and desirable? If so, how are specific commodities to be selected for stockpiling, and what kinds of operating rules would have to be established?
5. How active a role must the Government take to assure the longrun availability of raw materials? Is there need for an increased role in monitoring developing supply/demand trends? Is increased financing of long-range R&D on materials substitution required? If so, how is the Government to decide which projects are worthy of support? Does the situation dictate that the Government undertake something approaching long-term planning?

B. SUMMARY OF TASK FORCE REPORTS

Task Two

Group A	Group B
Points of Agreement	
Shortages during 1973-74 were not related to a scarcity of underlying raw materials, These shortages were directly related to the lack of capacity of conversion and processing facilities to respond to unusual surge in demand due in part to Federal intervention.	During the 1973-74 period there was no "real" scarcity of materials. The problems were essentially those of unsound Government actions and the resultant "shortage mental ity."
The U.S. should not endeavor to be self-sufficient In 011 materials. The acceptable degree of import dependence must be examined on a case-by-case basis using an adequate set of criteria includlng effect on employment, economic dis - Iocatlons, and strategic security.	Self-sufficiency is not a goal in itself. The greatest degree of sufficiency is needed in critical commodities and essential industrial materials. Accurate information is needed to establish criteria needed to define these critical and essential materials.
It IS not desirable at this time to create a new bureaucratic function in establishing a materials information system, The further development of MIS can be pursued through more aggressive and directed effort of existing bodies	To establish a materials information system it would appear feasible to make use of current information systems with evolutionary changes as required for centralized coordination.
Industry must be a partner in, contributor to, and user of the MIS	Industry information systems for reciprocal inputs are equally Important to a MIS with the Government/industry interface being of major concern.
Points of Disagreement	
Stockpiling industrial materials should be on an emergency basis only. in response to embargo, limited to short term demand for a few materials. to gain time until other normal free enterprise market forces act to limit or ellminate a perilous gap.	A limited economic stockpile for critical commodities and essential industrial materials is desirable, until the ultimate goal of free and open trade on a world wide scale can be" achieved.
Comments	
A materials Information system must contain provision to assure that constructive analytical use IS made of proprietary data without compromise to its source	To assure the long-run availability of raw materials the major Government role is to supply accurate and timely information sufficiently in advance to ensure that the market will give the proper response. There should be a stated Government policy of collecting as much detailed mineral information as possible and industry associations should endorse this goal Government and industry commodity experts should meet frequently to standardize data definitions and format and to minimize overlap.

TASK THREE: CONSERVATION OF ENERGY IN MATERIALS PROCESSING

A. TERMS OF REFERENCE

There is an increasing recognition that a national energy policy need be compounded from considerations of national self-sufficiency, environmental concerns, and retention of economic advantage in international commerce. How important a role should conservation play in that policy, and more particularly, what is the proper emphasis to be placed on conservation in the production of materials?

Rationale

Sharp drops in the historic growth rate of energy consumption were noted in 1974 and 1975 as a result of patriotic concern, reaction to increased gasoline, fuel oil, and electricity costs, and an overall recession. In 1976 energy consumption has returned to its old trend line fueled by what the New York Times has called a "Bicentennial Driving Binge" and some improvement in industrial activity.

Nonetheless, the long-term concerns inspired by the events of 1973 are a proper business of policy makers, Can energy sufficiency adequate to an independence of action in international politics be reestablished without material changes in lifestyle? Or need we prepare ourselves for a declining standard of living or greater accommodation to outside forces than we would prefer to face?

In addressing national energy policy, the chemical industry has sought to develop positions in each of three areas which, taken together, are conceived to represent definition of an energy policy; i.e., Conservation, Wise Use of Resources, and Additional Indigenous Fuels. The national policy focus is increasingly on conservation, and it would seem particularly on conservation of energy and materials in industrial production, This is understandable, in that industry uses about 41 percent of primary energy (1970), and the chemical industry uses one-fifth of that. Industry is more organized into large entities subject to definition and discipline than, for example, households are, and already motivated by changing costs to address the issues involved. One authority cites two ways to make savings:

- Use of heat that otherwise would be thermal waste;
- By making industry less energy intensive; i.e., changing the weighting of the product mix to make things which are more durable.

Questions

1. How should we define' 'conservation" for purposes of a fruitful study? Should it be "continual progress in reducing the energy consumed per unit of output (or GNP) ," or should it include consideration of reduced consumption of particular fuels in short supply, and/or changes in product character which lead to longer product life and/or otherwise reduced consumption?
2. The electrical system is the onIy present vehicle for delivery of renewable resources (solar, geothermal, tidal, fusion), and the major one for utilization of coal and nuclear energy forms. At the point of use, electrical energy is the most efficiently used energy form. Should national policy encourage, through price or other incentives, the high-voltage, high-load-factor use of electricity?
3. What potential for reduction in energy consumed per unit of material output is theoretically possible and practically possible over the short term (1985) and the long term (2010)?
4. Will the current and future increases in energy costs adequately motivate industrial energy conservation efforts, or are mandatory national requirements a better way? That is, from the standpoint of national policy, is there a parallel between Environmental Protection and Industrial Energy Conservation?
5. What constructive changes in regulatory practices would encourage more industrial electricity self-generation in a dual cycle mode (i.e., a manner to use the heat produced as well as the electricity), yielding marked improvement in thermal efficiency?
6. What should the role of Federal funding in energy conservation be— to accelerate research into energy conserving unit operations (i.e., more efficient separation techniques); and/or to encourage retrofit of obsolete facilities?
7. What should be the role of tax policy in encouraging conservation investment, or replacement of facilities with more energy conservative plants?

B. SUMMARY OF TASK FORCE REPORTS

Task Three

Group A	Group B
Points of Agreement	
Long-term energy efficiency should increase substantially but will depend on the specifics of the materials and technology yet to be applied.	Potentials for reduction of energy consumption in materials are widely variant from material to material but on a long-term basis new facilities necessary to replace energy-intensive processing such as open hearth furnaces will require 30 to 50 percent less energy.
Tax credits. tax exempt energy bonds, and quick write-offs are possible tax policles that would encourage energy conservation.	Tax policies to relieve the high cost of replacement capital equipment plus high interest rates on borrowed money and to expedite capital equipment write-offs are encouraged as incentives to energy conservation by industry.
Points of Disagreement	
National policy should encourage high load factor use of electricity y.	Use of high load factor electricity should not be encouraged for most material processing or extractive applications,
Comments	
Federal R&D funding for industrial energy conservation should be related to needs not now fulfilled by industry.	Industry in general is confused as to what the Federal policy actually is toward encouraging tbe conservation of energy. See no evidence of real. across-the-board Government-originated incentives for energy conservation at this date.
	Process analysis using material/energy balance equations familiar to the chemical engineer can point out the most energy-intensive steps that R and D efforts may minimize.
	Time demand clocks, microcomputer control of processes, adaptive control for optimizing energy of manufacturing processes, use of available waste heat for preheating precursor material, and DC power generation from thermal furnaces all have their place in energy conservation and should be encouraged.

TASK FOUR: THE ROLE OF MATERIALS IN DEFENSE

A. TERMS OF REFERENCE

How can the Department of Defense better address its materials aspects and problems? Are DOD's (and NATO's) scientific, technological, and industrial bases adequate to support their missions?

Rationale

The primary role of the Department of Defense is to provide maximum security to the United States and the Atlantic Alliance. To achieve this goal, new military systems and weapons must be developed or improved constantly. Advanced materials and technology must be available to permit the development of these new concepts and systems which generally are stymied by materials limitations, The narrowing lead of the United States and NATO in science and technology apparently is affecting their development of advanced materials and the accompanying technology,

Questions

1. How can materials research and development be made more productive in a world of declining real dollar funding ?
2. Can implementing the design team approach (designer, materials engineer, nondestructive evaluation, process planning and manufacturing, and maintenance and repair) from the time of the conceptual stage provide a significant increase in cost effectiveness?
3. What is the best way to expedite the development of materials and technologies that limit the development of new systems and weapons?
4. Would permitting the allocation of DOD funds to basic science not directly tied to specific missions be more effective in furthering the long-range, materials-associated needs of DOD than continuing the present restriction largely to National Science Foundation funding?
5. Can centers of excellence for areas, such as casting and welding, that would involve individuals from industry, academia, and Government and multidisciplines be effective in advancing and disseminating technology? How should it be structured—Government owned? Consortium of interested parties? Permanent or rotating personnel?

6. Is the trend toward reduction in DOD's manpower and resources in its materials and structures divisions severely reducing its effectiveness? Concomitantly, do reductions of staff and effort in other agencies such as the Bureau of Mines contribute measurably to the decline of materials development and technology? How can policy level officials be made more aware of the importance of materials to defense?
7. How could the research and development programs of Defense Services be coordinated better to more effectively develop new materials and technology? How could Government-civilian agencies interact in such a system? What international measures concerning materials would be most effective in promoting and strengthening the NATO alliance?

B. SUMMARY OF TASK FORCE REPORTS

Task Four

Group A	Group B
Points of Agreement	
DOD should adopt the design team approach, Matters such as acquisition cost, Iife cycle cost, methods of nondestructive evaluation, and general materials evaluation must be considered as early as possible in the design program	The design team approach should be followed with emphasis on recognition of an adherence to common standards and specifications
A materials properties data bank should be established between Government and Industry to aid in the development of materials and processes specifications and standards and the accomplishment of engineering design	DOD should use contract provisions to require that data (such as mechanical and physical properties of materials and structures. including processing where appllcable) developed under Government contract be submitted in an orderly fashion to designated Government Information systems for storage and retrieval.
DOD must have a strong role in choosing its basic research and relatlng it to its missions because ıt can best judge its overall needs	NSF-funded basic research is not provldlng enough new materials ideas to adequately support future DOD hardware requiremments. DOD should expend its dialogue with NSF with the objective of correcting this deficiency
Points of Disagreement	
Except in unusual instances, acknowledged, rather than Government-crrated “centers of excellence” are more llkely to be effective and competent. and to have long-term viabllity and real acceptance	The Government should fund on a continuing basis “centers of excellence” on Government owned property to develop the expertise and manpower as needed for emerging DOD goals
Comments	
For years, Congress and DOD officials have not appreciated the tmportance of and limitations of materials Increased effort should be devoted to bring to the attention of all executives In Government and business the crltical dlmensions of materials problems and appropriate actions	Mandatory reviews should be made of all service needs to identify common materials problems and make the findings public as far as possible DOD should improve its technology transfer and information exchange mechanisms

TASK FIVE: UTILITY OF ORGANIC RENEWABLE RESOURCES

A. TERMS OF REFERENCE

What are the policy implications for engineers and scientists of the potentially increased availability of and new uses for renewable organic resources?

Rationale

As prime reserves of exhaustible materials are depleted, the requirements for these materials will not diminish but are likely to rise. Resort to lower grades of mineral deposits implies increased costs of both dollars and energy. The great bulk of organic renewable resources are left in the forests or fields as largely unused and even dysfunctional wastes. Their energy content is neglected. The total mass of this unused resource is substantial. Technologies are already available to convert organic materials into engineering-structural or fuel-energy materials. Other technologies are in prospect. The principal deficiencies in the further utilization of organic renewable resources are the lack of awareness of their potential and a lack of organization and management to exploit them. Uncertainties about the economic incentives, ecological impact, future land use policies, etc., are also barriers in the substitution of fossil carbon sources with renewable organic resources.

Questions

1. What are the policy implications of the rising costs of liquid and gaseous fossil fuels, and their foreseeable exhaustion, for the organic renewable resources? Can a situation be defined at which substantial substitution is likely to occur?
2. What is the relationship between the solid fossil fuels–coal, lignite, and peat—and the renewable organics? What opportunities are there for establishing a symbiotic relationship between the renewable organics and the exhaustible minerals to maximize their joint utility?
3. How quantitatively significant are the renewable organics? Is their production amenable to technological measures to increase their abundance?
4. What policy principles should govern the utilization of renewable organics? Economic value? Technological considerations? Preservation of high energy levels of organic molecules?

5. What would be the appropriate directions of research and, especially, development to exploit renewable organics of high economic promise in industry at an early date?
6. What would be the appropriate directions of basic research and exploratory development to exploit renewable organics of potentially great impact in the long-range future?
7. How will the competition for renewable organic resources and land, primarily for food production, affect the future uses of these resources for materials and fuel, and to what extent can symbiotic relationships between end uses be visualized?
8. How can natural renewable resources, especially fibers, be developed and exploited to optimize the combined use of fibers from this source with fibers made from fossil raw materials?

B. SUMMARY OF TASK FORCE REPORTS

Task Five

Group A	Group B
Points of Agreement	
In the utilization of renewable resources economlcs IS the controlling factor.	Economic value Will provide the principal driving force for utilizatlon of renewable organics Periodic economic evaluation of the potential for such utilization will be needed to capture economic benefits that may arise,
Assessments should be made of the technical and economlc feasibility of the feedstock approach of producing chemicals for polymers from renewable resources These efforts should be backed up by research on the Improvement of processes of enzymatic hydrolyses of various lignicellulosic and carbohydrate materials,	One research area should be the development of new materials based on the carbohydrate backbone polymerized with other synthetics. Specific efforts should be aimed at biodegradable polymers. high impact strength polymers and strong absorbent polymers
Comments	
Technologies for burning coal in combination with other fuels with low sulfur-content should be advanced	Coal liquefaction should become a massive source of competitlvely economic aromatics, and coal gasification should become an economic source of synthetic gas for NH_3 and methanol
A National Commission on Land Use should be established with representation and input from a I 1 affected areas	The term renewable resources should not become equated with unlimited resources.
	The extent to which wood IS available for substitution of petroleum-based, energy-intensive, or resource- llmlted materials IS not consldered extensive without significant technological Improvement in all phases of production.

SUMMARY OF TASK ONE (A)
NATIONAL MATERIALS ASSESSMENT FOR CONGRESS: STRESSES ON THE TOTAL MATERIALS CYCLE

Recognizing the complex and highly interactive nature of materials problems and responses to them, this task force was requested to identify the most important stresses on the total materials cycle and possible alternative policy responses to avert or relieve these stresses. The need for and purpose of this evaluation is detailed in the tutorial lecture, "Materials Assessments for the United States Congress," appearing earlier in these proceedings,

Identification of Stresses

Since an attempt to list all of the important stresses associated with the materials cycle would have exceeded the time available, the following stresses were identified as having greatest potential impact in the opinion of the Task Force members:

- Increase in world population;
- Increase in per capita demand for materials;
- Environmental impacts and regulations;
- Health and safety impacts and regulations;
- Actions by foreign governments;
- Internal difficulties in foreign countries;
- Other Government regulatory policies and actions;
- Decrease in rate of mineral discovery;
- Increase in energy costs;
- Long-term trend of declining materials investment, increasing capital intensity, and cyclical nature of demand and prices;
- Destabilizing factors outside materials cycle, i.e., domestic currency inflation, drop in productivity, etc.;
- Permanent changes in demand resulting from the use of new technology; and
- Shift to processing at home of raw materials in foreign countries.

Selection of "Critical Few" Stresses

To narrow the scope of the problem and to assign priorities, the Task Force singled out four principal issue areas as follows:

I. The increasing per capita demand for materials, largely attributable to rising standards of living;

IL Internal difficulties in foreign countries and actions by foreign governments affecting supplies of imported materials;

111. Environmental, occupational health and safety impacts and regulations; and

IV. The declining long-term trend in materials capital investment.

Interestingly, although not surprisingly, these stresses are closely related to those factors occurring in the materials cycle which were viewed as most directly and significantly impacting upon considerations outside the materials cycle, i.e., those materials-related stresses having ramifications or perturbations in the total economy, natural environment, or society as a whole. In all but one of the materials-related stresses having a macro or societal effect, a close correlation with the Task Force's priorities can be seen, thus providing evidence of the interacting or two-way nature of materials-related issues. Those materials cycle stresses directly impacting conditions outside of the materials cycle are summarized in the following five problem areas:

- Environmental, occupational health, and safety issues;
- The materials industries' share of energy use, as well as the materials requirements for energy production;
- The potential stresses upon national capital markets and labor pools resulting from a possible reversal in investment trends of materials industries;
- The trend of shifting mineral extraction, processing, and fabricating industries from the U.S. to foreign sites; and
- The interacting stresses affecting foreign relations and international economic policies (including supply access goals, international commodity agreements, law-of-the-sea negotiations, investment in developing nations, multi-federal trade negotiations, tariff preferences for developing countries, and export administration).

The complexity and extremely interrelated nature of materials/resources issues, the stresses themselves, and the materials cycle make clear-cut categorization of stresses difficult. Similarly, the diverse views represented within the task group frequently resulted in differing concepts of the stress topics themselves, complicating the task of definition. However, the Task Force agreed that the "critical few" selected appeared to be serious constraints to the flow of materials or susceptible to uncertainties that could cause world destabilization and stresses in the domestic economy, compounding total repercussions on the materials system.

Rationalization and Alternative Policy Responses

I. Increasing per capital demand.–The increasing total and per capita demand of most materials is unavoidable as long as the increase in world population remains unchecked, and the revolution of rising expectations in the poorer and most populated regions of the world is spreading. The Task Force feels that, for all practical purposes, these stresses cannot be relieved in the intermediate time frame (5-10 years) even though new materials standards, a conservation ethic, priorities in use and some fabrication, as well as process and engineering improvements, may somewhat slow down the rate of growth.

This leads us to the prospect that for the foreseeable future, this Nation and, indeed, most of the industrialized nations, will be importing an increasing amount of materials from foreign sources that are well endowed with as yet untapped deposits, or ore bodies that have been discovered or developed, and are capable of increased production.

As long as there is no danger of denial of supplies, interruptions, or price-escalation so severe as to damage the reliability or economic justification of foreign supplies, increased imports of materials are not detrimental, especially if U.S. exports of other commodities or services will also increase as fast), It is only when excessive dependence coincides with coercion or denial of a supply essential to U.S. well being and security that other alternatives should be explored (soberly, considering feasibility and all trade-offs), These include:

- Increased supply from less desirable domestic sources,
- Alternate foreign sources of supply,
- International counter-measures, and
- More radical conservation and distribution, etc.

The Task Force finds that an early warning system of changes in the international environment or local unrest endangering the flow of imported materials should be given more detailed and specific study.

Congress and industry should be briefed (within reasonable constraint as to security and proprietary nature of the information) on the changing risks, perils, or trends as soon as they become perceived by the United States.

The international specialized and leading agencies should be informed of the dangers of irresponsible interference with the free flow of materials to world trade.

The Task Force proposed that the following policy responses be considered for relieving the stresses on the materials cycle resulting from reduced supply:

1. Expand U.S. and worldwide minerals exploration,
2. Expand systematic analysis and cataloging of the world resources (by both USA and OECD),
3. Additional assessment of R&D needed to improve all phases of the materials cycle,
4. Improve access to Federal lands, where feasible, and
5. Improve access to foreign material supplies by a cooperative promotion of international trade by Government and industry, acting as a single trading unit in foreign negotiations with underdeveloped countries. Trade with OECD and other industrialized countries should be on a looser cooperative basis.

