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RESOURCE SCARCITY, ECONOMIC GROWTH, AND THE ENVIRONMENT

HEARINGS

BEFORE THE

SUBCOMMITTEE ON PRIORITIES AND ECONOMY IN GOVERNMENT

OF THE

JOINT ECONOMIC COMMITTEE CONGRESS OF THE UNITED STATES

NINETY-THIRD CONGRESS

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RESOURCE SCARCITY, ECONOMIC GROWTH, AND THE ENVIRONMENT

WEDNESDAY, DECEMBER 19, 1973

CONGRESS OF THE UNITED STATES,
SUBCOMMITTEE ON PRIORITIES AND
ECONOMY IN GOVERNMENT OF THE
JOINT ECONOMIC COMMITTEE,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10 a.m., in room 1202, Dirksen Senate Office Building, Hon. William Proxmire (chairman of the subcommittee) presiding.

Present: Senator Proxmire; and Representatives Reuss and Blackburn.

Also present: Loughlin F. McHugh, senior economist; William A. Cox and L. Douglas Lee, professional staff members; Michael J. Runde, administrative assistant; George D. Krumbhaar, Jr., minority counsel; and Walter B. Laessig, minority counsel.

OPENING STATEMENT OF CHAIRMAN PROXMIRE

Chairman PROXMIRE. The subcommittee will come to order.

Gentleman, I am grateful to you for coming and I think these are very significant hearings. The problem is that I have an absolutely vital markup in the Senate Banking, Housing and Urban Affairs Committee of an overall omnibus housing bill. We postponed and postponed until today the critical decision on two amendments I have, which are very important amendments, so I am going to have to leave this morning at 10:30 but we will have another member of the subcommittee who will be here, I am sure, and take over and I will come back just as soon as I possibly can because I am very anxious to get into this area.

This morning the Subcommittee on Priorities and Economy in Government opens 3 days of hearings on "Resource Scarcity, Economic Growth, and the Environment."

Throughout our history, the United States has operated its economy on an assumption of resource abundance. This has been referred to as a "frontier" or "cowboy" mentality. The land, the forests, the water, the clean air, the fuels and minerals were there in plenty. Often they were free for the taking. Almost always they were cheap relative to the cost of labor and machinery.

In recent years, the more perceptive and farseeing among us have come increasingly to realize that we could no longer operate as a frontier economy; that natural resources are limited; that even our water and our air can be exhausted through saturation with pollutants. Finally, in this past year, everyone has suddenly become aware that serious shortages are possible even in the United States.

During the past year shortages of certain foods, of industrial raw materials, of manufacturing capacity, and now, most seriously, of fuels have wreaked havoc with the U.S. economy and the price system. The question recurs, of course, have we entered a period of scarcity? Must we expect continuously to confront one shortage after another? Must we choose between maintaining our material standard of living and preserving our environment?

Traditional economics teaches us that the price system will allocate scarce resources. The price of the scarce commodity will rise relative to other prices. This will encourage conservation and promote the adoption of substitutes. But recently we seem to have run out of substitutes. When beef prices rose this past year, consumers were advised to turn to other sources of protein. However, it did not take long to discover that chicken, eggs, cheese, milk, and even soybeans were also in short supply. Few substitutes were left.

Similarly, in the past we have turned to plastics and synthetics as substitutes for metals and for natural fibers. But now, as one outgrowth of the petroleum shortage, we face a growing shortage of plastics and synthetics. Now what do we substitute?

Can we continue to rely on the price system to allocate scarcity? What Federal policies do we need to supplement the price system? These are the questions we wish to examine this morning. Our witnesses are extraordinarily well qualified to suggest answers.

I want to thank Congressman Blackburn for coming over, and I apologize to him for the fact we have had, are holding the hearing here in the Senate, we have held more than we should in the Senate. We had a hearing the other day of another subcommittee in the House but they are all too rare. As I explained, I have to be at a committee markup, which is absolutely critical, at 10:30, so I am going to have to leave and you can take over the committee at that time.

Our first witness is Mr. James Boyd, who served as Executive Director for the National Commission on Materials Policy. We have asked him to discuss the report of that Commission and the policies needed to implement its recommendations.

Our second witness is Mr. Barry Commoner, director, Center for the Biology of Natural Systems at Washington University, St. Louis, Mo. Mr. Commoner is a noted environmentalist, and we have invited him to discuss the environmental consequences of our "frontier" approach to economic growth.

Our third witness is Mr. Gordon J. F. MacDonald. Mr. MacDonald served as a member of the President's Council on Environmental Quality, and in that capacity he testified before this subcommittee during hearings on the SST. Mr. MacDonald is now chairman of the Environmental Studies Board of the National Academy of Sciences. We have invited him to discuss their recent report, "Man, Materials and the Environment."

It will be helpful if each witness will limit his opening statement to about 10 minutes.

STATEMENT OF JAMES BOYD, FORMER EXECUTIVE DIRECTOR, NATIONAL COMMISSION ON MATERIALS POLICY

Mr. BOYD. Mr. Chairman, I am James Boyd. I have a biography here which I will not read to you if you would like to have it for the record.[1]

The National Commission on Materials Policy was established under Public Law 91-512 of the 91st Congress. under the title II "National Materials Policy." The report of the Commission was filed with the Congress and the President on June 28, 1973; in compliance with the act, the Commission has been disbanded. I, therefore, appear before you as a private citizen and feel honored to be asked to discuss with you the effect of resource scarcity on economic growth.