Demand-oriented options include:

1. Encourage conservation of materials by allowing their prices to float at real market values;
2. Encourage use of abundant (e.g., renewable) materials as a substitute for scarce nonrenewable resources;
3. Encourage materials recycling by Government-supported R&D and removing institutional obstacles;
4. Encourage conservation of materials while minimizing economic and social repercussions;
5. Encourage reduction of post-consumer waste material through changes in technologies to increase the durability and decrease the scarce material content of consumer goods and packaging;
6. Tighten use of export administration statutory authority, particularly with respect to raw materials and recycled materials. Encourage through the use of bilateral and multilateral forums reciprocal supply access where possible; and
7. Consider import tariffs on products imported from countries that do not control environmental degradation in their respective mining and processing industries, as a means of reducing competitive disadvantages to U.S. industries in world markets,

11, Foreign Country actions affecting imported materials. -Unfortunately, two stresses on the materials system will be felt worldwide to a degree that may be destabilizing to world trade.

The first is the increasing number of foreign material exporting countries where internal difficulties (e.g., labor unrest, tribal conflict, insurgency, etc.) imperil or reduce production or exports from existing sources, and/or halt exploration and development of new resources. The second stress includes deliberate actions by foreign governments to nationalize, take over, interfere with, prohibit, or make prohibitive, exports from operating deposits owned or managed by foreign investors. Interference by mandate of a materials cartel (i.e., groups of materials-producing nations that include the country now exporting materials to the United States) will obviously reduce investment in or exports from such deposits.

Alternatives to closing down such operations could entail:

- Increasing royalty payments. Yielding to all demands short of all-out take over (which ultimately takes place, more often than not);
- Slow but persistent negotiations to establish an early-warning system by common agreement of all materials consuming, or multinational interests in those countries and then attempt multilateral negotiations to protect the flow of locally extracted minerals to the world markets; and
- A serious effort by the United States to make a final attempt to reach an international agreement, at least among OECD nations, the international lending agencies and the most responsible LDC materials producers to position effective and visible responses to wanton spoilation of foreign investment,

The Task Force was unable to predict the degree of effectiveness of these measures, or the likelihood that the international environment will continue to change so radically that some of these foreign sources of supply will require export royalties or taxation so heavy, or involved to such extraneous and unpredictable variables as to endanger materials flow from these countries (Cf. UNCTAD demands).

111. Environmental, health and safety impacts.–The Task Force noted that environmental as well as occupational health and safety stresses are significant from the standpoint of their two-fold or interacting nature, i.e., in terms of the adverse impact of such regulation upon producing and consuming industries within the cycle and in terms of the beneficial impact of both stress categories upon other components of the cycle or upon the quality of life as a whole.

The most direct and significant stress primarily involves the cost of compliance with environmental regulations and its effect at all stages of the cycle. Although the single greatest problem area [in the opinion of the Task Force] is control of sulfur dioxide emissions at the smelting stage for non-ferrous metals, environmental statutory requirements and regulations promulgated by the Environmental Protection Agency and its predecessor a agencies also impact upon other stages of the materials cycle ?e.g., water effluents in the electro-plating industry, water pollution in iron ore and other mining stages, the cost of reclamation in mining and the increasing problem of handling overburden, tailings, or air emissions; and the impact on coke production, foundries, and ferroalloys).

The principal concern expressed by the mining/materials industries, and by a majority of the Task Force, relates to the diversion of capital for compliance with these requirements away from cash flow that might otherwise be utilized for expansion or development of new capacity or productivity improvements in existing capacity. The capital diversion also includes diversion of research funds to develop process technology for compliance that might otherwise be, and traditionally has been, expended on innovation.

Concern must be expressed also over the implementation of environmental legislation which requires for compliance either technology that does not exist or which is not economically feasible under most commercial circumstances. The uncertainty generated by the continually changing nature of future environmental requirements, i.e., new statutes or interpretations of existing authorities, are acting as a deterrent to new capacity investment and contributing to the other investment uncertainties described below.

The Task Force made note of the need to examine land use policies and the widespread withdrawal, in recent years, of Federal lands, preventing exploration or multiple-use of such lands,

On the plus side, environmental concern has given rise to a whole variety of beneficial stresses on the materials cycle, such as resource recovery, solid waste disposal, and new incentives for increasing supplies of recycled materials. The Task Force also recognizes the many advances in technology created by the mining and materials industries which contribute to improved environmental quality, land reclamation, recovery of tailings and mine wastes, and previously non-existent supplies now part of the materials cycle,

In the occupational health and safety area, it was noted that regulation of mine safety as well as regulation of health and safety at other stages in the cycle often have a twofold effect, Improved safety and health standards, particularly those imposed voluntarily by industry, often have a favorable impact on overall productivity and efficiency. However, imposition by statute, interpretation, or promulgation of standards of health and safety regulation, without consideration of the standard level to the health/safety impact and without consideration of commercial feasibility, can seriously impact operation throughout the cycle.

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The Task Force recognized the need for understanding the unique nature of mining in conducting health and safety research and in promulgating these standards or conducting inspections for mine compliance. Beyond the mining stage, health and safety standards are generally promulgated on the basis of exposure to individual substances considered toxic, The Task Force suggests that similar consideration should be applied to the unique factors affecting conditions at all stages in the materials cycle rather than across-the-board application to all industry.

As policy, the Task Force recommends that strong consideration be given to balancing all the ramifications, positive and negative, of environmental and health/safety standards upon the materials cycle. An urgent need exists for better understanding of the interactions between these desirable social goals on the one hand and their effects upon energy use and materials productions, as well as upon international competition on the other,

Other policy responses suggested by the Task Force included:

1. Expand Government~-sponsored R&D on pollution control,
2. Encourage R&D for developing less polluting processes,
3. Reassess pollution standards regularly to balance more accurately and realistically costs and benefits,
4. Place potentially polluting processes in locations sufficiently remote to minimize environmental and health impacts,
5. Discourage consumer waste and littering of containers and packaging by allowing the full cost of control to flow through to the consumer. This might be done by special taxes, and
6. Educate the consumer by allowing the true costs of pollution control to flow through to the user.

IV, Declining trend in materials investment.– A majority of the Task Force finds that serious stresses might result from persistent and unfavorable trends in capital investment into the materials system. These are characterized by a long term decline in the flow of funds as compared with the general level of capital expenditures and by the increasing capital intensiveness of the materials industry (i.e., the increasing capital cost per ton of producing capacity; the rate of inflation in mining machinery, salaries and processing equipment appears higher than for other capital goods, etc.), Last but not least, the scarcity of capital and the high cost of money causes more severe stresses on long payoff, capital-intensive industries (as those in the materials cycle) than on quick turn-over consumer industries or short term loans. In addition, the profitability of materials industries is much less than in other sectors, so that the borrowing is not easy and internal profits are insufficient to finance improvements. It may be that to remedy this, the need to modernize our materials facilities and invest in new R&D will justify special incentives or financial guarantees to facilitate the flow of funds into the materials cycle,

The Task Force hears, loud and clear, the industry statement that, above all, the materials industry problems stem from the lack of freedom in the marketplace, and adequate profits to enable investments of the proper magnitude to maintain domestic supply and demand levels.

SUMMARY OF TASK ONE(B): MATERIALS ASSESSMENTS FOR CONGRESS: STRESSES ON THE TOTAL MATERIALS CYCLE

Introduction

The total materials cycle begins with the exploration of the earth and ends with either the recycling of the material or its return to earth by disposal. From a generalized material cycle* in the OTA report on materials information systems, the Task Force developed a series of specific stresses for each phase of the cycle. Many of the stresses were common to several phases of the cycle. These 19 specific stresses are listed and discussed below.

Since many of the specific stresses had facets in common, the 19 specific stresses were grouped into six "summary stresses" from which the policy alternatives and recommendations were generated.

Specific Stresses

1. Environmental Concerns: All active phases of the materials cycle, from exploration to disposal, generate environmental impacts, sometimes severe. Public pressure for a minimization of such effects on the environment will continue to increase.
2. Depletion of US Resources: In many materials, U.S. resources are depleted and the country is dependent solely on foreign sources.
3. Uncertainty of Foreign Supply: Swiftly changing world conditions can result in sudden embargoes of vitally needed supplies. This ever-present threat of complete shut off or severe restriction of supplies can perturb the materials cycle.
4. Capital Acquisition: The lack of investment capital in recent years, due in part to high interest rates, has deferred or even terminated proposed development of production facilities.
5. Government Controls: The increasing number of Government controls and regulations on various parts of the cycle make operations throughout the cycle more difficult and costly.

● OTA report on Materials Information Systems, figure 11-1, p. 22, US. Government Printing Office, 1976.

6, Uncertain Government Policy: In all too many instances, e.g., pollution control, safety standards, Government regulations are inconsistent or appear to fluctuate from month to month,
7. Constraints in Land Use: Government regulations, in the use of park lands for example, appear to be overly restrictive and sometimes capricious.
8. Inadequate Technology: In many technical areas of the cycle, we lack basic technology, For example, a real advance is needed in geophysical exploration techniques. New extractive methods need to be developed to process very low grade ores,
9, Health and Safety Laws (OSHA): In many areas, the application of these laws is inconsistent and variable.
10, Manpower and Training: An increase in the number of trained technical people for the early phases of the cycle (mining and milling) is needed.
11. World Financial Climate: The financial climate outside of the United States has made foreign investment attractive to the detriment of U.S. development.
12. Energy Availability: The increasing cost and limited availability of energy imposes a stress on many phases of the materials cycle.
13, Availability of Indirect Materials: Increasing constraints in the supply of "indirect materials" such as water, fer~ tilizers, etc., poses production stresses for many industries.
14. LDC Industrialization: The entrance of developing countries into the world production generates additional competition for material supplies and markets.
15. Transportation: Biasing in Government regulation toward certain modes of transportation for various commodities imposes stresses. For example, freight laws are designed to favor ore transport but not recycled materials.
16, Public Attitudes: In many areas of the materials cycle, the public attitude is negative—resulting in restrictive legislation or adverse community action.
17. Inadequate Design / Performance: Inadequate service life of many of the industrial tools results in increased production costs. Inadequate product performance results in early replacement.
18. Financial Incentive (profits): Both the Government and the public often do not understand that financial incentive must be present and sustained for successful industrial development.

19. Legal Relics: Outdated laws pose problems in conformance to various regulations.

Summary of Policy Alternatives

(Given in descending order of priority)

A. Lack of Availability of Competitive Domestic Resources–ore, energy, materials (specific stresses 2, 12, 13)
   - Government aid and promotion of exploration especially through amending and expanding the Office of Minerals Exploration;
   - Government aid for general replenishment of renewable resources;
   - More effective utilization of domestic resources through tax incentives to industry; and
   - The promotion of substitution, recycling, and product durability.

B. Uncertainty of Foreign Supply (specific stresses 3,11, 14)
   - All responses of A;
   - Establish a stockpiling policy (stabilizing supply situation allows for negotiation time in short term situations);
   - Government should increase technical aid to foreign countries for resource development for the purpose of encouraging multiple sources of supply of critical minerals; and
   - Amend and expand by means of increased funding the Overseas Private Investment Corporation to promote new development of critical materials.

C. Financing Difficulties–Poor Investment Climate (specific stresses 2, 4, 18)
   - Tax credits for critical materials production.

D. Federal Legislative and Regulatory Constraints (summary stresses 1, 5, 6, 7, 9, 15, 19)
   - Resolve conflicting environmental and OSHA regulations, stabilize "uncertain," fluctuating, regulations;
   - Promote multiple land use;
   - Reappraise freight rate regulations;
   - Reappraise price controls on oil and gas; and
   - Government should promote a freer exchange of technical information (e.g., statistical data or supplies) between companies in the same industry by reevaluation of the present antitrust laws.

E. Inadequate Technology and Science Base (specific stresses 8, 10)

- Develop exploration, extraction, recycling, and substitution technology through Federally supported programs for basic and applied research;
- Support research for production and utilization of renewable resources through Federal funding;
- Encourage research in private industry through tax incentives; and
- Encourage educational programs in mining, milling and extraction engineering.

F. Lack of Public Understanding (specific stresses 1, 7, 16)

- Industry and Government formulation of education programs involving the public, industry, and Government concerning the environment and land use in resource development.

SUMMARY OF TASK TWO (A): GOVERNMENT, SUPPLIES AND SHORTAGES

The Task Force began its deliberation with acknowledgement of its limited resources of time and authority. Yet the fortuitous variety of its experience, expertise, and political bias provided a constructive, objective, and always colorful debate on the role of Government in response to chronic shortages and their underlying considerations.

In addressing Task No. 2, the Task Force chose to focus its attention on the first four questions and on the proposed Materials Policy Act of 1976; response to question five is implicit in the comments on the earlier issues.

On the Sources of Scarcity

The Task Force believes that the shortages observed during 1973-74 were not related to a scarcity of underlying raw material resources. Rather, those shortages were directly related to the lack of capacity of conversion and processing facilities (due in part to Federal intervention) to respond to unusual surges in demand. In this regard, we share the judgment of the staff of the Commission on Supplies and Shortages.

The adequacy of the resource base frequently is confused with the capacity of the supply system; the chain of process facilities from mine, well or field, to refinery, or sawmill, to fabricating plant; and the associated transportation systems, This confusion has led to frequent misperception of the basic problem. Adequacy of short term supply at the point of use is dependent on the capacity of the intervening extraction, process, fabrication, and transport facilities, Adequacy of long term supply depends primarily on the availability of essential technology to convert existing natural resources to man’s needs.

On The Question of Self-Sufficiency

The Task Force agrees that self-sufficiency in materials is an inoperative and undesirable goal, The United States cannot, need not, and should not endeavor to be self-sufficient in all materials. It is further agreed that the issue of sufficient resources for military security is a separate matter, one of assuring that adequate divertable industrial capacity exists to provide critical military needs for the period of limited war; this capability is being examined separately and is the responsibility of the military establishment, The term “degree of self-sufficiency” is semantically misleading; one is either self-sufficient, or he is not; it is not a matter of degree, The acceptable degree of import dependence must be examined on a case-by-case basis, using an adequate set of criteria including economic dislocations, effect on employment, effect on quality of life, and strategic security. The operative institutional framework must include and feature extensive cooperation between Government, Congress, and industry. The ultimate concern is not only the adequacy of industry but the health of industry, upon which the health of the Nation depends.

On the Question of the National Materials Information System

We concur with the staff of the National Commission on Supplies and Shortages that it is neither practical nor desirable at this time, to construct a new materials information system from the “top down.” However, in the longer term, experience may show that both the facility and the need may justify development of a better system. In the interim, the system, as developed, must be open-ended in design, adaptable to changing requirements and capabilities. We would refer to the well-established and rather more integrated information system in food and that evolving in energy as examples worthy of examination. Existing components of a “national materials information system” in various agencies should be maintained and upgraded, Care must be taken to avoid impairment of raw data systems by neglect as analytical capabilities are added or refined. In most instances, data collection and dissemination should be vested in the same agency. (This latter recommendation, incidentally, is not original; it appeared in the Hoover Commission Report in the 1920s.)

A “national materials information system” should not be limited to serving Government alone; its resources should be available to, and designed to serve, industry and the public as well, Industry must be a partner in, contributor to, and user of the system. To maximize its potential for service to both communities —Government and industry—the system should incorporate technical as well as economic data.

An important consideration is proprietary data–both industry and Government. Provisions must be made to assure that constructive analytical use is made of proprietary data without compromise to its source. The Task Force felt that this is an important factor in industry acceptance of the concept of a “national materials information system, ” and in its cooperation with the participating agencies.

We concur with the statement in the OTA report that the information system should include “capability of interrelating many factors to generate information specifically oriented for materials decisionmaking. ” But the degree to which such analytical capabilities should extend to development of policy options is debatable; it is not the function of an information system, per se, to be sensitive to the subtleties of political considerations. An information system should provide only objective facts, without bias or coloration.

However, a primary ingredient of the information system concept should be the capability to select and effectively translate pertinent information into language suitable for the definition of Federal policy alternatives, We believe the system must provide an authoritative source of comparison between policy actions on the one hand and industry, market, and societal responses on the other.

A further essential function of the system is provision for anticipation of supply-demand disruptions. Tools for accomplishing this function—on a macro basis— exist in the present system. Expansion of these capabilities, in both scope and detail, from a coordinated national viewpoint—is necessary. The Department of Commerce Early Warning System may fulfill this need, However, we would caution that it is insufficient to consider the domestic economy in isolation; our supply-demand system is inseparable from that of the global community. We encourage expansion of the DOC EWS concept to consider and report on foreign economic, technological, and political factors affecting the flow-both import and export—of materials through the domestic cycle,

We believe that the creation of a new bureaucratic function is not necessary; the further development of a “national materials information system” can be pursued (as suggested under Approach No. 2) through more aggressive and directed effort of existing coordinating bodies, e.g., OMB. Congressional encouragement and guidance is essential, The chosen coordination agency should be charged with “bringing about improvements in the existing system” and “assuring the addition of new supplementary information services as necessary” (quoted words taken from the description of one alternative approach cited in the OTA report, Materials Information Systems, Feb. 1976).

On the Issue of Stockpiling

With reference to the extensive OTA study of economic stockpiling objectives and alternatives, the Task Force is of the opinion that there is a “prima facie” case for a carefully planned stockpile system to meet military needs, geared to the national strategy, and the weaponry requirements of the national readiness plans, Such a stockpiIe system should not be comingIed with, or used for, domestic or international economic purposes, It is our perception that our present strategic stockpile system suffers from gross imperfections, particularly when combined with or attempting to justify changes for economic objectives. It may now be necessary to substantially revise or reduce the number of materials in the strategic stockpile system, and to carefully examine the form in which such materials are stored,

The examination of scenarios and alternatives for economic stockpiles leads us to the view that an overall economic stockpile of materials for the purpose of price stabilization is not advisable, Stockpiling, as we conceive it, should be a response to an embargo on those materials, the supply of which is essential to avoid disruption of our economy. It should be an emergency stockpile, limited to short term demand for a few materials, to gain time until other normal free enterprise market forces act to limit or eliminate a perilous gap. It should not be designed to counteract swings in prices; this would imply policy decisions against a background of a less than glorious past performance.

Where such an insurance is desirable, the alternative of inventory stockpiling by the consuming industries at point of use (with some Government guidance and visible tax or other incentives to encourage prompt response) would be preferable to new and cumbersome bureaucratic management and Federal intervention.

On the Proposed "National Materials Policy Act of 1976"

Although the Task Force cannot endorse the proposed Act, the Task Force commends the interest, imagination, and concern of the authors of these bills, We encourage the articulation of a National Materials Policy, However, recognizing the inseparable relationships between energy, environment, and materials (and the necessity of integration of relevant national objectives), we believe the objective should be the expression of a National Natural Resources Policy, encompassing all these issues, rather than the more limited implications of the proposed Act.

Further, we find that the Bill does not, in its present form, define even a Materials Policy. The major function of legislation on this subject should be to state National Policy Goals(perhaps using the five elements of policy voiced by the National Commission on Materials Policy as a basis), And the responsibilities for implementation of those policy goals must be clearly defined. The proposed Act is not clear in this respect, (The structure of the Energy Resources Council appears to be a useful example for Executive Branch authority; congressional analogs also are needed; in this respect, we endorse the proposed legislation.)

The Bill focuses on materials research and development, which we recognize as an important ingredient of policy—but only one of many. Although we do not subscribe to the proposed institutional measures, we note the omission of the Administrator of the Environmental Protection Agency from the "Commission on Materials Research and Operations," and suggest that, in view of its major contributions to materials R&D, the Department of Defense should also be represented in such councils. And we would further voice some concern with the scope of the functions proposed for this Commission, which would appear, in many respects, to overlap those of existing agencies,

In summary, we heartily endorse the concise statement of a National Materials Policy, provided that it is in the context of the larger issue of National Natural Resources, and that it does not add to the burden of Federal bureaucracy. Although a useful beginning, the proposed Act does not meet these criteria.