The potential for material scarcities was described 20 years ago by the President's Materials Policy Commission (the so-called Paley Commission). The reports of the Bureaus of Mines, Minerals Facts and Problems, published last in 1970, and more recently the Secretary of the Interior's reports under the Mining and Minerals Policy Act of 1970 have repeatedly indicated the magnitude of the problems involved in continuing to supply a rapidly expanding industrial economy. In the NCMP report we were forced to say, "We have concluded that the Nation faces grave energy challenges. We find no easy way to avoid a serious and costly imbalance in supply and demand in the near term." That is the end of quotation. Although this was specifically directed at energy materials, it applies in varying degrees to many of the raw materials which are needed to harness, distribute and utilize energy.

As an example, there is already a shortage of specific forms of steel to drill oil wells. This leads indirectly to a reduction in energy available to make steel in the near future, and to other products on which steel production depends. The cycle of interdependence is almost too complicated for the human mind to follow. It is essential for the Congress to recognize this while it is considering legislation to correct the problems of material supplies, and while it considers legislation to correct other problems which at the time might seem remote to materials supply.

I should like, Mr. Chairman, to review with you, before we get into the discussion period, some basic principles of material supply which are imperfectly understood. Unless we understand them clearly, we are likely to come to some erroneous conclusions.

The first of these is the meaning of the word "resources." This has been treated in depth in the Geologic Survey's professional paper 820, published earlier this year, but briefly described in chapter 4B—supply of NCMP report. There is a tendency to describe resources as limited when we may be meaning that known economic resources are limited. These are more frequently referred to as "reserves." Energy is a typical example of this. The resources of energy are almost limitless from radiation from the Sun; to the geothermal heat rising from the interior of the Earth; and that stored in uranium, thorium, and deuterium, et cetera. The resources. primarily the fossil fuels, coal, oil, gas, oil shale, et cetera, although still enormous are definitely limited, and those specifically delineated as reserves are actually declining as discovery falls

[1] See biography of Mr. Boyd, beginning on p. 7.

behind production. We have developed reliance on the fossil fuels throughout our complex industrial and social system. We have not, however, permitted the supply systems to evolve as reliably as we might wish to have done. A resource fails to become of use to us unless it is equipped with the machinery and industrial and financial complexes required to put it to our use. The failure to permit our domestic industry to provide these economic systems is responsible for our current dilemma and has permitted others from outside our borders to dictate our immediate destiny.

The next illustration of resource principle is to be found in steel. We, and actually most of the world, are currently short of steel. Yet, iron, the principal ingredient in steel, is one of the most common elements in the Earth's crust. The growing industrial ambitions of all the world have led to the search for, discovery, and equipment of a large number of mines throughout the world. The delineated reserves behind these mines are large enough to last the entire world for 500 years. It is clearly not a resource that is lacking; it is the industrial capacity to take the basic resource and convert it into the form in which it is used. Policies must, therefore, be adopted which not only help in the discovery of reserves, but also provide the systems that put these reserves to use.

Following the publication of the report of NCMP in June 1973, our staff, while it was cleaning up the affairs of the Commission, made a brief survey to find where energy material shortages had accentuated the shortages in other materials. In order to inform Congress and the President of our findings, we delivered a supplementary report to them. This gave examples from five industrial sources of what had already happened in the curtailment of production and resulting loss of jobs last summer. I have a copy of that supplementary report for the record if you would like to have it.[1]

Chairman PROXMIRE. I should be happy to have it for the record.

Mr. BOYD. Thank you, sir.

In it there are striking examples of the magnitude of economic dislocation that can and are resulting from shortages of specific materials.

This committee and its wonderfully competent staff are in a better position than I to evaluate the total effect of a reduction in the supply of an essential material by as small a factor as, for example, 10 percent.

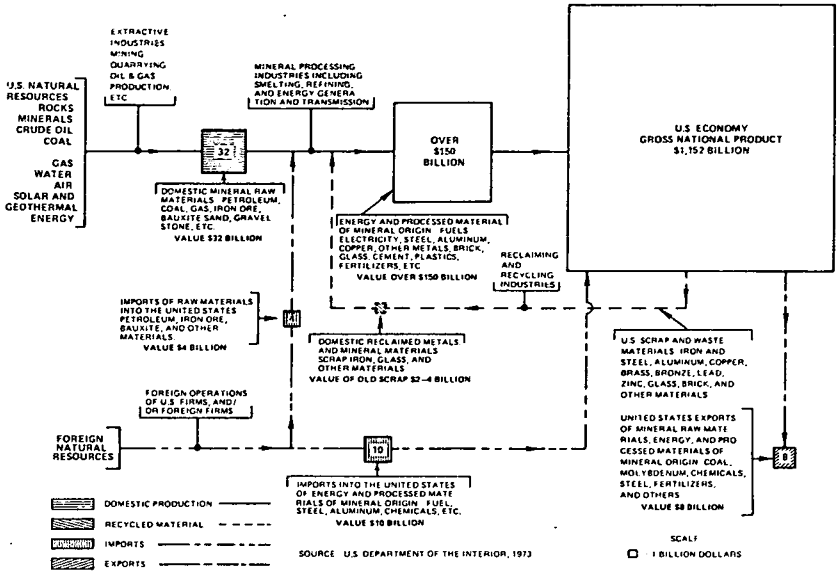
But I would like to refer you to a chart which appears on page 2–2 of the NCMP report. It is reproduced and attached to this statement for you.

[The chart follows:]

[1] See supplementary report, beginning on p. 8.