SUMMARY OF TASK TWO (B): GOVERNMENT, SUPPLIES AND SHORTAGES

This report approaches the Task by considering each question posed in turn. Some redundancy occurs using this approach, but it serves to highlight the major concerns which are summarized in the answers to the last question.

1. (a) There are now strong indications that the shortages observed during 1973-74 had little or nothing to do with an underlying scarcity of raw materials, Was there a misperception of the basic problem ?

The direct answer to the question is yes, It would appear that the comprehensive investigation and findings of the Staff of the Commission on Supplies and Shortages is definitive. There was, in fact, no "real" scarcity of materials. The problems were essentially those of unsound Government actions and the resultant "shortage mentality, " A major concern is whether the conditions leading to these shortages will happen again. Here we first recognize that the supply and demand became imbalance for a variety of reasons but it is necessary to classify the shortages in supply as either short or long term. It is important when considering recommendations on possible Government intervention that a clear distinction be made between shortages arising from previous Government actions, unexpected machinations of the free market system or other temporary interruptions in the supply system, as opposed to long term shortages perceived as inadequate future supply because of exhausting domestic resources and increasing dependence on foreign supply.

In all probability supply/demand will never be in balance since producers will tend to produce for profitability while consumer demand might tend to the opposite direction. This occurrence may in fact be desirable since it can act as an incentive for private sector action, Hence, we may expect temporary supply/demand perturbations (or short term shortages), particularly in end products and not necessarily in raw materials. In general, market forces will adequately handle such problems, though time will be a factor. The 1973-74 shortage may well have developed from a unique set of factors which have a low probability of repetition. Even so, some rational Government/industry action will be useful.

1. (b) What lessons for future Government policy can be learned from the 1973-74 experience?

It should be recognized that Government intervention is desirable, but that there is an optimum level of Government action and industry response. This condition does not now exist and a proper balance must be sought. The major need is for accurate, timely, and reliable information to allow for proper Government policy determination and appropriate marketplace response. The latter implies that the Government should rely on the market system to correct shortages whenever this is judged appropriate. Industry must improve its efforts to supply the Government with timely and accurate reporting of the required information. There is some concern that a formal policy might be needed in this area, In addition, the Government must strive to coordinate its policies among some 67 agencies. In this regard legislative guidelines and congressional overview is desirable if not mandatory.

2. (a) Total self-sufficiency in raw materials is not a desirable goal for the United States. Accepting that statement, how should the proper degree of sel~-sufficiency be determined?

Self-sufficiency is not a goal in itself. What is required is sufficiency in "critical commodities" and "essential" industrial materials, The first ingredient is accurate information to define those "critical" commodities and "essential" industrial materials. Beyond this, the group did not attempt to quantify the degree of sufficiency.

2. (b) What policies are required to attain this level?

The Government should apply incentives to allow industry to respond with technological developments that would ensure the proper degree of supply sufficiency. Then the Government should monitor industry and apply further incentives or regulation to achieve the desired result. Here it is important to recognize the impact of the interdependence of the world's national economies (with the development of their apparent synchronized behavior) on the determination of the degree of sufficiency.

3. In light of the recent OTA study on materials information system requirements, what, if any, changes in Government materials information systems are feasible and desirable ?

The big shortfall in materials shortage problems appears to be the lack of adequate information management, Decision makers must be well informed. Policies which are uncoordinated and inconsistent can lead to uncertainty in the private sector. Basic improvements are needed in the quality of information. Uniformity of presentation for comparison in use, and better analytical tools for analysis, are also required, The Government's basic role is to accumulate needed information and provide it in a timely fashion for both its own internal use and for use publicly, These actions should operate to provide a "certainty feeling" which inspires confidence on the part of the private sector which in turn will stimulate the market to react suitably, In this regard the Government might, for example, periodically publish its interpretation of the supply/demand inventory situation. Should the Government foresee a period of shortages, it should publish its assessment of the reason for the impending shortage. In short, the Government should "sell" industry on its capabilities in this capacity. Some more detailed thoughts on implementing information needs is included as follows:

Quality, quantity and timeliness of mineral data could be improved by:

- Much closer cooperation between Government, industry, and industry associations. In particular, it might be possible to arrange for a sampling of data to be transmitted directly from the mine or plant to the final compiler.
- Encouraging the State Department to transmit more foreign mineral data more frequently from its embassies. The U.S. Bureau of Mines should continue its strengthened foreign activities program.
- Having a stated Government policy of collecting as much detailed mineral information as possible, and have industry associations endorse this goal.
- Encouraging Government and industry commodity experts to meet frequently, to standardize data definitions and format, and to minimize overlap.

It would appear feasible to make use of current information systems with evolutionary changes as required for centralized coordination. Note here that industry information systems for reciprocal inputs are equally important, with the Government/industry interface being of major concern.

4. (a) A recent OTA study of economic stockpiling suggests objectives for stockpiling and estimates benefits and costs for alternative policies. In your opinion, is stockpiling for any of the suggested purposes both feasible and desirable?

Economic stockpiling, per se, while feasible, is undesirable and, in fact, should be an action of last resort. In general, it can be expected that all the heretofore identified risks will be realized, and hence such policy will be more disruptive than useful, There does, however, appear to be a justifiable need to assure the supply of "critical" commodities and selected "essential" industrial materials.

4. (b) How are materials selected for stockpiling?

Critical commodities are readily identifiable, and strategic stockpiling has been an accomplished fact. Essential industrial materials can best be selected by analytical models and historical perspective that show a relatively high probability of shortages. These materials might best be stockpiled by extending the concept of the strategic stockpile and incorporating in it the concept of an economic stockpile.

4. (c) Might stockpiling have other benefits and aggregate a variety of objectives?

An interim economic stockpile or a stockpile as defined above might come about as the result of a sound, long-range Government plan based on the accumulation and analysis of reliable, high-quality information. For example, the policy statement might be that free and open trade on a worldwide scale is to be sought as the soundest way to solve supply problems, and some form of economic stockpile is desirable while this goal is being achieved. There are a variety of desirable objectives obvious in such an exercise. One opinion has also been advanced that stockpiling of critical materials might act as a deterrent to disaster.

4. (d) What about international buffer stock programs?

Seven such programs in the minerals area are now operative, Experience with them would indicate that they are a poor or unsatisfactory mechanism for achieving any of the economic stockpiling objectives. Participation in these schemes is not recommended.

5. (a) How active a role must the Government take to assure the long run availability of raw materials?

Again, the major Government role is to supply accurate and timely information sufficiently in advance to ensure that the market will give the proper response, e.g., R&D programs, substitution and recycling studies, etc. If shortages are short term, action by the Government should be exercised with extreme caution, The Government should monitor the market to see that long-range policy objectives are really being attained. If the condition is unsatisfactory, the Government should have available the proper incentives for rational market response. One proper Government role is the support of R&D which is appropriate to observed needs but for which industry has no incentive. Three such projects which might be found suitable upon assessment are (a) **design** of products for longer life, (b) design for recycling, and (c) design for material substitutability.

5. (b) Is there a need for increased monitoring of supply/demand trends ?

Yes, as a basic part of reliable, quality information for decision-making.

5. (c) Is increased financing of R&D on materials substitution required ?

Implicit in the recognition of “essential” industrial materials is the concomitant need for long range R&D on substitution. It should be recognized that substitution encompasses physical, functional, and social aspects, e.g., substituting one element for another in an alloy or changing the mode of transport between stations in an operation or moving from a suburban to an urban living environment all for one or more reasons involving scarcity.

5. (d) Does the situation dictate that the Government undertake something approaching long term planning?

Yes, to the extent that the following four items are recognized and implemented: (1) obtaining and communicating reliable information in a timely manner to inspire private sector confidence, (2) monitoring results of actions on stated policies to see that results are being achieved, (3) intervention only as required and whenever possible the use of incentives to allow free market response, and (4) coordination of policies and actions within and by the Government aimed at guiding the market system rather than disrupting the same. This should come as a result of guidelines prepared and monitored by the legislative branch.

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SUMMARY OF TASK THREE (A): CONSERVATION OF ENERGY IN MATERIALS PROCESSING*

1. Conservation is the wise (labor, capital, materials) and efficient (strategic, economic, political, environment use —not curtailment of use) of fuels and materials; its means is through substitution, selectivity of mix, efficiency of materials use, and minimizing waste. Measurement units include Btu/unit of output (preferred), Btu/capita, Btu/GNP, energy dependence ratios,

2, National policy should encourage high load factor use of electricity. Price should be based on cost.

3. Theoretical energy efficiency data are controversial. Practical efficiencies range from 20-90 percent (Battelle report). Short term improvement could average 10-16 percent by 1985, using currently available technology. Long term efficiency should increase substantially but will depend on the specifics of the material and technology yet to be applied.

4. Price controls diffuse proper signals from energy costs to motivate industrial energy conservation. Voluntary guidelines should be adequate.

There is no parallelism between environmental protection and energy conservation. They are trade-offs.

5. Generally, industrial energy self-generation is not necessarily efficient (size effect). To achieve utility/industry dual cycle, dual incentives are required, Match between available thermal mix and industrial needs must be designed, Reliability is essential. Siting regulations and tax credits are possible regulatory changes.

6. Federal R&D funding for industrial energy conservation should be related to needs not now fulfilled by industry. For example, the chemical industry generally does its own R&D. More R&D is needed in mining, blasting, movement of ore and comminution, etc., by the minerals-producing industry. Loan guaran-

‘Task Force Chairman’s comment: This report hardly reflects the lively and fruitful discussions of the Task Force. The final approved report has been hedged and generalized and several statements cited below were deleted to avoid specificity and controversial items:

3. Battelle analysis of thermal efficiencies was considered inaccurate by some. Long-time efficiency was estimated at 20-30 percent but then removed because it is a guess.
4. Market forces internalize costs and prices reflect this addition in domestic markets but not where price is determined in an international market.
8. Recycling incentives were considered inadequate by some to recapture old scrap (except autos).
9. Import high-grade ore in place of oil difference needed to mine equivalent low-grade ore and thereby conserve energy. Concept discussed and eliminated as too detrimental and controversial.

tees are helpful for industry where capital formation is otherwise impossible, i.e., small businesses, but tends to encourage lower management efficiency, Obsolete facilities should be replaced, not retrofitted.

7, Capital formation is the primary role of tax policy to encourage conservation investment or facilities replacement. Tax credits, tax exempt energy bonds, and quick write-offs are possible actions,

8. Sufficient market forces exist to encourage recycle for energy conservation

SUMMARY OF TASK THREE (B): CONSERVATION OF ENERGY IN MATERIALS PROCESSING

Assumptions

Industry (materials-producing plus materials-application) uses approximately 40 percent of the total energy consumed each year in the United States, This Task Force addressed the role that conservation of energy could play to reduce this large consumption rate and the proper emphasis that should be given this role by both industry and Government.

The energy content of final products is made up of two parts: (1) the direct energy content contributed by the firm manufacturing the product and (2) the indirect energy content contributed by the primary materials producer. The ratios of direct to indirect energy vary widely between industry groups and even within an industry group, depending on a large number of factors such as the maturity of the industry, size of capital investments in operational but technically obsolete equipment, and whether the materials and final product are produced in a continuous or intermittent operation.

Our Task Force represented a wide variety of materials-application companies and Federal agencies. It was unfortunate that only one basic materials producer was represented since the highest percentage of energy involved in the manufacture of most products is the indirect portion attributable to the highly energy-intensive production of the primary materials.

1. Definition of "conservation of energy" as applicable to materials processing.

The Task Force agreed that there was no across-the-board, single common denominator for defining or comparing conservation of energy, Total energy consumption expressed in terms of dollars, tons of fuel (or barrels of oil equivalents), Btu's or kWh's are misleading since population growth and expansion of the economic base will cause consumption to grow even though sizable conservation efforts are made, Consumption of energy rates per capita, per unit of GNP, per ton or volume of material types are also misleading (i.e., one class of steel may require much higher energy to process than another). Life-cycle energy costs of products may be the best way to compare product families such as automobiles, air conditioners, etc. All consumer (and capital goods) equipment have energy consumption contents in three stages:

1) Direct/indirect energy for generation of manufactured products,

2) Consumption of energy during life of product including energy input into maintenance, and
3) Energy consumed in disposal of product after its useful life is-exhausted,

As an example, an average American automobile (3545 pounds) requires only approximately 100 X 10’ Btu of energy in Stage 1 but 1500X 10^6 Btu of energy during Stage 2.

Process vs. alternate process energy comparisons are valid only when studying a single industry and a single family of materials, Consequently, the Task Force cautioned against the imposition of arbitrary energy reduction quotas, The real-world experiences of our group led us to conclude that such a simplistic approach to energy conservation would fail.

Process analysis using material/energy balance equations familiar to the chemical engineer can point out the most energy-intensive steps that R&D efforts may minimize. Moreover, product mix considerations by the materiaIs producers and design changes by the materials application industries have a great potential for reducing energy content and maximizing materials effectiveness. What we really need to emphasize is the wisest use of available energy rather than arbitrary reduction quotas,

2. Encouragement of use of electrical energy for materials processing.

Question 2 asks whether national policy should encourage the use of high-voltage, high-load factor electricity. While it is true that electricity is the most convenient form of energy for many applications (especially in the non-thermal manufacturing processes), it is certainly not the most efficient energy form for most thermal applications and particularly in the materials-producing fields. Many of the necessary processes require thermal inputs inefficiently supplied by electrical power. Hence, the response is negative for most material processing or extractive applications.

The Task Force recognizes that it may be necessary or mandatory to switch from such energy sources as natural gas and fuel oil to less efficient electrical power in the near future. When this occurs, there are real advantages and savings in fuel consumption by the electrical power utilities in maintaining a high-load power factor to meet these industrial demands.

3. Potential for reduction in energy consumption.

Both the short term and long term potentials for reduction of energy consumption in materials processing are widely variant from material to material. The chemical and chemical by-products industry has demonstrated the ability to incorporate process changes (that may or may not conserve energy) more rapidly than mature industries such as steel. Here again, the high cost of capital expenditures to change basic processes in mature industries must be emphasized and understood. All materials-producing and materials-application industries know how to reduce energy consumption and/or to increase productivity, but capitalization and high interest rate (plus recent mandatory expenditures to conform to OSHA and EPA edicts) preclude such massive expenditures on a short term basis (1977-85). On a long-term basis (1985-2010), new facilities necessary to replace such energy-intensive processing as open hearth furnaces will require **30 to 50** percent less energy.

4. Will energy costs motivate conservation efforts or are mandatory requirements a better way?

Recent experiences of governmental agencies imposing on industries rather arbitrary quotas, allocations, or percentages lead the Task Force to oppose mandatory energy reduction requirements, The profit and competition (or dollar) incentive are considered the best at this time. When energy and material costs increase to a point at which profits are seriously jeopardized or until industry cannot compete with foreign or domestic firms, management will find technical ways and necessary capital to introduce energy-saving processes. Government aid in forms of tax incentives and short equipment writeoffs would be in order if and when this occurs. (See comments on question **6** for other ways that both Government and industry can expedite energy conservation.) Some members of the Task Force pointed out that energy cost increases have not become so out of line with other cost increases as to be the controlling factor in the motivation to introduce less energy-intensive processes.

Some concern was expressed that actual shortages of available energy fuels for processing (such as natural gas and fuel oil) would make allocations of priorities for energy by industries necessary. In such a situation, small firms without auxiliary fuel supplies and technical know-how could be mortally hurt. Moreover, public and social concerns make it mandatory that a governmental agency (rather than the local power company) determine the priorities for available energy.

5, How to encourage industrial electricity self-generation in dual-cycle mode for materials processing.

While some materials producers and application industries have generated their thermal energy requirements for basic processing steps, it was generally agreed by the Task Force that electrical generation can best be supplied by large utilities. There is a strong move towards load-level management by both the electrical utilities and the major industrial users, and this effort should be encouraged and rewarded. One member cited a survey that showed that effective load Ievelling alone by industry and utilities could save 1.8 X 10^{Y} barrels of oil per year out of 16 X 10” barrels. Time/demand clocks, microcomputer control of processes, adaptive control for optimizing energy of manufacturing processes, use of available waste heat for preheating precursor material, DC power generation from thermal furnaces—all have their place in energy conservation and should be encouraged. Converting to low efficiency self-generation of AC electricity (or switching to all electrical energy for furnaces) could result in a paradox of higher thermal efficiency at the plant site but increased overall fuel consumption.

6. Role of Federal funding in energy conservation as related to materiaJs processing,

The Task Force agreed that experts in devising ways to conserve energy are needed in the specific industries that process material or manufacture final product. For example, even large companies that know their sub-contractors or vendors very well lack the “degree of technical knowledge and judgement” to advise them on energy-saving methods except in a general sense. We feel even stronger that Federal agencies lack this necessary knowledge and judgement. Tax credits for energy-saving R&D and/or expedited writeoff of energy-saving processing equipment should be considered as state governmental and Federal roles or options. Publicizing successful energy-saving methods (where proprietary information is not compromised) for smaller concerns lacking R&D capabilities should also be considered as governmental roles or options. The Task Force felt that industry in general is confused as to what the Federal policy actually is towards encouraging conservation of energy. Moreover, regardless of the policy, we see no evidence of real, across-the-board, governmental-originated incentives for energy conservation at this time,

7. Tax policy for energy conservation in materials processing.

The answers to Question **6** apply to this tax policy query. The Task Force repeats that most industry is not using all known processes that conserve energy today for the following important reasons:

- Profits generate capital too slowly to incur major expenditures for capital equipment. We can always turn off lights, but real energy savings will incur high capital outlays (with their own energy content);
- High cost of replacing capital equipment plus high interest rates on borrowed money would cause slow replacement even if profits could provide capital;
- Expedited capital equipment writeoffs based on energy saving are not available to encourage their early incorporation;

- Major capital investments to meet local, State, and Federal mandatory edicts by OSHA/EPA/FEA have taken priority over energy-conserving expenditures; and
- Energy saving alone has not had sufficient dollar impact to incorporate known processing improvements.

To the extent that governmental relief via tax policy changes can change the above basic factors, the Task Force encourages their incorporation.

Questions 1 & 3

I, How can materials research and development be made more productive in a world of declining real dollar funding?

3. What is the best way to expedite the development of materials and technologies that limit the development of new systems and weapons?

The needs of the DOD in the areas of materials and structures technology have expanded because of increased demands on improved performance of DOD weapon systems, coupled with increasing demands of structural integrity, minimum life cycle costs, and enhanced safety. In many instances, systems requirements make it necessary to choose materials that are not completely characterized. Moreover, the data base in many cases is not adequate for detailed design, and the constraints on the system do not allow the necessary data base to be developed under the basic and applied materials research programs of the DOD.

One important and necessary method to expedite the development of materials and technologies that limit the development of new systems and weapons would be in the creation and operation of a materials properties data bank between Government and industry organizations involved in materials R&D and materials properties characterization. Such a materials properties data base would be most important to the development of materials and processes specifications and standards, and in the accomplishment of engineering design.

Much of these data are generated during the engineering development phase of major weapons system design and in the production of materials and mill-product forms relevant to that application. It is accomplished on a large number of mill products and heats at great cost. Because of costs for this type of data, it is not economically possible to generate them in the applied research phase of the materials investigation. Therefore, what is needed by the DOD is:

- a means of generating information about materials properties for the data base,
- a means of analyzing the data for the best statistical analysis,
- a means of formatting the data so that they are readily available in a meaningful manner, and

- a means of retrieving these data by potential users in an expeditious manner and useful form.

The materials properties data base can serve to direct support to basic and applied materials research so that the necessary engineering materials properties will be available for use in systems development.

As concerns making materials research and development more productive in a world of declining resources in the face of an inadequate technology base, selectivity in R&D programs in certain areas is mandatory. With this selectivity should be the assured financial support of basic and applied research as a fixed percentage of the materials R&D budget to insure that new ideas and technology will be developed, and to insure that creativity and innovative ideas are supported to supply the basis for the needed technology.

Question 2

2. Can implementing the design team approach (designer, materials engineer, nondestructive evaluation, process planning and manufacturing, and maintenance and repair) from the time of the conceptual stage provide a significant increase in cost effectiveness?

The consensus of the Task Force is that the DOD should adopt the design team approach, with the materials systems rationale in DOD management in cases where materials area critical element of a system. Matters like acquisition cost, life cycle cost, methods of nondestructive evaluation, and general materials evaluation must be considered as early as possible in the design program,

Question 4

4. Would permitting the allocation of DOD funds to basic science ‘not directly tied to specific missions be more effective in furthering the long-range, materials-associated needs of DOD than continuing the present restriction largely to National Science Foundation funding?

There are often difficulties in defining the role of basic research applicable to DOD needs. The spectrum of research runs from basic to applied areas, and all are needed, as long as they comply to the concern of relevance to broad mission areas, It was the view of the Task Force that the entire spectrum of research is needed by DOD and that it would be unwise to relegate the basic research component to another Government agency that might not be in a position to recognize DOD’s needs. Since the economic health of the Nation depends, among other things, on the technical community's ability to innovate, the role of basic research takes on added meaning to the innovation process when it helps to accomplish added missions at minimum costs. The process is not limited to the DOD, but involves industry and academic participation in the needs of the DOD.

It is not within the province of this Task Force to suggest how research is to be funded, but rather to urge that DOD have a strong "role in choosing its basic research and relating it to its missions, because it can best judge its overall needs.

Question 5

5. Can centers of excellence for areas, such as casting and welding, that would involve individuals from industry, academia, and government and multidisciplines be effective in advancing and disseminating technology? How should it be structured—Government owned? Consortium of interested parties? Permanent or rotating personnel?

The Task Force agrees that there is value in identifying centers of excellence for specific technology areas which impact significantly on the missions of the Department of Defense. The Task Force believes that, except in unusual instances, acknowledged, rather than Government-created, centers of excellence are more likely to be effective and competent, and to have long-term durability and real acceptance.

In addition to identifying centers of excellence, an analysis should be made of gaps in technical competence which should be corrected, for strategic and technological planning reasons.

More specifically, the Task Force recommends that:

1. Minimum 'criteria for designation as a center of excellence should be established but without any minimum size limitation.
2. Centers of excellence which are important to the Department of Defense mission should be identified and evaluated.
3. Evaluation should be made by a group of (e.g., 3-5) peer authorities in the identified field (not necessarily a part of the Defense establishment).
4, Designation of centers of excellence should be reviewed and considered for renewal after an appropriate time period (e.g., 3-5 years). This action should include recommendations for adjustments in manpower and funding levels, in accordance with evolving Defense Department priorities.

The Task Force does not believe that there is one best structure or institutional format for the centers of excellence, What is most important is that the contribution from the Centers are effectively coupled to the relevant mission-oriented Defense Department programs.

Question 6

6. Is the trend toward reduction in DOD's manpower and resources in its materials and structures divisions severely reducing its effectiveness? Concomitantly, do reductions of staff and effort in other agencies such as the Bureau of Mines contribute measurably to the decline of materials development and technology? How can policy level officials be made more aware of the importance of materials to defense?

The Task Force expressed concern over the asserted reduction in materials technology manpower as related to defense. This reduction is taking place at a time when demand on materials performance, reliability and cost effectiveness are complicated by materials availability problems.

For years, Congress and DOD officials have not seen the need for a comprehensive materials policy, and have not appreciated the importance of and limitations of materials. The downward trend in manpower and resources in the DOD and other agencies devoted to materials and structures is further evidence that experience in recent years has not brought home the message,

This Task Force recommends that increased effort be devoted to bringing to the attention of all executives in Government and business the critical dimensions of materials problems and appropriate actions, Although efforts have been put forth by many in the past, much more needs to be done, such as:

1. Increased support and awareness of the National Academy of Science/National Academy of Engineering efforts to make officials aware of materials problems and options;
2. More effective coordination and participation by the DOD with standards-setting committees of such societies as ASTM and ASME;
3. Increased activity of the individual technical societies and the Federation of Materials Societies to bring the message not only to their individual members but also to the executive level groups in Congress, Government agencies, and business;
4, Encouragement to the DOD and its contractors to predict materials performance needs; and

5. Encouragement to the continuing and improved analysis of materials research now supported by the Federal Government, and the adequacy of the current programs in relation to a continuing assessment of needs.

Question 7

7. How could the research and development programs of Defense Services be coordinated better to more effectively develop new materials and technology? How could Government-civilian agencies interact in such a system? What international measures concerning materials would be most effective in promoting and strengthening the NATO alliance?

The Task Force understands that through periodic summary reviews (e.g., technical coordination papers) of-ongoing materials technology programs, the DOD adequately disseminates information among its own research organizations, While coordination with other departments and Federal agencies concerning its research programs is useful, we concur in the proposal that meetings be held to review these programs in concert with officials responsible for other Government R&D materials research.

The Task Force is concerned that unclassified information from DOD's periodic summary reports is not shared with the private sector. We believe it would be useful to make available information on research areas which are of mutual interest and recommend that (I) briefing sessions be held for this purpose with industry representatives, and (2) unclassified versions of its research summary reports be prepared and distributed. Responsible officials and organizations in the international community likewise could be briefed and kept informed of unclassified research activities in the DOD.

The recommendations offered here, if implemented, could yield as much, or more, information to DOD than it makes available to the private sector.

TASK FOUR (B): THE ROLE OF MATERIALS* IN DEFENSE

Rationale

The primary goal of the Department of Defense is to provide adequate and sustained U.S. security. To achieve this goal, the United States must develop and maintain modern defense systems. Increasingly, such systems are constructed from improved and advanced materials designed to meet high levels of performance under the extreme conditions encountered in actual service. Indeed, the materials required to carry out the 14 missions established by the Joint Chiefs of Staff are all materials-limited. Thus, continuing preparedness requires adequate supplies of strategic materials, a strong base of materials research and development, and rapid exploitation of new technological developments.

Though providing security is a primary national goal, pressures to achieve such other national goals as a benign environment and an adequate energy supply have led to a shift in the available Federal R&D resources toward more civilian-oriented technologies. As a result, an increasing proportion of military-related R&D is devoted to attaining short term objectives. Thus, the basic research to meet future defense needs is not being carried out at an adequate level, In addition, the growing U.S., dependence on imported raw materials, coupled with the advent of resource diplomacy as a feature of international relations, has increased the vulnerability of the United States in the longer term. To ensure national security, while at the same time meeting other national goals, the United States must efficiently allocate R&D resources not only among the several national goals but also between short and long term objectives. Obviously, to achieve this balance, U.S. materials policy must establish efficient systems for managing defense-related R&D, for coordinating this R&D with other agencies, and for transferring technology.

1. Materials R&D Management

POLICY: To develop, improve, and advance the technologies to support future military systems and weapons, the Department of Defense should adopt a more expansive materials R&D policy, Its policy should encompass the efficient management of both fun-

● The term "materials"' as used in this report is intended to include processes and structures.

damental and applied research necessary to maintain maximum national security in the present and in the future.

Therefore, it is recommended that:

1, DOD strengthen its use of MBO (management by objectives) in the management of its programs by requiring that the following steps be followed in each program?

a) Defining problems in greater detail.
All DOD Pacing Materials Problems (PMP) need to be phrased in sufficient quantitative detail so that the technical objectives are clear both to the scientist/engineer who responds with a research proposal and to the DOD personnel who review the proposal and manage the subsequent research program,

b) The PMP should be updated from the 1972 edition with quantitative objectives and kept current on an annual basis.
The PMP was the title chosen for a statement of materials limitations in various Army and Navy mission areas identified at a DOD materials conference held in May 1972. (The Air Force should be encouraged to publish their materials problems in a similar format so as to make the approach of all three services consistent.) The Joint Chiefs of Staff have established 14 mission areas to be covered by the Army, Navy, and Air Force in compliance with the Mansfield Amendment. In support of these mission areas, which are intended to provide DOD with the elements to attain its national security goal, a series of technology coordinating papers (TCPS), including one on materials technology, have been developed. These papers identify the materials barriers or problems which, if not adequately solved, will result in below-acceptable performance. These barriers define much of the needed R&D program.

c) Mandatory reviews should be made of all service needs to identify common materials problems, and make the findings public (unclassified) as far as possible.
The grouping of common problems should make the setting of priorities easier as the major materials problems should then be more apparent. Focusing on the major problems should provide some of the increased productivity and expediting sought by DOD. By making the documents unclassified, their usefulness to

the materials community and, therefore, to DOD itself, should be greatly enhanced.

d) Prioritizing the PMPs and subsequent R&D programs. Publish an unclassified document containing pacing materials problems (with a classified supplement if needed) in a prioritized way so that the more critical and important materials problems will be defined for the technical community. For each PMP, a DOD lead laboratory should be designated, and a technical contact listed from the lead laboratory staff. It is suggested that resources be emphasized on a relatively few Pacing Materials Problems where good solution ideas have been proposed, rather than arbitrarily spread over all problems.

e) Make a mandatory annual assessment of R&D program progress.
Each DOD lead laboratory should be required to conduct and publish an annual assessment, of progress toward program objectives on each of its assigned PMP. The assessment needs to be critical and quantitative with respect to technical progress, in order to provide a rational basis for the reprogramming recommendations which are the primary goal of the progress assessments.

f) Reprogram materials R&D activities as required.
The reprogramming action is essential in order to terminate unproductive research and development projects, to increase effort on productive work if warranted, and to initiate innovative new projects.

2. The design team approach should be followed with emphasis on recognition of an adherence to common standards and specifications.
Design, materials engineering, nondestructive evaluation, process planning, manufacturing, maintenance, and repair should all be brought in at the conceptual stage to save time and expense due to reworking as a result of omissions of these factors, thereby providing a cost reduction. This concept could be tested by trying a few experimental cases.

3, Some larger, significant percentage of total military materials funding should be dedicated to basic knowledge seeking research in areas identified by DOD as relevant to future systems needs. A method for accomplishing this could be via the "earmarking" of a certain percentage of the RDT&E costs already incorporated into the billing for foreign military sales (FMS) for fundamental research, The present NSF-funded program in basic research is not providing enough new materials ideas to adequately support future DOD hardware requirements. Hence, it is recommended that the DOD expand its dialogue with NSF with the objective of correcting this deficiency. The earmarking clause in FMS for fundamental research needs could be accomplished with minimal changes in present accounting procedures. It is suggested that the receipts from this procedure could be placed in a revolving fund administered either by the DOD, or by the NSF with performance input from the DOD.

4, "Centers of Excellence" or Process Centers for Innovation and Development, should be identified or created for specific areas of materials, process, and structure expertise which would serve as a resource and training ground for well qualified personnel to staff Government and industry.

(The reasoning for the establishment of these Centers is presented in section II under recommendation 4.)

5. The effective coordination of materials R&D programs and results should be improved further through formalized inservice technology exchanges, In addition, interagency inputs, as well as those from industry and academia, should be more fully utilized.

Implementation of the policies outlined in the above 'will improve tri-service coordination, and should lead to the development of new improved materials and materials technology. Interaction of Government and civilian activities will be improved by dissemination of the prioritized Pacing Materials Problem document. A series of briefings may be useful in dissemination of these materials needs; and distribution of the document to industry, universities, and professional/technical societies may also be usefuI. In this respect, removal of security classifications to the maximum extent possible would be very helpful.

With regard to the NATO alliance, the Advisory Group for Aerospace Research and Development (AGARD) is functioning and could be improved by increasing technical activity within its charter. In addition, it may be useful to broaden the tri-partite technical coordination program (TTCP) activity to other NATO countries,

6. A continuous evaluation of DOD materials research programs should be carried out in order to isolate projects suitable for application in commercial markets, The efficiency of a research effort is to some extent dependent on

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the ability to utilize research results in any application regardless of the primary goals. In situations where research results indicate possible application outside the general objectives of the organization it is desirable to provide license-free rights to private industries that may be interested in further developing or marketing the process or product. The benefits of such endeavors may include the following: (a) DOD research may accomplish improved contact with materials research and process technology, (b) DOD scientists and engineers will have the opportunity to follow the idea from conception to implementation, (c) DOD scientists and engineers will be, to a greater extent, exposed to limitations and possibilities in the production of materials, (d) in general, successful research projects will create a more innovative research atmosphere which in turn will attract creative scientists.

H. Technology Transfer and Coordination

POLICY: To expedite development and improvement of new military systems and weapons, the Department of Defense should adopt a policy to facilitate the flow of information relating to the promotion and development of advanced and improved materials and process technology within the Government, private industry, and academia. This effort should provide broad support for early implementation of research results both in areas for which the work was originally undertaken and in other areas where new knowledge may be applied.

Therefore, it is recommended that:

1. DOD should continue to support materials information systems and weigh the subsidization, if any, needed to better disseminate the available data pertinent to specific areas. Technical data and information are the foundations on which materials technology and processing are built. Information systems still are in early stages of development regarding the best methods for collection, retrieval, and dissemination at minimal costs. Continued innovation and support are necessary to develop the most flexible system to utilize the voluminous data that are generated continuously.

2. The DOD should improve its technology transfer and information exchange mechanisms by initiating a variety of programs such as: (a) a more extensive visiting scientist program at its service laboratories, (b) promotion of con-

tact with researchers involved in apparently unrelated technologies, (c) expansion of the existing Executive Exchange program between DOD and industry. to include non-executive level scientists and engineers, (d) expansion of contacts with the private sector to encourage the use of the civilian sector of new technologies developed by DOD research, and (e) educational programs for the DOD research management structure in order to inform them of materials problems.

Technology and information transfer are the cross fertilization of principles and information between disciplines and people and may be affected by methods such as (a) the implementation of research and development into the applied research and production areas, and (b) the innovative transfer of research results into areas and disciplines not contemplated when the program was planned originally. Generally, it is believed that such transfer is effected best through personal contacts by individuals in discussions during informal meetings, seminars, or conferences.

3. DOD should use contract provisions to require that data (such as mechanical and physical properties of materials and structures, including processing where applicable) developed under Government contract be submitted in an orderly fashion to designated Government information systems for storage and retrieval.

   Considerable data (mechanical and physical properties, and material characterization) and processing information have been developed by various DOD contractors. Such data are not required to be assembled or submitted by the contractors in any orderly manner and generally are lost to the Government or are redeveloped by subsequent programs. To utilize and disseminate these data, DOD must establish appropriate contractual requirements and insist on compliance,

4. The Government should fund on a continuing basis "centers of excellence" of process centers for innovation and development, on Government owned property to develop the expertise and manpower as needed for emerging DOD goals. It is believed that these centers should be operated by a relatively permanent, innovative managerial staff with possibly one relatively permanent resident scientist in each discipline, The remaining personnel should be recruited from industry, academia, and Government on a rotating basis in order to promote the introduction of new ideas.

High productivity in the development of new knowledge is dependent on programs which will fund efforts of individuals who have developed after many years within a stable, invigorating, and innovative leadership and atmosphere. If many disciplines are involved in this effort, increased creativity may result. To achieve and maintain such excellence, particularly in areas where the commercial payoff is distant or jeopardized by the vicissitudes of the business cycles, "centers of excellence" appear desirable, "Centers of excellence" are defined as Government-owned establishments devoted to (a) using applied research in materials and processing in solving DOD roadblocks in specific military systems, (b) developing needed manpower in particular areas, (c) establishing the engineering criteria upon which to base standards and specifications. These centers should be on Government property and could be directed to processes such as melting, casting, joining, powder, metals, and polymer chemistry.

5. DOD and non-Government standards-writing organizations should coordinate and integrate a national effort on specifications and standards.

   The manufacture of materials and products of uniformly high quality require specification and standards that characterize materials properly and clearly state the requirements— function, minimum life, inspectability, and maintainability as appropriate, These specifications and standards should be up-to-date and responsive to the needs of Government and industry. To develop the engineering data upon which to base such specs and standards, it is believed that there should be a coordinated and integrated national effort involving Government and industry.

TASK FIVE (A): UTILITY OF ORGANIC RENEWABLE RESOURCES

Organic renewable resources provide a significant reserve of potential energy supplies, This reserve ameliorates, to a limited degree, the threat of rising costs of liquid and gaseous fossil fuels. According to the report of the Committee on Renewable Resources for Industrial Materials of the National Academy of Sciences (CORRIM Report), the total residues from agricultural and forest crops at 1970 levels of production and use efficiency could provide energy equivalent to 11 percent of U.S. energy requirements.

In projecting the use of renewable resources for fuel, other points, in addition to potential contribution to total energy needs must be considered. These points include ecological impact, cost of collection, cost balance between fossil fuels and organic renewable resource fuels, and available technology.

It is the conclusion of the CORRIM study that, in general, the environmental impacts associated with the production and use of biomass for fuel are much less severe than are those resulting from the use of fossil fuels and nuclear power in terms of duration of impact or effect upon human health or welfare. Nonetheless, the Task Force concludes that more information on the effects of total or near total removal of biomass from land is needed.

Costs of agricultural and forestry residues in place in a dry condition at conversion plants or power generating plants are estimated to vary from $15 to $34 per ton. A likely cost for a dependable supply in significant quantities (1,500 tons per day) over the long term might cost $30 per ton. For use as fuel, this would be equivalent to about $1.75 per million Btu's. Oil costs are at this level now and are projected to increase in constant dollar values through 1985.

With this situation it is indicated that industries located close to such residue sources as pulp mills would soon be in a favorable position to switch from the use of liquid and gaseous fuels to the use of more fuels from residues.

More rapid change in sources of fuel for pulp and paper mills could be encouraged by greater efforts in development of machines and processes for harvesting, processing, transporting, and using residues. This would be a beginning step toward conserving the fossil fuel supply and decreasing our dependency on imports.

Recovery boilers in pulp and paper mills are an effective means of using isolated lignin and making it available for process fuel. There is an added bonus in burning lignin since it has a significantly greater fuel value than other wood components. By the same token, there is a good potential for using lignin in higher value applications than for fuel.

According to the CORRIM report, if all U.S, energy needs were to be filled by using coal as the fuel source, we could obtain about 148 years of our requirements based on 1970 consumption rates.

Much of our coal has a significant sulfur content which causes problems in emission control when the material is burned as a fuel, If coal is burned in combination with low sulfur fuels such as agricultural and forest residues, the emission control problem is significantly reduced.

Technologies for burning coal in combination with other fuels with low sulfur content should be advanced. There should also be increased efforts in planning land restoration after strip mining and erosion control after other land disturbances to establish biomass for economic as well as aesthetic purposes.

Recently, there have been recurring suggestions for growing trees and annual crops, such as grasses, for fuel, Conceivably, fuel from such plantations would be used in boilers to power electrical generating plants. There is no question that production of agricultural and forestry biomass could be increased with the application of more intensive cultural practices.