THE ROLE OF MINERALS IN THE U.S. ECONOMY

(ESTIMATED VALUES FOR 1972)



THE FLOW OF MINERAL MATERIALS THROUGH THE U.S. ECONOMIC SYSTEM

Basic mineral materials, including metals, nonmetallics, and fuels, constitute only about 3 percent of the Gross National Product. As these materials are processed, their value is multiplied nearly 15-fold by inputs of labor, capital, productivity, and enterprise. The areas of the squares, drawn to dollar scale, put into focus the respective segments of the economy. Source: Bureau of Mines data, U.S. Department of the Interior, 1973. Reference (1).

Mr. Boyd. It shows in proportion the size of the domestic mineral raw materials used every day. These are industries including petroleum, coal, oil, gas, iron ore, sand and gravel, copper, aluminum, and a hundred other mineral commodities. This approximately $32 billion is the life blood of a $1,152 billion economy. There is a multiplier effect implicit in this which could magnify a 1 percent shortage of materials or $300 million into a $10 billion reduction in the total economy. Larger percentages than this are decidedly indicated, as the minerals producing industries are energy-intensive. If they are to be cut back by the 5 percent that has been suggested, the economy could be directly reduced by $50 billion and the side effects would be very much more.

In fairness, I must point out that this approach is entirely the result of considering the materials side of the economy. I have neither the staff or the facilities to relate this to the services segment. Furthermore, the cuts suggested are from projected demands, not necessarily from the existing rates. It is much too early yet to evaluate the effects of a genuine desire to conserve, which I think we can detect around us.

The next resource principle is that of the interchangeability. In making economic analysis, it is easier to follow through the system on one commodity by itself. This can and does lead to serious misconception of the total materials economy. In analyzing the effect of possible shortages of one commodity, it is necessary to remember that we use materials for the properties they have and that it is rare that a desired function cannot be performed by the properties of more than one other material. Shelter is the most dramatic function and is performed by the properties contained in wood, concrete, steel, aluminum, glass and even mud and sticks. The choice of materials is in the hands of a designer or in this case an architect or engineer. He has a choice of alternative materials to perform the ultimately desired function. The designer will consider availability, physical properties, ease of application, cost, aesthetics, et cetera. In the industrial sense when the conduction of electricity is required in a vast array of products, the designer has a considerable amount of leeway in his choice of materials, for he can choose from silver, cooper, gold, or aluminum depending on the factors involved in that particular application. I have deliberately not used the word "substitution" in this consideration as I think it connotates the choice of a less-desirable material in substitution for an economically unavailable material for that product. The word "interchangeability" fits the process better.

Now, with these basic principles in mind, the National Commission on Materials Policy developed three directives for policymakers and attempted to develop its recommendations within that framework:

1. Strike a balance between the "need to produce goods" and the "need to protect the environment" by modifying the materials system so that all resources, including environmental, are paid for by users.

2. Strive for an equilibrium between the supply of materials and the demand for their use by increasing primary materials production and by conserving materials through accelerated waste recycling and greater efficiency-of-use of materials.

3. Manage materials policy more effectively by recognizing the complex interrelationships of the materials—energy—environment system so that laws, executive orders, and administrative practices reinforce policy and not counteract it.

That is the end of the quotation.

The second of these is the most pertinent to this discussion today, so I shall spend a minute or two going over the Commission's recommendations in this area. I will have to do this very briefly to reach your 10-minute deadline, sir.

The Commission recommended that the Congress articulate an objective of the United States to "provide adequate energy and materials supplies to satisfy not only the basic needs of nutrition, shelter, health, but a dynamic economy without indulgence in waste." Inherent in such an economy is the drive to enrich life, materially, mentally, and spiritually.

The interplay between these goals and the variety of choices available to reach them makes it more and more obvious that "traditional U.S. economic policy be maintained by relying upon market forces as a prime determinant of the mix of imports and domestic production * * * where costly and dangerous reliance upon imported materials appears the outcome of existing trends, the Government must intervene. * * * Since the private sector is the source of nearly all supply, the proper role of the Government is to facilitate industry's striving to meet its responsibilities to supply materials providing a congenial economic and institutional climate." That is the end of that quotation.

If our concept of the relative abundance of resources of materials and energy is correct, then it is necessary to promote the search for those materials that are now scarce by providing surer access to public and private lands and the Government should expedite decision-making in the energy-materials-environmental area.

There has been much concern over recycling. For it is expected that a well-conducted program can improve supply a little and at the same time materially help the environmental conditions. The Commission, therefore, recommended that a national resource recovery system be established, through public and private sector cooperation to achieve three objectives.

(a) Discourage dumping and encourage resource recovery as a means of turning waste into a national resource;

(b) Encourage disposers to prepare waste for recovery rather than dumping; and

(c) Create markets for recovered materials by recycling technology, by Federal procurement policies, and by equitable tax and transportation rates for virgin and secondary materials.

There are over 178 specific recommendations listed in the report designed to carry out these basic goals. But perhaps the most important of these was that of organizing the Government to cope with complex interrelationships of the materials-energy-environment systems, so that laws, Executive orders, and administrative practices reinforce policy, as I said, not counteract it.

We are facing at this moment virtually the same raw material problems we faced in early stages of World War II and the Korean war even though the reasons are different. If we are to solve them we must be sure we know what they are and then reach quickly for the solutions. But we must be sure we have assessed them and provide the proper climate in the economy for industry to solve them. Only industry, in our type of economy, can solve such complicated problems. But in times of severe shortage, Government must set the rules.

It is not industry's function, for example, to allocate resources in an emergency, when there is a shortage, yet if Government does not assume the responsibility, industry is forced to do so by default.

Mr. Chairman, I am and many others who have been through this mill two or three times, in the Second World War and the Korean war, before are convinced that material supplies are rapidly becoming as relatively short as energy. It is encouraging that this Committee has seen it coming and I hope in time to do something about it.