However, we believe that only in comparatively few locations should biomass be grown exclusively for fuel. Generally, there are more important uses than fuel for most biomass crops. Fuel can often be a secondary use for portions of the crop or tree harvest. In considering biomass crops for fuel, fresh and salt water plants should not be overlooked. The possibility of using solar energy to dry biomass fuels, especially those from water plants, should be explored.

We believe more attention should be given to cultivation of grasses in place of feed grains for animals in production of red meat.

In the utilization of renewable resources, we believe that economics is the controlling factor. Technology for using biomass residues for fuel and chemical feed stocks can be improved, but generally it is not limiting.

We agree with the tutorial lecturer, Dr. Falkehag, that it is desirable to attempt to use agricultural and forest crops at their highest enthalpic value, We should not increase entropy and destroy a composite material when we do not have to in order to meet our need,

We recommend that past research results on biomass for fuel and chemical feedstocks be reviewed and that possibilities for their application in today’s economy be analyzed.

We have defined the following objectives for research in renewable organic materials:

a. Control the biosynthetic process in order to improve the yield of fibers suitable for paper production, to improve the yield of wood polymers for fuel or other purposes, and to improve the yield of chemical byproducts from pulp and paper manufacture;
b. Develop new enzymatic and fungal systems to manufacture chemicals or feedstocks from organic materials;
c. Develop new materials based on the carbohydrate backbone polymerized with other synthetics. Specific efforts should be aimed at biodegradable polymers, high impact strength polymers and strong absorbent polymers;
d. Conduct research in the areas of fiber and cellulose morphology, biosynthesis of natural polymers, enzymatic systems in growing plants, rheology and physics of crystalline materials and physical chemistry of wood-based polymers;
e. Increase research on the potential for lignin for applications other than fuel;
f, Develop new techniques for reducing energy consumption and materials savings in the pulp and paper industry including improved efficiency of the recovery boiler, reduced energy consumption in mechanical pulping, increased dryness after wet pressing, improved control and process knowledge to obtain a functionally-oriented product and increased strength potential of recycled paper; and
g. Increase efforts to apply intensive culture in forestry and thereby increase forest productivity.

We recommend that international seminars on the subjects of controlled synthesis of polymers in plants and plants as sources of chemical feedstocks be established. We recommend that exchange of scientists between national and international locations be encouraged. We encourage universities to build up programs in physics of wood-related polymers.

The Task Force does not feel competent to recommend policies for regulating use of land for competing purposes in the future. In like manner we have no recommendations with regard to multiple use, dominant use, or restricted use policies. However, we feel that land use considerations are important enough to warrant the establishment of a National Commission on Land Use. This National Commission should develop land use plans for regional implementation, but it should have representation and input from all affected areas.

We believe that the combined use of natural fibers and fibers made from hydrocarbons other than plants will progress only as economic conditions favor this development,

TASK FIVE (B): UTILITY OF ORGANIC RENEWABLE RESOURCES

Renewable resources in the foIlowing discussion means: wood and wood-based materials; agricultural sources such as nonfood oils, fats, cereal products, natural fibers, crop and animal residues; and biomass in general not used for food.

In order to examine and derive policy implications of importance to engineers and scientists of the potential increased availability and use of renewable organic resources, questions posed to the Conference were considered in some detail. Some of the points, issues and rationale developed in these considerations are listed in association with each question.

1. Policy Implications of Rising Costs of Liquid and Gaseous Fossil Fuels.

It seems most likely that rising costs of liquid and gaseous fossil fuels will restrict their use, the degree of restriction depending on the extent to which such costs will relate to those of feasible alternative fuels. Restriction of use of fossil fuels will have the three major impacts of (1) reducing the rate at which they approach possible exhaustion at present recovery levels, (2) increasing the incentive to extend recovery technology to lower recovery levels, and (3) hastening the time at which alternative materials become competitive. Deregulation of oil and gas prices in the United States will tend to accelerate these indicated movements. Other efforts to meet the stated national goal of reducing dependence on oil imports will also encourage development and feasible substitution of alternative fuels,

It seems likely that coal resources will be developed and substituted first for liquid and gaseous fuels, before extensive development and substitution by renewable resources. However, development technology for renewable resources for alternative fuels should be encouraged and will be accelerated by rising prices of currently-used liquid and gaseous fuels. In this connection, it will be important to conduct periodic economic analyses of the relative feasibility of fuel supplies from coal and from renewable resource materials.

Since we are dealing here with a shifting economic base, it seems unwise to attempt to focus on one option for alternative fuel supplies. Rather, multiple R&D approaches are needed. These would include, but not be limited to, research and development aimed at improving the substitutability of renewable natural resource materials. Particular attention should be given to exploring the feasibility of alternative fuel use of forest and agricultural residues that do not now enter the production stream.

We see opportunities for substantial substitution in some areas. Examples are the substitution of Iignin and starch derivatives for carbon black, and the adhesives derived from wood processing for phenolics derived from petrochemicals. For fuels substitutions we would see these first occurring on farm, and near locations where they are generated. Rural residential heating, drying of crops, and processing of wood products are applications which come to mind,

2. Relationship between the soJid fossil fuels and the renewable organics and opportunities for a symbiotic relationship between the renewable organics and exhaustible minerals to maximize utility.

Prior to development of low cost, petrochemical building blocks, wood and grain by-products were major sources of organic chemical intermediates such as acetone, methanol, dienes, and ethanol, With the expansion of the petrochemical industry after World War II, basic petrochemical building blocks were produced economically on a very large scale, and biomass sources became generally uneconomic except for special uses (e.g., potable grain alcohol). During this period aromatics (benzene, toluene, and xylene) were extracted from refined gasoline components, and olefins were produced by cracking natural gas liquids (ethane, propane and butane). Rapid growth in the 1960's (12 percent/yr) of building block production continued into the early 1970's and by 1973 consumed about 7 percent of petroleum supplies as fuel and feedstocks. Natural gas was the principal source of fertilizer (NH3) and methanol. Over 75 percent of olefins and aromatics are used to manufacture materials (plastics, fibers, and synthetic rubber).

Liquid petroleum fractions will be the principal source of basic building blocks through 1985 or 1990, after which coal-source chemicals and OPEC imports will extend domestically manufactured petroleum source material, It does not appear likely that renewable sources can develop new product technologies for substitution by 1995. It is possible that in the 1995 timeframe, technology could be developed to produce olefins and carbon black substitutes. The key idea is that utilization of renewable resources in selective situations over the timespan considered will be possible, Coal liquefaction should become a massive source of competitively economic aromatics, and coal gasification should become an economic source of synthetic gas for ammonia and methanol. Olefins and carbon black substitutes appear to be the most fertile area for post 1995 development to extend plastic, fiber, and rubber supplies from renewable resources without development of complex downstream technologies.

3. Significance of quantities of renewable organics and amenability of production to technological measures to increase abundance.

Potential increase in yield of products from commercial forest lands is estimated as two to three times current levels and can be attained through improved management practices, on forest holdings in all ownership classes, and enhanced utilization based on broad application of the best techniques, A continuation and strengthening of current incentives to encourage better management should receive continued attention as a necessary element in attaining these increases.

These increases are. sufficient to meet increasing demand in traditional uses without the necessity of increased imports, The extent to which wood is available for substitution of petroleum-based, energy-intensive, or resource-limited materials is not known, but is not considered extensive without significant technological improvement in all phases of production,

A significant and abundant source of underutilized biomass is that of agricultural residues. Agricultural residues left in the field annually amount to almost one-half the heating value of coal produced annually. Two-thirds of these residues can probably be safely removed from the soil and used for energy or materials purposes. The use of agricultural residues is environmentally favorable, would encourage the production of more food, and can begin within a crop year.

The energy farm concept, in which plants selected for rapid and efficient capture and storage of solar energy are grown and harvested to be substituted for fossil fuels, may also have potential for materials applications.

Abundance ,of agricultural products from cereal grains, oil seeds, animal fats and hides suitable for use as engineering and other materials is such that some replacement of other materials is possible.

4. Policy principles governing the utilization of renewable organics.

It seems likely that economic value will provide the principal driving force for utilization of renewable organics. Periodic economic evaluation of the potential for such utilization will be needed to capture economic benefits that may arise.

However, such economic utilization will be dependent on establishing a strong base of science and technology, as is treated under items 5 and 6 of this task. A general principle for such technological development should be that of retaining the highest possible energy levels of organic molecules. This governing principle will both guide the technology along lines that are likely to be most productive of practical utilization options and enhance economic feasibility.

There may be merit to considering resource values in terms of highest, long range public benefit, rather than leaving development and use of increasingly scarce materials entirely to the influence of the market. Development of materials policy regarding alternative use of renewable organics should include consideration of the degree to which such a principle could be applied to that case and of mechanics for its implementation.

5/6. Research and development needs and directions.

As a matter of science and technology policy, the materials foundation of science of renewable resources should be strengthened and extended. The structure/property /performance/requirement relationships for renewable resources alone and as composites should be the subject of an extensive basic research program. For this "research the methods of material science and materials engineering should be applied to wood and its components and materials of agricultural origin. Wood and plant components should be viewed as members of the family of materials. Wood science groups should be brought into centers of material science and engineering. This approach should also be extended to education.

The incorporation of wood and wood-related materials (materials derived from the biomass) in the domain of materials science and engineering (MSE) would hold substantial potential benefits for wood science. At the same time, for MSE it would represent the addition of a major new component with a consequent strengthening of this still-developing, multidisciplinary field.

Materials research laboratories, polymer and material science departments of universities, and existing concerned Government laboratories should be given incentives for the development of strong and imaginative programs on the material science and engineering of renewable materials. The roles of various Federal agencies in relation to the materials science and engineering research effort should be defined. There are some immediately applicable research areas such as ligin and starch substituting for carbon black in rubber reinforcement or as an adhesive in reconstituted wood products. There should be new emphasis on long-range research leading to substitution of natural macromolecules and structures for petrochemically -derived materials and the development of new synergistic combinations of natural and synthetic materials.

Multidisciplinary studies and joint programs between forestry- and agriculture-related research groups should also be encouraged, A quantitative and qualitative survey of all types of potentially available biomass is essential to selective development of applications. The potential for major improvement of bioproductivity, the extended use of biological nitrogen fixation, and the selective production of high value chemicals from plants and other photosynthesizing systems should be the subject of major cooperative basic and applied research programs.

An assessment should be made of the technical and economic feasibility of the feedstock approach of producing chemicals for polymers from renewable resources, Specifically, a demonstration program on an integrated ethanol —furfural —phenol production from hardwoods should be evaluated. These applied efforts should be backed up by research on the improvement of processes of enzymatic hydrolysis of various IignicelIulosic and carbohydrate materials. Basic research on a "biological feedstock" approach for production of small molecules by organisms of microbes should be encouraged as well as work on photolysis for hydrogen production.

7. Competition for land resources

Complex interactions are involved in the use of land for production of renewable resources, production of food, production of energy, and for social uses. In some cases, increased emphasis on one may increase the production of another, while in other cases direct competition will occur as pressures on these resources are intensified.

Land policy at Federal, State, and local levels needs to be examined and tailored to national resource development in satisfying needs for energy, materials, food and social purposes. In particular, this policy is important in resolving conflicting priorities among critical and sensitive needs.

Question 8 was considered to address a technical matter beyond the expertise and resources of the task force.

The Task Force considered it very important that both the public and the scientific and engineering communities be aware of the factors limiting the use of renewable resources. In particular, the term "renewable resources" should not become equated with unlimited resources, Renewable resources are dependent on land, plant nutrient availability, and ultimately on genetic limitations and the photosynthetic process.

Other limitations arise through the vulnerability of plant materials to fire, vagaries of weather and climate, disease and pests, all of which create an element of unpredictability in yields. This is not to suggest a pessimistic view of the utility of renewable resources, but rather to avoid creating an oversimplified and unbridled enthusiasm for renewable resources as a major and an immediately available solution to all materials needs which might divert attention from other alternatives.

TASK No. 1: Materials Assessments for Congress: Stresses on the Total Materials Cycle

Discussion on the two Task Force reports revolved around five of the major issues raised in the reports: the implications of technology transfer for the U.S. competitive position; the suggestion in the reports that more governmental actions could be utilized as responses to stresses; the role of education in relieving stresses; the importance of recycling as a means to respond to stresses; and an apparent shift in conferees attitudes toward the needs of industry.

Some attendees were concerned that the suggestion to aid developing countries in their mineral exploration and extraction technologies might eventually place these “new” suppliers in competition with the United States in world markets. Although others agreed that such actions did pose such a risk, they felt that trade-offs might be necessary in order to develop adequate world supplies. It was agreed that OTA should undertake an examination of all these alternatives and should attempt to determine the impacts,

It was noted that one of the stresses mentioned had been a proliferation of uncoordinated (and sometimes conflicting) Government actions, such as environmental, health, and safety regulations, It seemed to some conferees that the suggestion of further Government actions in so many of the responses was in conflict; however, the OTA representatives did state that they considered no Government action as an acceptable alternative to be examined. Others in the audience suggested that some actions would be useful such as: Government support of information systems; performance of R&D; or, absorption of the nontechnical risks in international development,

In briefer comments, various attendees noted that recycling should have been given greater attention as a means to relieve stresses on the materials cycle. It was felt that technology was in hand to retrieve usable materials from municipal wastes, but that the more obsolete sources of secondary materials needed examination. There was some disagreement on this issue, since one attendee said that industrial materials users are aware of the value of their materials waste and attempt to recycle such,

The role of the FMS in public education of materials cycle stresses was brought up, This group has a new program for this and desire to have short “papers” in lay language which can be used for talks to public groups.

It was observed that the responses in both reports seemed to indicate a shift in the attitudes of the attendees toward more understanding of the needs and problems of private industry and market forces,

TASK No. 2: Government, Supplies and Shortages

Only two issues were raised in the discussion period in response to the two reports: various points about a materials information system; and the question of economic stockpiling,

Attendees discussed the fact that one report suggested that a materials information system need not be sensitive to political considerations. It was agreed that data should always be unbiased, but that attention to policy considerations could make such a system more able to respond effectively and quickly to immediate needs. It was suggested that data format in an information system could be varied according to the apparent decisions that might be called for in the near future. It was cautioned during the discussion that a top-down modification of existing materials information systems could have major perturbations on the accuracy and reliability of subsequent data for many years. OTA representatives pointed out that their report had recognized this possible effect,

It was pointed out that the two task forces had opposite views on the desirability of economic stockpiles. One viewed stockpiles as undesirable for normal conditions, while the other suggested that the strategic stockpiling concept could be extended to include this. Both groups accepted stockpiling of certain commodities in anticipation of abrupt supply disruptions as reasonable. Some attendees felt the task forces had not paid enough attention to this topic, especially in view of the fact that the country has already embarked partially on such a policy by passage of legislation to stockpile petroleum.

TASK No. 3: Conservation of Energy in Materials Processing

Most of the comments on these reports concerned the selection of certain policy tools to control the conservation of energy and materials, It was suggested that the task forces had been too narrow in their recommendations, since they had focused on tax credits alone. It was stated that such tax credits are generally considered to be ineffective and inefficient for accomplishing a chosen goal. Other policy tools suggested were: taxation of inefficient energy users; direct subsidies; guaranteed loans for equipment modifications; and others. Although one task force said they had discussed punitive measures, they had rejected them since such measures often resulted in extremely negative economic impacts on certain industries. An industry representative expressed the opinion that certain of the suggested alternatives would result in Government control, an option the industry would not generally be willing to accept. It was also noted that it should not be assumed that industry was not currently attempting to conserve energy on its own, as a response to rising costs and potential scarcities. The problem was that major processing modification took a number of years to gain full utilization.

Other comments from the audience included the notion that perhaps conservation should not even be pursued as a policy. This conferee suggested that energy needs could be met now by conversion of all stationary facilities (coal consumption). New technology could then be relied upon to provide energy solutions for the long term.

Another conferee commended both task forces for making valuable contributions to the reduction of short term energy use but wondered why they hadn't condemned some of the suggestions that are often made about the possibilities for certain long term percentage reductions in energy use by the adoption of certain conservation policies now.

In the final comment, an attendee wondered whether a group such as this could help industry plan for changes in energy costs due to rising prices and conservation measures. He explained that industry must plan years in advance for costing purposes and that the fluid situation in energy costs and payoff from conservation measures made such planning difficult. He felt that a "cross-over" point could be desired in these costs which would be helpful to industry.

TASK No. 4: The **Role of Materials in Defense**

Much of the discussion of these reports centered on the "centers of excellence" concept or on the suggested allocating of a set percentage of foreign military sales as R&D costs to be diverted back into fundamental R&D.

The conferees differed on these concepts, although support for and disagreement with each idea could be heard. One of the task forces had supported the idea of creating "centers of excellence" if existing facilities could not be identified, One conferee said such centers never do turn out to be "excellent" and suggested instead that short-lived, interdisciplinary task forces could be formed to solving processing problems, The other task force clarified that they had taken a cautious approach to the idea of these centers and had not suggested creation of permanent centers by the Government, There was concern among some of the attendees about the suggestion for earmarking of part of the RDT&E costs in foreign military sales for a revolving fund for fundamental/basic research. It was clarified by the task force members that such funds would not be tied to any particular budget but should relate to the basic research needs for meeting broad DOD objectives. One industry participant felt that such a clause would only increase the price of the equipment, and decrease the competitive edge of the United States, or would be taken out of the profit portion of the supplier. He thought that a better method for increasing fundamental R&D efforts for DOD needs would be to change the effects of the Mansfield amendment.

A university participant felt that all the talk of "more fundamental R&D" was rather useless. He suggested that basic research has nothing to do with the real needs of DOD, or any other mission-oriented agency. In further remarks, he stated that the Federal agencies/institutions were "psychologically incapable" of performing basic research in any case.

TASK No. 5: Utility of Organic Renewable Resources

Most of the discussion on these reports centered on the definition of "resource" in this context, and on two issues not considered by task forces in their reports.

One attendee pointed out that the real resource, in his opinion, had not been clearly defined by these two reports. He felt that it was important when talking of "renewable resources" to consider topics such as genetic stock, nutrients in the soil, and sunlight. Too much emphasis had been placed on biomass, which is really the product of the renewable resources. He suggested that a change in point of view would have led to discussion in the reports of such topics as soil conservation and preservation. The task force chairmen agreed that these topics were important and that they would have included such discussions in any comprehensive report on this subject. They clarified that it was important to distinguish the definition of "resource" as used in this discussion, and that used by the US. Bureau of Mines, or the Department of Interior, in their work. It was noted that the CORRIM report did try to define the term "renewable resources" and could be consulted when in doubt.

One attendee suggested that it would have been interesting to consider whether materials science programs in universities should include wood-derived materials. He said that there was still some lack of acceptance of these materials in design and engineering which could be overcome partially by university curriculum improvements.

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Another conferee wondered whether the task forces had considered the extent to which this sort of technology could be used to help underdeveloped countries, rather than concentrating so much effort on trying to substitute such materials for established uses in developed countries. Although the reports did not address this issue, the task force members agreed that the issue warranted examination. The opinion was voiced that wood was already used to a great extent by such countries. It was pointed out, however, that poor management practices in such countries had destroyed major areas of the world for renewable resource production. Therefore, it would be useful to examine the possible uses of technology to revitalize these areas,

V. Friday Morning Papers

SUBSTITUTION –SOME PRACTICAL CONSIDERATIONS

by H, Dana Moran
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"Substitution" is a term and a concept which has been much overworked in recent years. It has been, directly or subliminally, the subject of many papers, of conferences, and of studies by both Government and industry. It has been blessed by Congress, encouraged by the Administration, and will be thoroughly assessed by OTA in coming months. But in the context of future constraints on the supplies of materials, substitution is not a unique solution; it is only part of a larger response. Typically, the replies to threats of shortages are "conservation" and "substitution." Both of these require substantial changes in social attitudes and in technology. If our experience with the energy "crisis" is a precedent, the latter will be more easily achieved than the former, And yet real growth in technology also requires modification of the prevalent community attitudes on science and technology, so one might argue that the initial burden is on the social scientist rather than the technologist.

Further, I'm not comfortable with the popular implications of the terms; "conservation" seems to infer sacrifice and deprivation, and "substitution" suggests to many the use of less satisfactory or ersatz materials. The objective, in my view, is the "Intelligent Use of Material Resources," the equitable sharing of a finite (although theoreticall y inexhaustible[1]) body of resources among a steadily growing quantity and variety of demands. Goeller and Weinberg[2] foresee an "Age of Substitutability," an era in which we have solved all the necessary technical problems to permit essentially infinite interchangeability of materials. I am persuaded by their arguments, but underline their observation

1 Although I subscribe to the Frascheian view that total exhaustion of any mineral resource will never occur (see D. F. Frasche. NAS-NRC Publication 1OOO-C, p. 18 (1963),) at any given time, the availability of a resource is 1 imited by the current technology; hence. at any given time the usable resource is finite.

2 H. E. Goeller and Alvin M. Weinberg, The Age of Substitutability, Science, Volume 191. No. 4228, pp 683-689, February 20, 1976.

that achievement of that ideal circumstance and accessibility of the essentially inexhaustible natural resources of our planet depend on timely development of the necessary technologies. The ultimate burden is, indeed, on the technologist.

James Boyd, Materials Policy-Maker Emeritus, prefers to use the term "interchangeability of materials." But this expression, too, has implications of the ideal world, of technological Nirvana. In the Goeller-Weinbergian Stage 3, interchangeability will be the order of the day; but in our age the process is impeded by the realities of a pragmatic society.

Lacking semantic innovation, I am thus resigned to accept for the moment the term "substitution" to describe one of the basic processes in the Intelligent Use of Materials Resources. The fundamental philosophy of substitution has been well reasoned. In their excellent appendix to the COMRATE Report, Chynoweth, Huddle, and Speer[3] examined the concept of substitution and provide, in my judgment, the definitive statement of the subject. Their study addresses the practical considerations in response to shortages by replacement of critical materials. They provide a very realistic introduction to the substitution issue.

Rather than attempt to construct heady forecasts or Newtonian hypotheses, I'd like to expand a bit on the CHS (Chynoweth/Huddle/Speer) concept of substitution. The following discussion is based primarily on a recent Battelle report to the Office of Technology Assessment as part of the Assessment on Materials Information Systems.[4] Battelle's study examines the information systems implications of substitution analyses. I'll not go into the information requirements in detail, but address the motivations for and nature of substitution analyses.

Defining Terms

Let's begin at the beginning—with a definition of "materials." As you will already have recognized, there is some debate about the limits of the term. For the purpose of this review, we're defining "materials" very broadly—to include all substances used by mankind, except food and drugs, It is useful to classify materials,

[3] A. G. Chynoweth, F. P. Huddle, and F. Speer, Materials Conservation Through Substitutes and Product Design. Appendix to Section 1, Report of Panel on Materials Conservation Through Technology, Mineral Resources and the Environment (COMRATE Report), NAS, PB 239580, February. 1975.

[4] J. L. McCall, H. D. Moran, and W. L. Swager, Materials Substitutability and Information Systems Implications, Volume IV, Assessment of Materials Information Systems, Office of Technology Assessment, U.S. Congress, February, 1976.

however, both in accordance with their intended use and relative to their state of manufacture, as done in table 1.

TABLE I.—Definition of Materials

By Use Category	By State of Manufacture
Physical/Structural	Raw, Semifinished and Finished
Reagents and Intermediates	Components/Applications
Energy/Fuels	Systems

The terms used in table 1 may be further defined as follows:

- Physical/Structural materials include all substances in raw, semifinished, and finished form used in the manufacture of goods, which remain in identifiable form during a period of use, They include metallic minerals, metais, construction minerals, wood, paper, cotton, wool, plastics, and ceramics.
- Reagents and Intermediates include all substances which are used in the manufacture of a finished product but do not remain as part of it. Such substances generally include chemicals, fertilizers, abrasives, solvents, and industrial gases.
- Energy/Fuels materials include the various mineral fuels and products refined from them. They include petroleum coal, natural gas, natural gasoline and liquified petroleum gases.
- Raw, Semifinished, and Finished materials include ores, concentrates, and basic metals and alloys. Also included are agricultural and wood products.
- Components/Applications include all parts of consumer and industrial durables. Also included are pesticides, pharmaceuticals and household cleaners, as well as finished grades of petroleum products.
- Systems include all finished household and industrial durables. The term "systems," as applied to energy/fuels and reagents and intermediates, usually refers to the method by which these classes of materials are used.

The reasons for this little classification system are made clearer by the examples in table 2. Using both classifications, we can begin to categorize substitution in order to separate the concept into manageable elements. The nature of substitution analyses vary according to classifications of this sort.

But then we also need to agree on a definition of "substitution," It is obvious, and CHS have told us, that the concept of substitution cannot be limited to the simple replacement of one material with another, It also involves the replacement of one process with another or changing the functional characteristics of a material or part, Further, these three classes of substitution—material, process, and function—can occur at any of the steps in the resource, processing, and manufacturing cycle, from raw materials through primary products, parts manufacture and components, to final system desigfi and assembly. Table 3 offers some illustrative examples of these classes:

In proposing these three classes of substitution, we've departed slightly from Chynoweth, Huddle, and Speer in that we've separated process from material-for-material replacement, Since the objective—presumably — is conservation of essential materials, processes which offer reduced wastage (and/or reduced energy consumption) may achieve the same purposes more efficiently than introduction of an alternative material. And CHS included the additional category of "System Substitution," wherein an entire system may be replaced, with concomitant changes in materials utilization. Examples would be mass transit to replace personal automobiles, optical communications replacing electronics, or solar power alternatives to fossil fueled systems. I would contend, however, that such overwhelming developments are not in themselves initiated for the purposes of conservation of engineering materials and, hence, are beyond the context of this discussion, They may alter or eliminate the demand for essential materials, but as an effect rather than a cause.

A glance at table 3 reveals the obvious: that the distinctions between these classifications are tenuous, They overlap in many instances; for example, replacement of a basic material will, in perhaps a majority of instances, require process changes; process changes may affect the design; design changes almost inevitably mean new material requirements. Nonetheless, each analysis begins with an initial objective falling into one of these classifications,

Those of our colleagues who are diligently pursuing the difficult goal of metrication refer to the process of conversion as "hard" or "soft"–development of completely new metric standards versus conversion of English units to metric in existing

TABLE 2.—Examples of Substitution Involving Various Classes of Materials

Category of Material, by State of Manufacture	CLASS OF MATERIAL—BY USE		
	Physical/Structural	Reagents and Intermediates	Energy/Fuels
Raw, Semifinished, and Finished Materials	Alunite for bauxite	Recovered sulfur for Frasch sulfur	Western coal for Eastern coal
	Raw polyester for raw cotton	Natural brines for rock salt	Gasified coal for natural gas
	Alcoa's chlorlde alumlnum reduction process for the Hall process	Mining of natural soda ash for Solvay process soda ash	Fuel 011 for natural gas
	Basic oxygen furnaces for open hearth steel-making	Phosphoric acid from furnace phosphorus for wet process acid	Formed coke for metallurgical coke
Components/Applications	New copper alloy for present alloy in auto radiator	Hydrochloric acid pickllng for sulfurlc acid pickling	Lead-free gasollne for regular
	Aluminum alloy for copper alloy In auto radiator	Direct application to soil of anhydrous ammonia for liquld application of ammonim salts	Propane for fuel 011
Systems	Air-cooled auto engine for water-cooled engine	Not applicable	Geothermal for coal-fired steam boiler
	Mass Transit for automobiles		Solar heating system for natural gas system
	Video phone communications for business transportation		

TABLE 3.—Examples of Three Broad Classes of Substitution

One Material for Another

- Aluminum for Copper in a Bus Bar
- No. 2 Yellow Pine for No. 1 in Woodwork for Home
- Mica-Based for Asbestos-Based Insulation
- Polyester Fabric for Cotton
- Painted Plain Carbon Steel for Stainless Steel
- Aluminum Building Wall Studs for Wooden
- Graphite Golf Club Shafts for Steel/Hickory
- Copper Laminate Coin for Silver

One Process for Another

- Friction Welding of Metal Parts for Butt Welding
- Rolled Threads on Screws for Cut Ones
- Castings for Forgings
- Float Glass for Ground Plate Glass
- Continuous Melt Extraction of Wire for Drawing
- 'Net Shape' Processes

One Function or Level of Functlon for Another

- Bulk Distribution of Oil Products in Place of Unit Containers
- Elimination of Chrome on Automobiles
- Air-Cooled Engine as a Substitute for Radiators in Water-Cooled Engines

standards. Similarly, a substitution action may be "soft" or "hard." Although perhaps trite, the distinction is one of economic significance, as illustrated in table 4. And this comparison reminds us of what might_be termed the Law of the Obvious: The Simpler the Application, the Easier the Substitution.

Decisions and Decision Makers

With something of a framework for categorizing substitution decisions, let's consider who is concerned with such decisions, and why. Although in some manner literally every one of us makes materials substitution choices (viz., the housewife who must choose between plastic wrap and aluminum foil), those whose actions will have a significant effect on the utilization of essential materials fall into two general categories: the Materials User and the National Policy maker (table 5).

TABLE 4.—'Hard' Versus 'Soft' Substitution

Soft Substitution:
Introduction of a replacement material without significant changes in tooling, processes, or design.

Example: Steel number plates for aluminum; minimal impact on costs

Hard Substitution:
Introduction of replacement material requiring changes in design and processes

Example: Aluminum baseball bats for hickory; substantial changes in tooling, processing, and labor costs

Table S.—The Decision Makers

Materials Users	National Policy-Makers
R&D Personnel	Government Administrators
Designers/Engineers	Congress/Executive Branch
Management/Entrepreneurs	Public Interest Groups
	Labor

The Materials User category includes literally anyone in the entire cycle, from raw material producer to scrap processor. Even producers of raw materials are users of materials in a less refined state, e.g., the alumina producer is a user of bauxite. Policy-makers are a more austere classification, including only those who define, implement, or influence public policy.

But why consider substitution in the first place? Four primary reasons, from the viewpoint of the National Policy maker, were spelled out in the COMRATE Report:

- Environmental and safety controls, which have introduced a whole new set of social specifications, creating a need to deal with shortages resulting from prohibited facilities, materials and processes

- Government intervention in the industrial system to overcome large dislocations such as the combined shortage of electric power and petroleum fuels
- Future prospects of dislocations in the flow of materials from sources in developing countries and unstable sources
- The need to reduce reliance on materials of rising cost from foreign sources to balance U.S. payments abroad and control inflation at home

Motivations for Substitution

On the other hand, the Materials User is motivated to consider substitution for one (or more) of three fundamental reasons: to reduce costs, to improve performance, or to replace a scarce material or component. His motivations are less ethereal, more pragmatic, and every bit as important to the maintenance of the free enterprise system. A variety of more subtle incentives derive from those basic motivations. Some examples are given in table 6:

Although our Materials User is an honest, dues-paying patriotic American citizen, we must recognize that there may exist, from time to time, a dichotomy between his pragmatic, profit-oriented purposes and those objectives deemed by the Policy maker to be in the National interest. It may be incumbent upon the Policy maker, then, to offer some incentives for substitution, when that action is necessitated by gross societal or political pressures, This is an aspect of the substitution issue which has received insufficient attention to date and which demands early consideration. Substitution, by the Materials User, may be voluntary — in response to motivations such as cited in table 6; or it may be enforced –by price controls, rationing, regulation, or decree, Surely all of us who are reasonable Policy makers eschew arbitrary enforcement. We must offer, then, suitable acceptable incentives to the Materials User, such as those listed below:

- Capital Investment Credits,
- Simplified and/or Relaxed Government Specifications and Standards,
- Subsidies,
- Tax Incentives,
- Low-Interest Loans,

TABLE 6.—Examples of Materials User Motivations for Substitution

Material Shortage/Potential Shortage
Price/Cost Advantage-Uncertain Future Cost
Higher/Better Performance
Increased Reliability/Decreased Maintenance/Increased Life
Increased Marketability
Skilled Labor Shortages
Fabrication/Production Facility Shortages
Poor Performance of Present Materials
Regulatory Actions
Development of Self-Sufficiency
Elimination of Single Source Dependency
Use of Internal Materials
Risk Minimization
Political Advantages
of Domestic Industries
Follow Competition

- Protective Tariffs,
- Preferential Shipping Rates,
- Relaxed Regulations, and
- Appreciation

Other examples might include:

- Relaxed anti-trust regulations to encourage cooperative research and development,
- Modification of Patent Law to provide protection with earlier disclosure and protection beyond the development period–which often may exceed 17 years, and
- Some form of liability deferment in instances where the consumer should share the risks as well as the benefits.

The last suggestion is not entirely facetious. Hundreds of corporations and labor groups have been proud to fly the “E” for Effort/Efficiency/Energy banner originated in World War II. A letter of thanks from the White House might not do much for the Finance Committee, but it can do wonders in explaining a two point drop in dividends to the stockholders.

If we are serious about planning for future constraints on essential materials—and I hope we are—policy development must include consideration of practical and positive incentives to industry for the implementation of conservation measures.

The Process of Substitution Analysis

Our two classes of substitution decision makers differ not only in their motivation but also in their approach to the analysis of alternatives. The Policy maker enjoys broader horizons and more flexible prerogatives, but because the impact of his actions may affect the entire society, his justifications must be significantly more persuasive, The Materials-User, on the other hand, must balance technical and fiscal considerations in assuring that revised designs will not compromise the profitability of his organization.

The Battelle study develops DELTA charts–logical networks of Decisions, Events, Logic, Time sequence, and Activity—for the two categories of substitution analysis. We include those charts here without detailed explanation,' merely to illustrate the differing nature of the decision processes and yet the relative complexity of any substitution analysis. We also wish to introduce a consideration on which we'll elaborate below—the requirement for an extensive variety of reliable information and data, much of which are not adequately available, especially to the Policymaker.

In both instances, the trigger is recognition that prevailing or prospective conditions are such that a substitution must be considered, The Policy maker must examine all present use patterns of the original material. He must consider the direct effects —economic, performance, and social —of the introduction of alternatives. And he must determine whether substitution of Material B for Material A will generate shortages of Material B, then necessitating the substitution of C for B—and so on—the so-called "ripple effect." The Policy maker must have sufficient knowledge (and understanding) of the state-of-the-art to deter-

[5] For detailed discussion see: J. L. McCal 1, H. D. Moran, and W. L. Swager, Materials Substitutability and Information Systems Implications. Volume IV, Assessment of Materials Information Systems, Office of Technology Assessment. U.S. Congress. February 1976.

mine the facility with which a substitution can be introduced. He has to consider available capacities, capital resources, and raw material supplies. He must contemplate the possible requirements for R&D investment to develop the alternative applications, He must especially consider the international and social impacts of dramatic changes in consumption patterns. And then he must be clever enough to frame suitable legislation or other policy actions to encourage and implement the change. Each of these decisions is depicted in figure 1,

Many of the same considerations—perhaps on a less macroscopic level— must occur to the Materials User, However, his analysis examines the design aspects for given applications. He is concerned with performance, cost trade-offs, and assurance of supplies of needed materials or components. He must take into account his present facility commitments, labor resources, and time lost in the market place, He must look into the applicable environmental and safety regulations and assure avoidance of conflict. Proprietary aspects are important, New capital requirements must be examined, And will he expose his organization to new liabilities? Ultimately, the question is simply, are the incentives sufficient to justify the change? Figure 2 displays the logic pattern for a manufacturing industry; similar DELTA charts can be developed for other Materials Users, e.g., process industries,

A moment's reflection on this logic process of the Materials User reveals a significant conclusion: from the standpoint of the Materials User, substitution is nothing more than a special case of materials selection, one in which one given material must be omitted from the candidates for a particular application. The decision procedure otherwise is identical to that followed in the original selection of a material for that application. And the information and data requirements, therefore, are the same. Materials selection takes place with a particular set of criteria; when those criteria are revised, another selection takes place— this time called substitution.