The large number of recommendations in the NCMP were selected as the most urgent of a much larger number that were raised during our studies. It will require attention of all of them, not just a selected few, on the theory that a "chain is only as strong as its weakest link."

Thank you, sir.

[The biography of Mr. Boyd and the report of the National Commission on Materials Policy follow:]

Biography of James Boyd

Mr. James Boyd, who served as director of U.S. Bureau of Mines 1947–51, was born in Kanowna, Western Australia in 1904. Coming to this country in 1922, he attended California Institute of Technology from which he was graduated in 1927. Following two years as a field engineer in geophysics, he entered the Colorado School of Mines graduate school to receive his Doctorate in Geology in 1934. After service in the Army, he returned as Dean in 1946. During the war years, he served as Army Representative on the War Production Board's Program Adjustment Committee; executive officer to the Director of Materiel, Army

Service Forces and Director of the Industry Division of Office of Military Government for Germany. He was promoted to full Colonel in 1943. Returning to the government in 1947 as Director of the United States Bureau of Mines, he concurrently served as Defense Minerals Administrator during the Korean War.

In 1951 he joined Kennecott Copper Corp. as exploration manager, and become vice-president in 1955. In 1960, he was elected President of Copper Range Company. He resigned as Chairman of the Board in 1971 to assume the post of Executive Director of the National Commission on Materials Policy, until the Commission completed its work in 1973.

He is past president of the Mining and Metallurgical Society of America, the American Institute of Mining, Metallurgical and Petroleum Engineers.

He received the Rand gold medal of the American Institute of Mining Engineers in 1963 and the distinguished alumnus awards of the California Institute of Technology in 1967, and the Colorado School of Mines in 1949. He delivered the Jackling Lecture before the Society of Mining Engineers in 1967 and the Distinguished Lecture to the American Society of Metals and The Metallurgical Society in 1973. He will deliver the Distinguished Lecture to the Ceramic Society in April 1974. In 1973 he was awarded the Ben H. Parker Medal of the American Institute of Professional Geologists of which he was Vice-President in 1966.

For his military service, he was decorated with the Legion of Merit with an Oak Leaf Cluster.

He is currently the chairman of the Secretary of Interior's Advisory Committee on metal and non-metal Mine Safety. He is a member of the National Academy of Engineering.

NATIONAL COMMISSION ON MATERIALS POLICY,
Washington, D.C., August 22, 1973.

To the President and Congress of the United States:

Since the issuance of its final report on June 27, 1973, the National Commission on Materials Policy has received evidence from industry that uneven distribution of those forms of energy producing materials which are in short supply has already caused plant shutdowns, curtailed raw material production, and resulted in unemployment. There is clear evidence that these are not isolated occurrences but indicate a worsening trend which may have domino effects. The impact on the nation's economy and on the people can be disastrous.

Industrial firms and others have advised the Commission, as illustrated in the attached letters, that disruptions have already occurred. These letters are from major corporations. If they are having such problems then smaller companies with less economic strength are faced with even greater difficulties. As these occurrences multiply, the disruptions reach crisis proportions. There are enough examples to indicate that an emergency already exists. We have thought it advisable to transmit these letters to you.

The public generally does not understand that each person is indirectly affected by each curtailment which may be visible only to the few that have experienced a layoff. The public, but there must be a galvanizing of government action which makes it unmistakably clear that the time for temporizing has passed and that an all-out effort is the only solution.

The Commission in its report released on June 27 made recommendations for basic policy decisions to meet the nation's near future and long term needs in the total materials field, including energy. This presentation emphasizes the urgent need for early action on those recommendations by government, industry and the public itself. Particularly needed is coordinated emergency action on energy, materials, the economy and the environment to meet immediate critical needs of the nation.

Respectfully submitted,

JEROME L. KLAFF, *Chairman.*

Attachments.

THE ANACONDA COMPANY,
New York, N.Y., August 10, 1973.

Mr. JEROME L. KLAFF,
Chairman, National Council on Materials Policy
Washington, D.C.

DEAR MR. KLAFF: The Anaconda Company is concerned about energy shortages and inflation in the cost of energy and recognizes the need for a sound national energy policy to resolve these problems. We would like to discuss briefly some of the problems which the non-ferrous metals companies, and particularly, Anaconda, are encountering in trying to obtain sufficient supplies of energy to maintain production in our mines, smelters, refineries and fabricating plants.

Anaconda is one of the oldest primary metals companies in the United States today. We mine copper ore, which we concentrate, smelt and refine to make copper metal. We smelt alumina to make aluminum. We roll and extrude copper and aluminium into a wide variety of shapes, including wire and cable, brass, aluminum doors, windows, siding and foil.

During 1972 Anaconda Company spent over $46 million for energy in the United States. Some $20 million was spent for electricity and over $8.0 million each for fuel oil and natural gas. Our production of aluminum requires about 14,000 kilowatt hours per ton, and our production of copper requires more than 600 kilowatt hours per ton. Natural gas is used for smelting, heating, drying, annealing, and metal working and for heating space for workers. Oil is used for some of these same purposes and also to fuel the truck fleets used in mining operations. Only two plants use substantial amounts of coal. Propane use is increasing and is used primarily as a substitute for natural gas and to operate industrial trucks. Some of our processes can only use natural gas, propane or electricity because other fuels would contaminate the metal. For example, copper used for manufacturing wire and cable must be melted in a shaft furnace using natural gas, propane or electricity because the copper must remain 99.9946 percent pure to match the quality required for electric wire and cable.