Information Requirements for Substitution Analyses

The DELTA Chart is particularly helpful in defining the separate—and common—requirements of the Policy maker and the Materials User for information and data. Although the Policymaker may operate in a larger universe, enjoying a loftier and perhaps more detached viewpoint, he requires much of the same pragmatic background for his comparison of alternatives. And the Materials User, especially under today's social constraints, must consider his actions in the light of community impact. In

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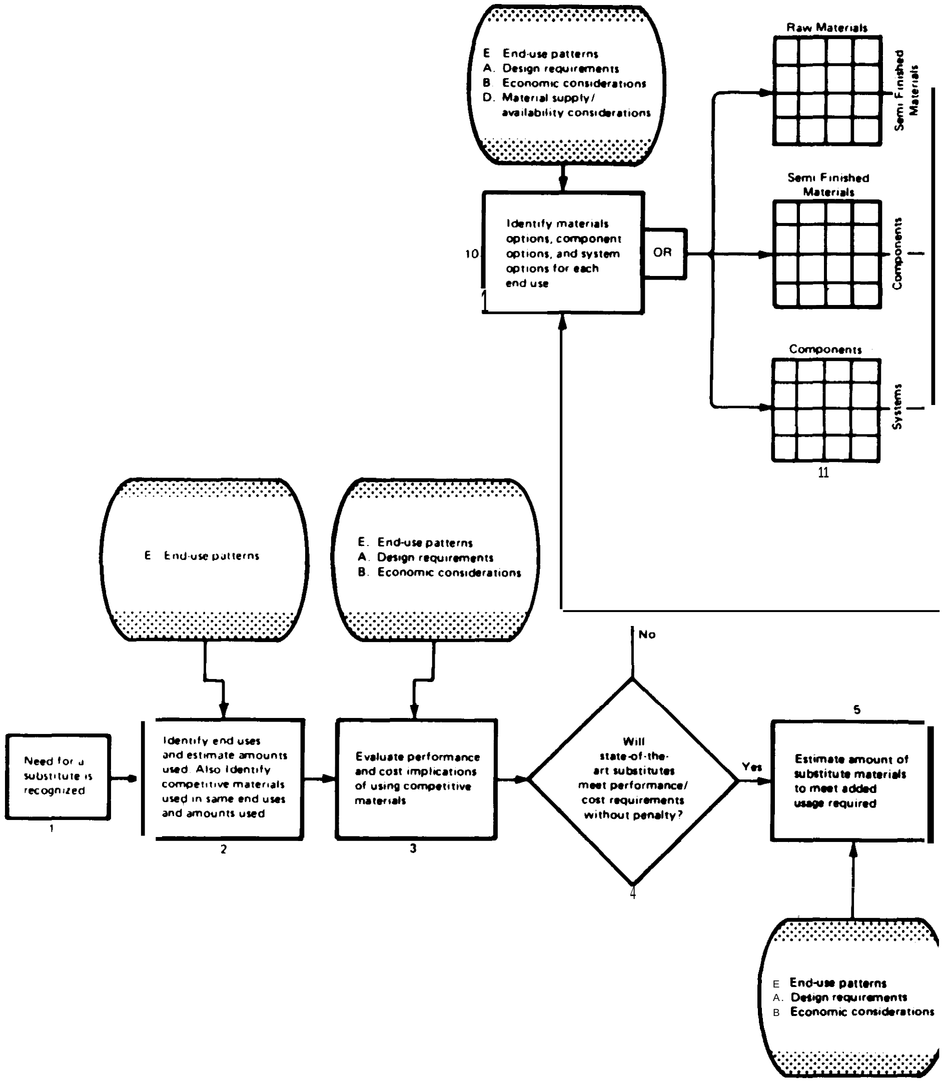
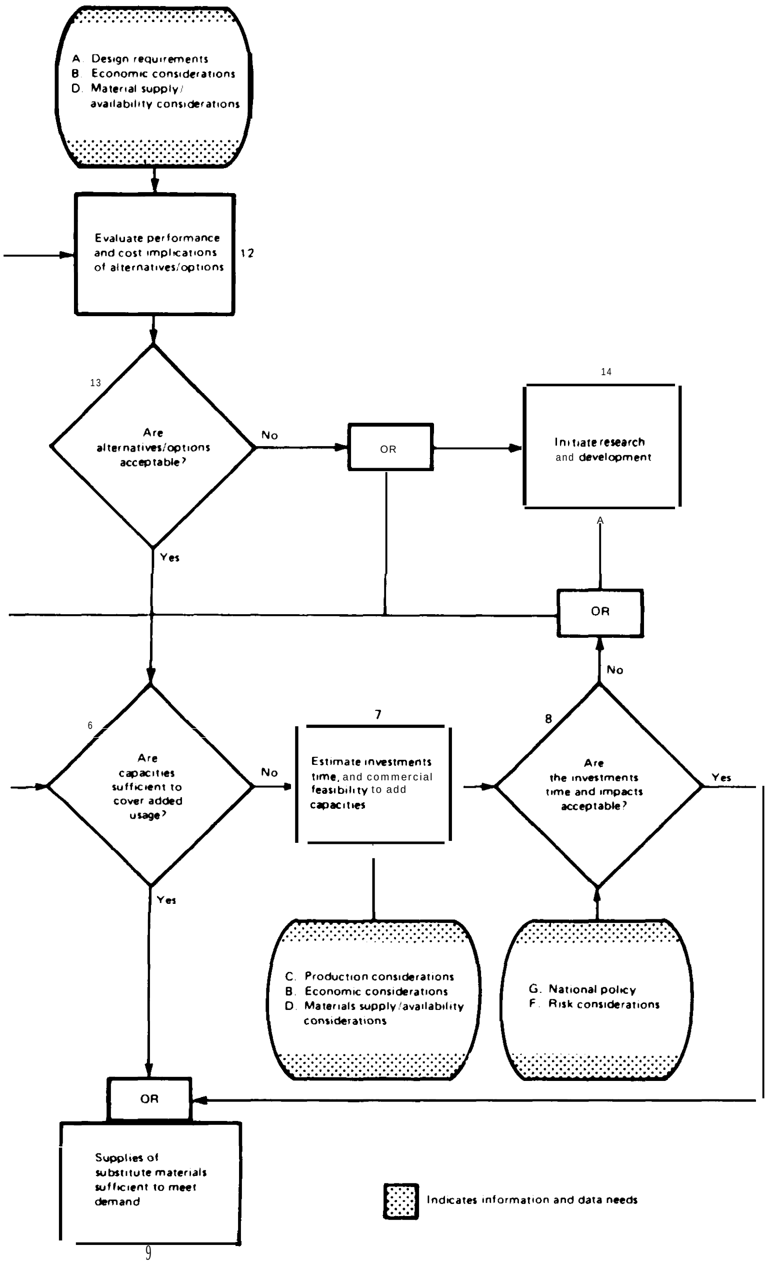
FIGURE 1—Substitution Analysis by National Policy Makers





A. Design requirements
B. Economic considerations
D. Material supply/availability considerations
Evaluate performance and cost implications of alternatives/options
12
13
Are alternatives/options acceptable?
No
OR
14
Initiate research and development
A
Yes
OR
No
6
Are capacities sufficient to cover added usage?
No
7
Estimate investments time, and commercial feasibility to add capacities
8
Are the investments time and impacts acceptable?
Yes
Yes
C. Production considerations
B. Economic considerations
D. Materials supply/availability considerations
G. National policy
F. Risk considerations
OR
Supplies of substitute materials sufficient to meet demand
9
Indicates information and data needs

FIGURE 2.—Substitution Analysis by Materials Users

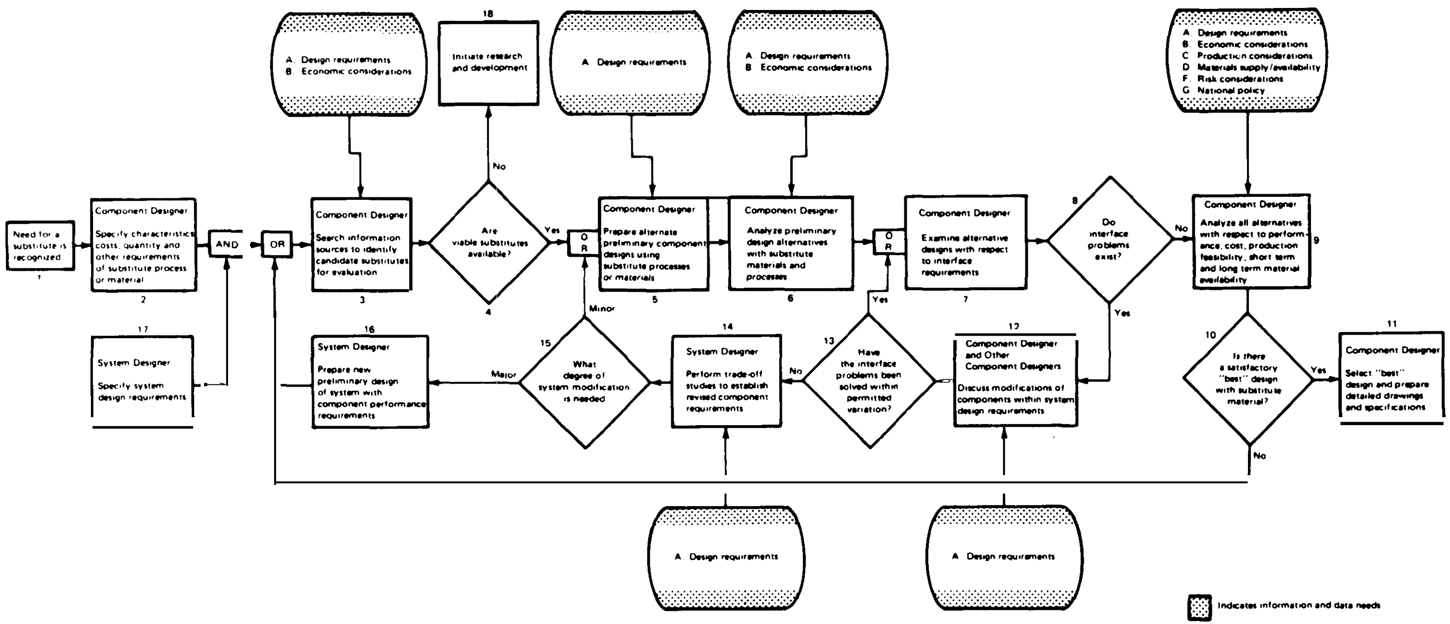


table 7, we endeavor to summarize those mutual requirements for information to support substitution analyses, in particular distinguishing between information required by one user group versus that required by the other, Since this table was extracted from the Battelle study, a word of explanation is necessary. Part of the objective was to define those quantitative data currently available, and those needed but not accessible to the particular user group, Further, the table indicates those types of subjective information needed in the decision processes, but not amenable to centralized collection and dissemination, i.e., those coded "O,"

These information requirements are restated in tables 8 and 9, identifying separately the needs of the two user groups, These tabulations certainly are not exhaustive, and many of the suggested items could be argued. However, the intent is to initiate the formulation of criteria for a National Materials Information System$_{\$}$

A morphology of the concept of Substitution is beginning to emerge, The important benefit is not in the academic exercise, but in the opportunity it provides for identification of those tools which are essential to the decision makers in Government and industry who are responsible for the intelligent use of our materials resources.

TABLE 7.—Information Requirements for Substitution Analysis

	Materials Users	National Policy-makers
A. DESIGN REQUIREMENTS		
Customer Acceptance		
Esthetics	0	N
Personal Bias	0	N
Market Acceptability	0	N
Performance Criteria	0	0
Materials Performance		
Mechanical Properties	1	N
Chemical Properties	1	N
Physical Properties	1	N
Fabricability	1	N
Machinability	1	N
Toxicity	1	N
Ease of Joining	1	N
Corrosion, Oxidation, and Fire Resistance	1	N
Compliance with Specifications and Codes	1	N
Protection Against Misuse	0	N
Vandalism Protection	0	N
Reuse/Recyclability/Disposal	1 0	1-0
Compliance with Specifications and Codes	1-0	10
Reliability and Maintainability	1 0	1-0
B. ECONOMIC CONSIDERATIONS		
Material Cost	1	1
Cost/Price Stability	1	1
Transportation Costs	10	10
Marketing Costs (to use substitute)	0	N
Production Costs	0	10
Investment Required to Incorporate	0	1 0
Life-Cycle Costs	0	0
Tariffs and Taxes	1-0	1
C. PRODUCTION CONSIDERATIONS		
Availability of Fabrication Facilities	10	1
Availability of Labor (specific skills)	10	1
Production Rates Achievable	0	1
Time Required to Incorporate Substitute	0	10
Use of Existing Facilities and Labor		1 0
Energy Requirements	1'0	1
Inspectability	0	N

	Materials Users	National Policy-makers
D. MATERIALS SUPPLY/AVAILABILITY CONSIDERATIONS		
Supply - Present and Future, Current and Potential		
Resources/Reserves	10	1
Stockpile Level	10	1
Imports/Exports	1 0	1
Defense Allocation	10	1
Inventories	10	1
Supply Assurance (including trade agreement)	0	10
Identity and Location of Supplies	1	1
Forms of Materials Available	1	1
Delivery Time (Lead Time)	1 -0	1
E. END-USE PATTERNS - Historical and Projected	1-0	1
F. RISK CONSIDERATIONS		
Legal Liability	0	N
Technical/Professional	0	N
Business	0	0
Political	0	0
G. NATIONAL POLICY CONSIDERATIONS		
Regulatory Agency Compliance (Federal, State, local)		
Environmental	1-0	1
Health/Safety	1-0	1
Energy	1-0	1
Economic Impacts of Using Substitutes	1 -0-N	1
Political Impacts of Using Substitutes	0 - N	0

1 = required and possible m system (hard data either technical or economic)

O = required but obtained outside system

N = generally not required by user group

TABLE 8.—Information Requirements for Substitution Analysis: Those Specifically Required by Materials Users are Underlined

A. DESIGN REQUIREMENTS	D. MATERIALS SUPPLY/AVAILABILITY CONSIDERATIONS
Customer Acceptance	Supply Present and Future, Current and Potential
Esthetics	Resources/Reserves
Personal Bias	Stockpile Level
Market Acceptability	Imports/Exports
Performance Criteria	Defense Allocations
Materials Performance	Inventories
Mechanical Properties	Supply Assurance (including trade agreements)
Chemical Propertles	Identify and Location of Supplies
Physical Properties	Forms of Materials Available
Fabricability	Delivery Time (Lead Time)
Machineabillty	E. END-USE PATTERNS & Historical and Projected
Toxicity	F. RISK CONSIDERATIONS
Ease of Joining	Legal Liability
Corrosion, Oxidation and Fire Resistance	Technical/Professional
Compliance with Specifications and Codes	Business
Protection Against Misuse	Political
Vandalism Protection	G. NATIONAL POLICY CONSIDERATIONS
Reuse/RecyclablIlty/DIsposal	Regulatory Agency Compliance (Federal, State, local)
Compliance with Specifications and Codes	Environmental
Reliance and Maintainability	Health/Safety
B. ECONOMIC CONSIDERATIONS	Energy
Material Cost	Economic Impacts of Using Substitutes
Cost/Price Stability	political Impact of Using Substitutes
Transportation Cost	
Marketing Costs (to use substitute)	
Production Costs'	
Investment Required to Incorporate	
Life-Cycle Costs	
Tariffs and Taxes	
C. Production CONSIDERATfONS	
Availability of Fabrication Facilities	
Availability of Labor (specific skillsj	
Production Rates Achievable	
Time Required to Incorporate Substitute	
Use of Existing Facilities and Labor	
Energ y Requirements	
Inspectability	

TABLE 9.—Information Requirements for Substitution Analysis: Those Specifically Required by Policy Makers are Underlined

A. DESIGN REOUIREMENTS

- Customer Acceptance
  - Esthetics
  - Personal Bias
  - Market Acceptability
- Performance Criteria
- Materials Performance
  - Mechanical Properties
  - Chemical Properties
  - Physical Properties
  - Fabricability
  - Machineabllity
  - Toxicity
  - Ease of Joining
  - Corrosion. Oxidation, and Fire Resistance
  - Compliance with Specifications and Code
- Protection Against Misuse
- Vandalism Protection
- Reuse/Recvclabilitv/Diaoosal
- Compliance with Soedifications and Codes
- Reliability and Maintainability

B. ECONOMIC CONSIDERATIONS

- Material Cost
- Cost/Price Stabllty
- Transportation Cost
- Marketing Costs (to use substitute)
- Productlon Cost>
- Investment Requlred to Incorporate
- Life-Cvcle Costs
- Tariffs and Taxes

C. PRODUCTION CONSIDERATIONS

- Avallabllity of Fabrlcation Facllltles
- Avallabllty of Labor (speclflc skills)
- Produ ctlon Rates Achievable
- Time Requlred to Incorporate Substitute
- Use of Exlsting Facllltles and Labor
- Energy Requirements

D. MATERiALS SUPPLY/AVALASILtTY CONSIDERATIONS

- Supply—Present and Future, Current and Potential
  - Resources/Reserves
  - Stockpile Level
  - Imports/Exports
  - Defense Allocation
  - Inventories
- Supply Assurance (Including Trade Agreement~
  - Identity and Location of Supplies
  - Forms of Materials Available
  - Delivery Time (Lead Time)

E. END-USE PATTERN--Historical and Projected

- Supply--Present and Future, Current and Potential
  - Resources/Reserves
  - Stockpile Level
  - Imports/Exports
  - Defense Allocation
  - Inventories
- Supply Assurance (Including Trade Agreement)
  - Identity and Location of Supplies
  - Forms of Materials Available
  - Delivery Time (Lead Time)

F. RISK CONSIDERATIONS

- Regulatory Agency Compliance (Federal, State, Local)
  - Environmental
  - Health/Safety
  - Energy
- Economic Impacts of Using Substitute

THE COMMISSION ON CRITICAL CHOICES FOR AMERICANS

by Michael J. Deutch, Consulting Engineer

The Commission on Critical Choices for Americans, a nationally representative, bipartisan group of 42 prominent Americans, was brought together at the end of 1973 by Nelson A, Rockefeller to develop information and insights which would bring about a better understanding of the problems confronting America in these troubled times, and attempt to identify the critical choices that must be made by our people.

In bringing the Commission on Critical Choices together, Mr. Rockefeller said:

> As we approach the 200th Anniversary of the founding of our Nation, it has become clear that institutions and values which have accounted for our astounding progress during the past two centuries are straining to cope with the massive problems of the current era, The increase in the tempo of change, and the vastness and complexity of the wholly new situations which are evolving with accelerated change, create a widespread sense that our political and social system has serious inadequacies.
>
> We can no longer continue to operate on the basis of reacting to crises, counting on crash programs and the expenditure of huge sums of money to solve our problems. We have got to understand and project present trends, to take command of the forces that are emerging, to extend our freedom and well-being as citizens and the future of other nations and peoples in the world.

Because of the complexity and interdependence of issues facing America ahd the world today, the Commission organized its work into six panels, which emphasize the interrelationships of critical choices rather than treating each one in isolation, Raw materials problems were considered by Panel III, together with industrial development, capital formation, employment, and world trade. 1 want to stress that the areas subject to the Commission's inquiry were quite extensive, and since the Commission on Critical Choices for Americans did not do research or make recommendations—but only placed before the public the choices–you cannot look to the Commission for any detailed study or conclusions on our materials problems.

Materials Supply and the Less-Developed Countries

My own view today on our problems with the supply of critical materials and the less-developed countries may be summarized as follows:

The United States, and most consuming nations, are overwhelmingly dependent on imports for only a few raw materials, and for some of these we have already "lived in coexistence" with cartels, The apprehension that other less-developed countries might emulate OPEC and deny us the supply of essential raw materials is less than for energy.

Materials prices are another matter: as compared with prices for petroleum, they are highly cyclical, The LDC'S prosper only when prices of their exports of materials are high, but when they rose sharply in 1973/74 in sympathy with OPEC, the LDCS could not compensate for the increases, Then materials went down from their peak throughout 1975 as a result of the protracted recession in most industrial economies, and began rising as the economic recovery set in. UNCTAD now feels that the richer countries of the world should provide for price escalation with the cost of essential imports to the LDCS.

The more relaxed view of the ability of the less-developed producers to emulate OPEC considers that there are few groupings of producing countries that could control over 50 percent of world demand in specific materials. Only in the case of bauxite has a cartel grouping been able to increase sharply the taxes and royalties paid by Western companies that own ore deposits in these countries, and the aluminum market was well able to absorb these higher ore costs.

Trouble could arise in three or four other minerals. However, embargos or severe shortages are not likely to occur, particularly if our mining trade is alert, our stockpiling is realistic, and the international environment does not deteriorate further,

This optimistic scenario is not that persuasive. While a detrimental cartel pricing or embargo that could endanger our materials system does not seem impending, it remains a potential threat that public officials will have to take into account in the formulation of our long term economic policy:

- The poorer nations of the world, where vast untapped resources of raw materials have been discovered (often by mining interests from the industrialized countries), have been hit mercilessly by OPEC, inflation, and by the recession in world trade. Their despair has already brought about in UNCTAD a clamor for a moratorium on LDC debts (some $142 billion) and further price increases (or price stabilization) of their crops. It could, in a bad international environment, bring about an unreasonable urge to emulate OPEC, or to expropriate natural resources owned by foreign interests.

- Paradoxically, this threat to the proved discovery, development, and marketing of much needed additional reserves of raw materials is pressing even in those less-developed countries that suffer most from unemployment and could not by themselves finance new production or gain access to the world markets. As long as this uncertainty persists, the world materials system will remain unstable.
- Much can be done to protect ourselves. A conservation ethic, eradication and recycling of waste, substitution of scarce materials by others that are more available, and by new materials, specially conceived for our future needs, etc. But all this will require much developmental talent, institutional change—and money.