It is not necessary to tell this Commission that natural gas is in short supply in the United States. We recently surveyed the reserve positions of our gas suppliers and the pipelines which supply our gas suppliers and learned that the supply for 16 of our plants will be drastically curtailed in the 1973–74 operating year. Utility projections indicate two of our plants will not have any natural gas available for up to four months this winter. In 18 additional plants, less severe curtailment may be expected, and in only eight of our plants is there a reasonable chance that we will get through the next operating year without curtailment. A similar survey of the reserves of our electricity suppliers indicates that severe curtailment may be expected in four of our plants next year. Already we have reduced production 20% at one of our major aluminum reduction plants in the northwest due to curtailment of our electric supply. Power probably will not be available to increase production back to normal levels until March, 1974. Due to this cut-back in aluminum production, an aluminum wire and cable plant has been closed. Our power survey indicates the possibility of some curtailment existing in 25 plants. In only 10 plants does it appear that the operating electric utility serving them will have sufficient reserves to assure continued operation during the next operating year.

Our surveys do not reveal any possibility that these power and gas situations will improve in the following year. In other words, our information is that we are faced with plant shutdowns unless we can find substitute fuels or substitute sources of natural gas and electric energy. We do not regard our situation as a Company to be unique. It is our view that this is the general situation faced by industry in the United States.

It is not only industry that will be affected by these shortages of fuels and electricity; however, we are alarmed at the current trend of regulatory commissions and federal agencies to attempt to place the entire burden of the energy shortages upon industry. There appears to be a disposition on the part of those charged with allocating the supply of scarce energy, particularly gas and electricity, to consider that if they are able to maintain supplies to commercial and residential customers that the shutdown of industry resulting from such allocation will not be of any consequence. We want to point out that nothing could be further from the truth.

It is not possible, of course to estimate accurately the entire effect on denying energy supplies to industry. However, we can get an impression of the effect on the American economy of denying supplies of energy to industry by making certain assumptions. In our own case, production could be cut on the average as much as 10% during the next operating year as a result of gas and electric curtailment unless we are able to obtain substitute fuels. Let us assume that this applies to industry generally and compute how this will affect the Gross National Product, our balance of payments, the prices of our products, and employment in the United States.

For 1972, the mining and manufacturing industries contributed just under one third of the Gross National Income in the United States. If the energy supplies of all industry and mining were curtailed with a resultant 10% drop in production, national income would drop approximately $31 billion if there were a corresponding drop in the sales of these industries. Undoubtedly, the effects would be considerably more severe than can be measured by the direct reduction in sales, however, since reduction in mining and manufacturing production would reduce the demand for all the other goods and services produced in the economy.

An economic dislocation of this size is almost unprecedented in post-war American history. The decrease alluded to would amount to 3.3% of the National Income for 1972. In the most serious post-war recession, that occurring between 1948 and 1949, real national income fell 3.5%. Obviously, a reduction of this type would have a very serious effect upon the level of unemployment in the United States.

Equally disturbing would be the loss of goods to export, at a time when the United States is suffering an unprecedented balance of payments deficit problem. Non-agricultural products comprised 83.4% of total U.S. exports in 1971.

These very serious economic dislocations call for a reasoned evaluation before an energy policy which unjustly discriminates against industry is adopted.

After studying the impact of the energy crisis on Anaconda, we believe that many things can be done to help make an orderly transition from an age of cheap, abundant energy to an age which requires effective energy management. We have been and are continuing to take positive steps in this direction.

It is important to reduce industrial waste of energy. Anaconda is carrying out a comprehensive energy conservation program. Industry alone cannot bear the entire burden of energy conservation. Other sectors of the economy must also respond, including the man on the street. In addition, there must be a positive government program to correct the energy supply-demand imbalance. To achieve this, the Federal Government must develop a well defined energy policy to increase energy supplies.

During the interim period, industry must not be expected to bear the entire brunt of allocations, curtailments, and increased costs. The severe economic dislocations which would result can be avoided with a reasoned and logical approach, and without discriminations against industry.

The impact upon all sectors of the economy must be considered before any program is developed. Extensive public hearings, must be held with the public, commercial and industrial interests represented.

Your very truly,

WILLIAM C. O'CONNOR,
Director of Transportation and Energy.

—

CORNELL, HOWLAND, HAYES, & MERRYFIELD,
Bellevue, Wash., August 1, 1973.

Mr. JEROME L. KLAFF,
Chairman, National Commission on Materials Policy,
Washington, D.C.

DEAR CHAIRMAN KLAFF: This letter to you provides more recent information to supplement my June 18, 1973 memorandum to Mr. Robert Blum with respect to some of the problems faced by industrial plants in the United States as a result of the current energy crisis.

In my June 18th memorandum, I commented at length about the power shortage in the Pacific Northwest which resulted from less than average precipitation during the current year. Ot the time I wrote that memorandum, the direct service industrial customers of the Bonneville Power Administration had curtailed one-half of their loads normally served by interruptible power because there were no available supplies of power to meet the load.

At the present time (July 31, 1973), all of the loads normally served by interruptible power have been curtailed. This is roughly one-fourth of the total industrial load and amounts to about 1,000 MW. This drop in load will be accompanied by additional industrial unemployment in a region which has never fully recovered from the 1969–1971 recession.

There is every reason to believe that firm power curtailments will be necessary this fall if the drought continues. The situation will be made even more serious if below normal temperatures are encountered. Low temperatures freeze the mountain streams feeding the rivers and reduce hydroelectric plant output. The same low temperatures increase the heating load.

The economic consequences of the curtailment of Pacific Northwest industrial loads are beginning to spread. I understand a shortage of chlorine and caustic has, in at least one instance, reduced papermill output. Other products produced by Pacific Northwest plants are also reported to be in short supply. These include ferro nickel, ferro silicon, silicon, silicon carbide, chlorine, caustic soda, aluminum and elemental phosphorus, as well as other ferro alloys and pulp and paper products.

In spite of the growing evidence that shortages of these basic industrial building blocks will adversely effect production and employment in other industries, regulatory agencies are still holding to their announced emergency curtailment plans—namely—in case of shortages, curtail industry first.

Very truly yours,

HERSCHEL F. JONES,
Director, Economics Division.

OSCAR MAYER & CO.,
Madison, Wis., August 6, 1973.

Mr. JEROME L. KLAFF,
Chairman, National Commission on Materials Policy,
Washington, D.C.

DEAR MR. KLAFF: As a result of several conversations with Mr. Robert Blum concerning the "Energy Crisis" we are sending information pertaining to Oscar Mayer & Co. which may be helpful in assessing the problem.

In 1972 (fiscal year ending October 28, 1972) Oscar Mayer & Co. had Net Sales of $712,282,000, Net Income of $15,975,000 and Domestic Sales Tonnage of 1,117,071,000 lbs.

We have eight meat processing plants and forty distribution centers throughout the United States. Our plants are located at Madison, Wisconsin; Perry and Davenport, Iowa; Chicago and Beardstown, Illinois; Philadelphia, Pennsylvania; Los Angeles, California and Nashville, Tennessee.

During the winter of 1972–1973, three of our plants came close to shutdown due to the unavailability of standby fuel.

A. PERRY, IOWA, PLANT AND LOS ANGELES, CALIF., PLANT

The main boilers in these plants are fired normally on interruptible natural gas. These plants are equipped with standby fuel oil, which in previous years was readily available when gas interruptions occurred. However, in the winter of 1972–1973, our regular fuel oil suppliers (who in each case were major oil companies) advised suddenly that they could not fulfill our needs. These needs, in each case, were barely met by other suppliers before a plant was forced to shutdown.

Substantially longer periods of gas curtailment during the recent winter added to our needs for fuel oil at both of these plants, and further compounded supply problems.

B. BEARDSTOWN, ILL., PLANT

This plant also fires its main boilers with interruptible natural gas. In the summer of 1972, the plant was advised by the supplier that it should expect about 45 days of gas interruption. The plant contracted for a 45 day supply of standby propane. The natural gas supply was curtailed much earlier than normal, and discussions with natural gas suppliers in December indicated that the plant would now be required to be on standby fuel about 100 days, rather than the 45 days promised in the previous summer. After extensive investigation, a sufficient supply of propane was lined up at an increased cost of approximately 40% over that purchased the previous summer.

Environmental requirements have made it necessary for our company to install afterburners at four plants, thus substantially increasing our consumption of firm gas. Also, we have been forced to convert coal-fired boilers to oil or gas fired at one location to meet environmental requirements, greatly increasing our needs for fuel oil and natural gas already in short supply.

Installation of standby fuel oil tanks and related equipment company-wide will cost an estimated $350,000 in the last half of 1973. This expenditure is necessary to meet the fuel crisis now facing us.

Attached is a listing of the fuel situation at our various plants. This review was made in March, 1973, and a report outlined the situation together with recommendations; the report has just been updated to include the action which has been taken.

Please let me know if you would like to have any additional information.

Sincerely yours,

CHARLES H. FENSKE,
Operations and Engineering.

Enclosure.

FUEL SITUATION—COMPANYWIDE/OSCAR MAYER & CO.

MADISON

Present fuels are coal, firm gas, interruptable gas and #2 fuel oil. Currently Madison has 7,000 tons of coal in storage and a 250,000 gallon tank for #2 fuel oil, plus a contract for an additional 250,000 gallons of fuel oil, if needed. The firm gas represents approximately 20% of our total power requirements and coal can represent the other 80%. This, coupled with our interruptable gas and #2 fuel oil standby, should be sufficient fuels to operate the Madison Plant.

DAVENPORT

Presently using coal, interruptable gas and #2 fuel oil. Two thirds of their energy is derived from coal and the other one third from interruptable gas (or #2 fuel oil). No. 2 fuel oil usage would be 8,000 gallons per day. The mine which their coal comes from is located 40 miles from the plant and shipment is made by large trucks. Davenport maintains 1500 tons in storage one mile from the plant.

Recommendations

1. Install a 250,000 gallon tank for #2 fuel oil to be erected so that it can be filled during the summer months.
2. Make space available for a second 250,000 gallon tank to be installed at a later date if needed.

Action

250,000 gallon tank being installed.

CHICAGO

Presently use interruptable gas and #6 fuel oil. However, Chicago has been off interruptable gas since May 1972 and they cannot expect anymore in the foreseeable future. Consequently their #6 fuel oil becomes their primary and only fuel. Chicago has a space problem insofar as on-site storage is concerned. However, they are close to refineries. They are currently using approximately 7,000 gallons per day of #6 fuel oil.

Recommendations

1. Install tanks to give them a 20 day inventory on-site.
2. Have a minimum of two firm contracts (2 different suppliers) for #6 fuel oil and to make sure these suppliers have this in storage and reserved for Oscar Mayer & Co. Would suggest these contracts be made for as long a period of time as possible up to five years.
3. Check possibility of using propane as a standby fuel.

Action

90,000 gallon tank being installed ($55,100).

PHILADELPHIA

Present fuels interruptable gas and #5 fuel oil. Using 4,000 gallons of #5 fuel oil per day. Space problems exist in Philadelphia also; however, the Philadelphia Plant is close to oil refineries.