There are two new international trends to which we will have to adjust. The first is the quest of the LDCS for more political independence and more economic growth, which leaves the industrialized nations in a more vulnerable position. The second is the realization that independence from materials imports can be achieved only at terrific cost, and security of supply is now possible only if we establish common economic objectives that will draw the world together to engage in fruitful exchange in commodities, transportation, and communications,

Thus, economic interdependence, with all its political stresses, is now the bellwether of a new world economic order, For the United States there is need to expand relationships with Socialist countries, and our relationships with the LDCS, from whom we now import one-half of our industrial materials and to whom we sell one-third of our exports to the LDCS, and where we have 25 percent of all our foreign investments. The even greater dependence of Europe and Japan on supplies from the LDCS also affects U.S. policies and supplies, We cannot remain indifferent to the plight of our allies,

Concluding Remarks

The main concern of this meeting is to determine whether the adverse impacts of the Nation’s materials problems can be anticipated, effective responses devised, and the respective roles defined for Government and business to implement the right policies. I would be less than candid if I ducked these questions by a ringing endorsement of free trade, high technology, the mining industry, the old-line specialized Government agencies—and the most high and mighty of them all—the National Laboratories and the Think Tanks. Each of these constituencies has richly deserved its fame and acquired some excellence and a function in the system, mainly through specialization and a lengthy record of performance in given roles and missions.

But the difficulties we now face (in energy, materials, economics, foreign policy, and defense) are interwoven, and quite different in that a technological breakthrough (e.g., a satellite, a new plane, or a new bomb) will not necessarily reduce the perilous impacts of world-wide changes, destabilization, and novel international and societal pressures. Also, most of our problems now involve much recrimination, damage, and uncertainty as to what may become of now-powerful constituencies,

There is an erosion of confidence and persistent doubts as to the soundness of our institutions that preclude assigning policy formulation and remedial action to any one of the academic disciplines, business interests, or administrative entities that served us well in the past. Whether the free marketplace together with a cyclical upswing will bring back lasting prosperity and quality of life is questioned even in the Establishment. Some feel that we should trust the future. Others worry that even if and when the cyclical upturn raises the rate at which we utilize our producing facilities (from 74 percent now, to a profitable 93 percent), demand is likely to overshoot capacity (that was not expanded or modernized during the recession because of shortages of energy materials or capital and institutional uncertainties). A new inflationary spiral may well ensue when the recession is over. Then there is the anti-business view that favors no-growth, “pristine living” syndromes, and others.

I submit that only a group of private citizens dedicated to public service but not beholden to any power center can undertake a thorough interdisciplinary diagnosis of the causes and remedies to our ills, and make policy recommendations that are not tainted by the daily responsibilities of organized leadership nor obscured by loyalty to their particular bureaucracy (public or private).

This is what the Commission on Critical Choices attempted to do at a time of severe stress on our society. From the obscurity of my station in the world of R&D societal planning, I feel that the Commission’s endeavor was a laudable patriotic effort – whether or not it produces a book or a chapter on materials.

HR14439/S3637: NATIONAL MATERIALS POLICY BILLS

by Philip Yeager, Counsel
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The commentary which you heard earlier from Mr. Teague and Senator Moss suggests a main key to the very genuine interest of the legislative branch in this conference.

I think it is important to reiterate that Congress–or at least a number of entities within it—are most anxious to have the results and findings of your various task groups, At a minimum, there are three or four Committees in each House of Congress, plus the Office of Technology Assessment, and the Congressional Research Service included in this group.

I believe it is important to bear in mind that, as a whole, we in the Congress are relatively unsophisticated with regard to the matters you will be discussing. We will, therefore, find it very useful if we can have described for us (1) the major materials issues as you see them and (2) what you believe are the various options for their solutions. We understand that individuals and groups alike are often hesitant to suggest solutions, but it seems to us that we have reached a point where it is time to start answering some questions as well as posing them.

Certain things are making an impression on current congressional thinking. As we look at employment problems, for example, we are beginning to realize that the traditional American stance of being short on labor and long on materials has now reversed itself. This is going to require drastic realignment in our thinking and our policy,

I think many of us, whether or not we will admit it publicly, are beginning to understand that we are not likely to make such a transition without somebody getting hurt.

This transition is what the Symington-Mosher bill and the Moss bill are designed to facilitate–that is, put the thinking process in motion. As you have already heard, the authors of these bills do not offer them as a basis for immediate legislative consideration, but we believe they will serve their catalyst purpose in this Congress and the next. I would like to quote from a recent letter received from Dr. Frederick Seitz, President of Rockefeller University:

> While our national energy situation has its precarious aspects, the fact remains that we have enormous reserves of coal and fairly complete knowledge of how to use uranium and related materials in fission reactors. In contrast, many of

> our most useful materials are available only abroad or are not available within our own borders on an economic basis. As a result I believe that our Nation has need of a materials policy. I am delighted that Mr. Symington is joining Mr. Mosher in taking a substantial initiative in this matter.

In conclusion, we hope that you will be blunt about whatever determinations you reach, that you will lay them on the line and that you will duck nothing. Most important, we are confident that your findings will not be on the basis of what you think people want to hear— for whatever reason, political, economic, or otherwise. That element, of course, is always difficult to avoid, but it is one which we now know that our people and our Government cannot afford to harbor much longer.

SUMMARY OF PANEL DISCUSSION ON HR 14439 /S3637

In general, the panel was supportive of the efforts to enact a National Materials Policy. Some felt, however, that such a policy should be more comprehensive in order to take into account the relationship between materials, energy, and the environment. This position was held by those in "Task Force No. 1" who included a special section dealing with the proposed act in their report on "Government, Supplies, and Shortages." This section follows:

The Task Force commends the interest, imagination, and concern of the authors of these bills. We encourage the articulation of a National Materials Policy, However, recognizing the inseparable relationship between energy, environment, and materials (and the necessity of integration of relevant national objectives), we believe the objective should be the expression of the National Resources Policy, encompassing all these issues, rather than the more limited implications of the proposed act.

We find that the Bill does not, in its present form, define a Materials Policy, The major function of legislation on this subject should be to state National Policy Goals perhaps using the five elements of policy voiced by the National Commission on Materials Policy as a basis). And the responsibilities for implementation of those policy goals should be clarified. (The structure of the Energy Resources Council appears to be a useful example for executive branch authority; Congressional analogs also are needed . . . in this respect, we endorse the proposed legislation,)

The Bill focuses on materials research and development, which we recognize as an important ingredient of policy—but only one of many. We note with some surprise the omission of the Administrator of the Environmental Protection Agency from the proposed Commission on Materials Research and Operations, and suggest that, in view of its major contribution to materials R&D, the Department of Defense should also be represented in such councils. But we would also voice some concern with the scope of the functions proposed for this Commission, which would appear, in many respects, to overlap those of existing agencies.

Concern was expressed that factors other than research and development be sufficiently woven into a National Materials Policy– to think that R&D will solve all our materials problems is "overly simplistic." Criticism was also leveled at the fact that representatives of the Environmental Protection Agency and the Department of Defense (which performs about 20 percent of the

Nation's materials R&D) were not included on the proposed Commission on Materials Research and Operations.

Many of these subjects were of concern to other individuals as well, One participant, in expressing his strong support for this legislative activity, reminded the other participants (as had Phil Yeager in his presentation) that it is important to consider not only what legislation may be desirable, but also what it is possible to move through the legislative process. This participant specifically referred to the fact that, although the conference participants recognize the inextricability of resources, energy, food, the environment, etc., in practice the Congress is not set up to deal with things in this way.

The general tone of "Henniker IV" was one of antipathy towards increasing Government bureaucracy, and this was reflected in many of the panelists' comments as well as in the task force report cited above. Some felt that it is now time to move on the findings and recommendations of the National Commission on Materials Policy and the National Commission on Supplies and Shortages, and that Congress should not "rehash" in hearings the work already done by these bodies, Some felt that we should "build on what we already have" in the materials area and avoid setting up another bureaucratic structure.

One panelist spoke forcefully about the need to make a national materials "policy" highly flexible. Another praised the inclusion of renewable resources within the scope of the bill, as he believed that this would open the way for some much needed discussion of their role in the materials field.

In summary, we heartily endorse the concise statement of a National Materials Policy, provided that it is in the context of the larger issue of National Resources, and that it does not add to the burden of Federal bureaucracy.

VI. Summary

THEMES OF THE CONFERENCE

Four, clear, unmistakable themes emerged from the Henniker IV Conference on national materials policy.

First, there was almost universal recognition of the need for a national materials policy, clearly expressed, well understood and agreed to, formally promulgated, and cooperatively implemented. The scope of such a national policy should, of course, include research and development goals and institutions, but it should extend much further. In particular, the policy should deal explicitly with enlisting the close mutual support of Government and industry by providing a national basis for cooperation of these two sectors in the public interest.

Second, there was an underlying concern over indications of excessive present and prospective bureaucratization of the relationship between Government and industry, or indeed Government and the public at large. This concern was manifest in such expressions as "overweening growth of bureaus and agencies, " "over-r emulation," and a persistent tendency toward reacting violently to crises instead of carefully, systematically, and perspicaciously analyzing trends in national affairs to avert and diminish crises before they occur. A specific example that commanded general acquiescence was that cited by George Eads: the idea of materials shortages as a self-fulfilling prophecy, caused by a "shortage mentality" that motivated actions that disrupted supply, violated the market, distorted prices, and led to uneconomical industrial inventories and distress buying.

Third, there was a general recognition that materials illustrated par excellence the need for the systems approach. That is the idea that everything is related to everything else. Materials policy for the United States needed to be formulated while bearing in mind the policy needs— for resources, markets, and capital—of other nations of the world. Materials policy in the United States could not be formed independently of policy for energy and the environment. The institutions of the Federal Government dealing with materials needed to be coordinated with each other, and all of them with other institutions, State, local, and private. Cooperation of the universities, industry, and Government again became seen as essential. An example of this interdependence was the discussion of renewable resources.

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Were they materials or substitutes for materials? Should policv aim to exploit biological resources for engineering applications~, or as a source of energy, or both? Ultimately, the issue turned on the question of entropy: what was the "energy cost" of any particular policy, process, or application? And energy cost, economic cost, and social cost all interacted in the decision process.

Fourth and last, there was the warning, stated well in the discussion of national security aspects of materials: we do not devise sound policy or creative implementation with dollars, with institutions, nor masses of people; we achieve these necessary purposes only by creative approaches, fresh ideas, and innovative concepts. Instead of throwing dollars at problems, we must think about them.

Appendixes

Appendix A

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June Cowan
Pearl Ferri
Lillian Ford
Martha Goldhoff
Kelly McElroy
Jean Gray
Louise Hibbard
Anita Kent
Mrs. Kirkemo
Ethel Kornhauser
Mary Leal
Karen Molzen
June Prindle
Mrs. Promisel
Robert Serig
Caroline Servi
Eli nor Swager
Marjorie Watson
Mary Yopes
Mary Zavist

Appendix B

TASK FORCE MEMBERSHIP

Assignment To Task Forces

National Materials Policy Conference

Task Force No. I C. E. Ford, Chairman	Task Force No. 2 R. M. Goldhoff, Chairman	Task Force No. 3 D. Ballard, Chairman	Task Force No. 4 C. McBee, Chairman	Task Force No. 5 J. B. Clark, Chairman
Tues–Task No. 1 H. D. Moran, Chairman	Task No. 2 W. Hibbard, Chairman	Task No. 3 A. Gray, Chairman	Task No. 4 Z. Zerbe, Chairman	Task No 1 A. Cowan, Chairman
Wed–Task No. 2	Task No. 3	Task No. 4	Task No. 5	Task No. 5
W. Boesmann	J. Agarwal	R. Allgaier	K. Abbott	A. Agnew
J. Boyd	J. Brown	N. Carlson	A. de Ruvo	M. Bever
D. Brobst	R. Gavert	C. Cupp	J. Ferri	D. Cox
C. Cosman	P. Hauser	E. Dyckman	R. Harmon	1. Falkehag
M. Deutch	M. Hoch	R. Gray	B. Kornhauser	H. Goeller
R. Horst	E. Passaglia	H. Kirkemo	J. Leal	H. Irvin
J. Kruger	M. Schwartz	D. Readey	A. Levin	J. Kent
J. McCall	I. Servi	M. Steinberg	W. Prindle	J. Meyers
W. Owen	S. Schilling	W. Swager	C. Reimann	
V. Radcliffe	H. Taylor	R. Wishart	R. Youngs	
E. Romagnoli	G. Watson	A. Zavist		
F. Smith				
P. Yopes				

Appendix C

DEFINITION OF RENEWABLE MATERIALS TERMS

by Ed Dyckman, DOD

Following the report of the Task Force Number Five on Utility of Organic Renewable Resources, the following issue concerning the term “renewable resources” was discussed.

A comment was made in the spirit of the Task Force’s stated concern over the awareness of both the public and scientific and engineering communities for the use of renewable resources. The observation was made that materials technology, in today’s industrially intense society, is all too frequently conceived as minerals technology as not to include non-minerals such as wood, plastics, agricultural products, and other organics.

Consequently, the attention of the public is often drawn by citation of metallurgical examples when scientists, engineers, and economists refer to important national issues as materials scarcity, materials energy intensity, and defense materials requirements. More public attention needs to be focused on organics as a family of materials of equal importance to minerals and metals when discussing the national issues.

As one means of accomplishing this objective, it was suggested that we adopt and communicate a new or extended definition for the term “renewable resources. ” To do this, we might borrow the popular and widely understood terms “reserves” and “resources” from the minerals community. In recent years, scientists, engineers, and economists have made uniform use of “reserve” and “resource” terminology following considerable urging by the U.S. Bureau of Mines and the US. Geological Survey. These agencies contend that such word-use is critical to better communication on the subject of minerals availability. Such may be the case for renewable materials.

The distinction between minerals resources and reserves is based on current geologic and economic factors. An extensive explanation of these terms can be found in the current issue of Minerals Facts and Problems which is prepared by the Department of the Interior. For the sake of brevity, however, a “resource” is a material in or on the Earth’s crust in such a form that economic extraction of a commodity is currently or potentially feasible, A “reserve” is that portion of the identified resource from which a usable commodity can be economically and legally processed at the time of determination.

Although the agricultural scientific community must reach collective agreement, as did the minerals community, on the use of terms, the following example was suggested for consideration: let “renewable resources” relate to a young forest and let “renewable reserves” relate to a mature or harvestable forest. In this context it will be possible for the public and scientific and engineering communities to conceptually quantify the distinction between different types of renewable materials. To this end, such understanding will help agricultural scientists to focus public attention on the need for long term research on renewable resources to accomplish their successful transformation from uneconomical into technically feasible and economically attractive sources of usable commodities.

Appendix D

A PERSONAL ACCOUNT OF THE HENNIKER IV CONFERENCE*

by James L. Holt
Assistant Program Manager, OTA

Every new problem with materials supply evokes discussion but when the problem fades, so does the discussion. Recently, though, people have begun to say, "Let's stop talking and do something before the problem develops. "

This new push for action was recently expressed by Representative Olin Teague and Senator Frank Moss in a joint letter to the fourth Henniker Conference on National Materials Policy. They wrote, "We do wish to impress upon you that materials problems and materials sciences and technology are now infiltrating the collective consciousness of the Congress to a degree that we believe has not heretofore existed."

The Henniker IV conference, August 8-13, 1976, sought to identify and discuss several major materials issues and the various policies and ways to deal with them. The traditional stance of being short on labor and long on materials no longer applies; we need a drastic change in our policy.

The Henniker conference, organized by the Federation of Materials Societies for the Engineering Foundation, met at New England College in Henniker, N.H. Franklin P, Huddle was scheduled to chair the meetings, with Nathan E. Promisel as cochairman. When Frank became ill, John Wachtman took over for him.

Henniker IV looked at national materials policy, in the context of "Engineering Implications of Chronic Materials Scarcity. " Special task forces spent several days discussing separately the following topics: 1. OTA materials assessments for Congress: stresses on the total materials cycle. 2. Government, supplies, and shortages: the work of the National Commission on Supplies and Shortages. 3. Conservation of energy in materials processing. 4. The role of materials in national defense. 5. Utilization of organic renewable resources.

● This article first appeared in Metals Progress, October 1976.

Value of Henniker Conference to U.S. Congress

The three previous Henniker conferences on National Materials Policy have had strong congressional support, and the results have helped Congress in a variety of ways. The first, in 1970, discussed the topic of "Materials Problems and Issues," and the proceedings were published by the Senate Committee on Public Works which prepared the bill creating the National Commission on Materials Policy, signed into law the following October.

The second Henniker conference, in 1972, was entitled "Resolving Some Selected Issues." Its proceedings were published by the National Commission on Materials Policy. The findings and concerns of this conference were put to use by the 93rd Congress, during the debate of S.3279, a bill to establish a National Commission on Supplies and Shortages. This bill was signed into law on September 30, 1974.

The third Henniker Conference, in 1974, examined various options in implementing a national materials policy. Its aim was to assist the Office of Technology Assessment in developing several assessments requested by Congress. Topics for discussion and analysis at the Conference included "Economic Stockpiling" and "Materials Information Systems." Assessments covering these subjects have since been completed by OTA and have been extensively used by the National Commission on Supplies and Shortages.

Need for a National Materials Strategy

The conference participants this year generally agreed on the need for wise, proper, and prudent use of our natural resources, but asked who should be involved in such determination. The consensus was that both public and private expertise should be included.

Equally important was the consensus that some overall strategy should be developed to insure that the United States has sufficient resources available to maintain the standard of living which most Americans now enjoy. With this in mind, it is interesting to remember what George Eads said during Henniker IV regarding the work of the National Commission on Supplies and Shortages. The Commission staff, he said, largely attributes the 1972-74 petroleum and natural gas shortages to the uncertain and vacillating nature of US. Government policies.

This conclusion was echoed by many people during the conference, among them Al Paladino, chief of the materials program of the Office of Technology Assessment. Dr. Paladino stated that OTA is considering the framework and component elements of a conceptual strategy for systematically reassessing current and alternative U.S. materials policies. Such an analytical framework would recognize what some observers often forget: that a national materials strategy need not intervene directly in the market system; that such action is certainly not a panacea for all problems; and that the most effective policy may be to do nothing and let the market correct itself. On the other hand, the strategy would also recognize that when the market system is not working effectively, it is the responsibility of Government to take whatever action is appropriate to promote the general welfare of the country.

Such a national materials strategy should ideally encompass not just metals and minerals, but all resources, both renewable and nonrenewable. Above all else, the strategy should provide the decision mechanisms for systematically considering each policy within the context of all other interrelated policies, taking into account domestic as well as international factors, This consideration must include, among others, foreign policy, especially economic policy; environmental policy; food policy; labor policy, and tax policy,

Systematic analysis of the total resource system and its component elements is necessary to reconcile such conflicting issues as: 1, Increasing consumption vs. declining capacity expansion. 2. The need for market initiative and creativity vs. growing Government regulations. 3. The desire to maintain the U.S. standard of living vs. the growing interest of the less developed countries for the larger share of the world's wealth. 4, The jurisdictional responsibilities of many current decision mechanisms vs. the international nature of the resource problems, 5, U.S. self-sufficiency vs. the interdependent nature of the world economy.

Partnership for Mutual Benefit

The OPEC embargo taught us that materials technology, like creativity, cannot be turned on and off like a faucet, and that dollars do not always produce good ideas. At Henniker we heard repeatedly that what this country needs is a partnership of public and private sectors, of experts and laymen, working together for their mutual benefit, To this end, we agree with Frank Huddle that both ". . . the future generations of Americans whose needs ought to be voiced today and the citizens of the world, our fellow passengers on spaceship Earth, whose views and attitudes transcend national boundaries in the effort to achieve wise, effective management of our total global pattern of resources" ought to be represented in our resource planning.