Recommendations

1. Install fuel tanks for a 10 day supply.
2. Retain available space for an additional 10 day supply.
3. Draw up firm long term contracts with at least two suppliers for #5 fuel oil.

Action

20,000 gallon tank installed. Appropriation approved to add 2/10,000 gallon tanks 6-14-73. ($33,000)

LOS ANGELES

Present fuels interruptable gas and #2 fuel oil. Using 5,000 gallons per day of #2 fuel oil. Space problems exist in Los Angeles.

Recommendations

1. Install tanks for #2 fuel oil for a 10 day supply.
2. Attempt to retain available space for an additional 10 day supply if needed at a later date. Los Angeles is close to refineries and, of course, does not have cold weather so that they should be able to stay on interruptable gas for longer periods of time than the midwestern plants.
3. Draw up firm long term contracts with at least two suppliers for #2 fuel oil.

Action

2/20,000 gallon tanks being added. ($30,000)

NASHVILLE

Present fuels, interruptable gas and #6 fuel oil. Currently Nashville has a 40,000 gallon tank which is a 20 day supply. However, in another year this could be only approximately a 10 day supply.

Recommendations

1. Install additional tank to give them a 20 day supply based on level of future production.
2. Secure long term contracts for #6 fuel oil preferably from two different sources.

Action

40,000 gallon tank #6 oil—20,000 gallon tank #2 oil—appropriation approved 5-23-73. Convert high pressure boilers to take standby fuel and change high pressure boilers to interruptable gas and afterburners to firm gas. ($22,500)

PERRY

Presently on interruptable gas and #2 fuel oil.

Recommendations

1. Install a 500,000 gallon tank for #2 fuel oil as standby. Here again this should be erected so that it can be filled during the summer months.

Action

500,000 gallon tank being installed. ($65,600)

BEARDSTOWN

Presently using interruptable gas and propane gas.

Recommendations

1. Install oil burning equipment in boilers and a 500,000 gallon tank for #2 fuel oil (60 day supply). This should be erected so that it can be filled during the summer months.
2. Retain a reserve (off-site) of propane gas amounting to 250,000 gallons (5-6 week supply). We suggest this be continued for at least another year or until we have more experience on the availability of #2 fuel oil in this area.

Action

500,000 gallon tank being installed ($145,000) plus lines and conversions.

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MEMORANDUM REPORT TO THE NATIONAL COMMISSION ON MATERIALS POLICY ON THE PROBLEMS OF THE NONFERROUS METALS INDUSTRY RESULTING FROM THE ENERGY CRISIS, JUNE 18, 1973

To: Robert Blum, Energy Director, National Commission on Materials Policy.
From: Herschel F. Jones, Director, Economics Division, Cornell, Howland, Hayes & Merryfield.
Subject: Problems of the nonferrous metals industry resulting from the energy crisis.

31-070 O - 74 - 2

With the exception of the companies immediately involved, it appears that not enough attention is being given to the problems caused by energy shortages and rising energy costs to the firms which mine and produce nonferrous metals in the United States. Only occasionally does a public official recognize that there is a serious national problem stemming from the inability of these firms to obtain the energy required for production.

Few public officials recognize that failure of these firms to produce at or near their current levels could pose substantial problems for the economy as a whole.

At your suggestion, I am setting forth below some of the basic problems which we have encountered as consultants with respect to the energy problems of several firms engaged in the production of nonferrous metals. Many of the illustrations I will use are tied to plants operating in the Pacific Northwest since the bulk of our experience lies in this area. However, during the past two years I have been consultant to several firms with plants in many areas of the United States and can speak from firsthand knowledge with respect to their experiences.

PROBLEMS CONNECTED WITH INADEQUATE SUPPLIES OF ENERGY

Natural gas

The form of energy which is subject to the greatest curtailment of supply for industrial use at the present time is natural gas. I have been told by regulators in several states that the time when natural gas will no longer be available in any quantity for industrial production is approaching. It appears that these gentlemen believe that all natural gas should be reserved solely for the heating of homes and commercial establishments and for the operation of gas ranges, water heaters, and clothes dryers. If this opinion prevails, industrial dislocation is very likely to follow.

The qualities that make natural gas a premium fuel for house-heating, cooking, water-heating, and other such applications also make it the most convenient fuel for certain industrial operations. For example, pure copper is melted and formed into ingots for wire drawings to make electric and telephone wire and cables. The melting is done by a cove furnace using natural gas as a fuel. Any attempt to substitute a fuel other than natural gas or its cousin, propane, in a cove furnace would contaminate the pure copper and make it unusable for the purpose for which it is being produced. It might be possible to design a furnace using an inert gas in place of natural gas for melting the copper, but this would appear to be prohibitively expensive and would require redesigning and rebuilding the melting facilities in the wire manufacturing plants. There are similar processes in the manufacture of other copper and brass products for which the substitution of fuel oil is not possible without completely redesigning the equipment.

At the present time the regulations for the curtailment of natural gas in the event of short supplies do not provide for these processes to continue to receive the premium fuel for which they were designed. This is a matter of grave concern. In the evaluation of the order of curtailment by regulatory authorities, the possible effect on the total economy of shutting down industrial facilities is largely ignored. Substantial curtailment of the production of electric wire, for example, will affect production of electric appliances and motors, the construction industry, the telephone industry, and of course the production of almost all modern devices which use electricity in any form. Also, the effect upon the expansion of electric utilities would be disastrous.

If it were possible for these premium industrial uses of natural gas to obtain adequate supplies of substitute fuels, the curtailment of natural gas would have a substantially less impact on industry and its production. The only practical substitute, however, which is propane, is also in short supply and is uncontrolled. Consequently, many industrial plants which have facilities for the use of propane in the event of natural gas curtailment have been unable to obtain adequate supplies and almost all of them have been unable to obtain long-run commitment for adequate propane supplies. The possibility of controlling the sale of propane during the emergency should be investigated.

There are other uses of natural gas where it is less difficult to substitute oil for natural gas as a fuel in the industrial process. For example, natural gas is widely used as a fuel to bake the electrodes used in most of the aluminum-reduction plants in the United States. Although not as desirable, fuel oil can be substituted for natural gas in this application. However, in these uses where oil can be substituted, it is important to recognize that oil cannot be substituted unless it can be obtained. Furthermore, only oil that can meet the environmental standards established for the area where the plant is located can be used. In some cases these standards are very strict, so that only oil with a sulfur content of less than one-half of 1 percent can be burned. I believe it is common knowledge that low-sulfur, low-ash oil is extremely scarce today. Furthermore, most firms find it impossible to obtain a commitment for a long-term supply of such fuel.

Electricity

Until the spring of 1973, most of the shortages of electricity in the United States which affected industrial production were of relatively short duration and occurred when individual utility systems were overloaded or when forced outages of equipment resulted in blackouts of areas for relatively short periods of time. While these interruptions of electric service to nonferrous metals plants were disturbing, they did not seriously reduce the production in these plants or have any important effects on the economy of the United States. In the spring of 1973, however, approximately 500,000 kW of power being furnished by the Bonneville Power Administration to its direct service industrial customers was abruptly curtailed. No substitute electric energy was available from any other source. This resulted in a 3.75-percent reduction in the total supply of aluminum produced in the United States. Since the aluminum industry was operating at essentially full capacity, the diminished supply from the Pacific Northwest will mean that some fabricators and some fabricating plants will have to do with less aluminum unless they are able to import it from abroad. We know of one plant manufacturing aluminum cable, steel-reinforced (ASCR) which has shut down as a direct result of inadequate supplies of aluminum from the Pacific Northwest. There may be others. Another direct result of the curtailment of power deliveries to the aluminum industry in the Pacific Northwest has been the unemployment of about 600 workers. These are the plant workers who were laid off or not hired as a result of the inadequate power supply. For each of these workers, it is estimated that from one to two additional workers in trade and services has probably lost his job. In the Pacific Northwest unemployment is still a serious problem, with the unemployment rate in the Seattle metropolitan area, for example, still hovering at the 7½ to 8 percent level, even though the average unemployment for the United States as a whole has dropped to 5 percent. The current power shortage in the Pacific Northwest was caused by substantially reduced supplies of water for the hydroelectric system which is the main source of power for the Pacific Northwest region. A comparison of projected loads and resources in the Pacific Northwest, however, reveals that the situation which exists today as a result of inadequate precipitation may well continue into the future, even though average water conditions return, because of delays in the installation of thermal generating capacity.

It is important to note that under ordinary circumstances the three extra-high-voltage transmission lines interconnecting the Pacific Northeast and the Pacific Southwest electric systems would have been able to supply substantial amounts of power to ease the shortage in the Pacific Northwest at the present time. However, the shortage of low-sulfur, low-ash fuel oil for the generation of electricity in Southern Cailfornia has made it impossible to import the energy required to meet the shortage in the Pacific Northwest at this time. This shortage stems directly from the severe limitations placed by environmental authorities on the quality of fuel oil to be burned in Southern California. This matter of protecting the environment, however, is not restricted to Southern California. The Centralia, Washington, steam-electric plant which is fired by southwest Washington coal has been restricted in its operation to approximately 50 percent of its 1,400-MW capacity because it has been unable to meet environmental standards.

In addition to the curtailment of interruptible supplies of electricity which is now being experienced by the direct industrial customers in the Banneville Power Administration, these same plants have been handicapped because they have been unable to contract for future increments of power to expand their operations. This situation may also exist elsewhere in the United States, particularly with respect to large blocks of power for industrial use. The typical industrial plant is dynamic in its use of labor and materials rather than static. Each plant manager is continually experimenting with the addition of units of materials or labor to increase his plant's output. If he is unable to obtain electrical power or other energy, he may be handicapped in his attempts to improve the efficiency of the plant.

Coal and coke

The nonferrous metals producers have converted the majority of their plants from coal to gas or oil, but there are still a few plants which are burning coal in some industrial applications. These plants have been subjected to rules concerning the coal which they can burn in order to comply with local air pollution standards. We have not heard of any plants which have been unable to obtain coal, but some of them have had difficulty in obtaining coal of the type which they were permitted to burn and some have been forced to obtain variances in order to continue their operations.

Petroleum products

So far the most serious problem met by the nonferrous metal producers appears to be the difficulty of obtaining satisfactory substitute fuels when natural gas is curtailed. It is not always possible to obtain the heating oils required for substitution in the event of gas curtailment although we have not heard of any plants which have shut down for extended periods because of the oil shortage.

One of the very large uses of oil by nonferrous metal producers is for haulage of ore from the mines to the concentraters. The earth-moving vehicles require large quantities of diesel fuel. If diesel fuel or gasoline are to be rationed, the probability is that the rationing will be based upon past use. This, in turn, may inhibit the opening of new mines or may, in fact, result in reduced production in open pit mines which as they go deeper require longer haulage. Here again the impact of rationing may reduce supplies of nonferrous metals to the economy.

EFFORTS BEING MADE TO CONSERVE ENERGY BY THE NONFERROUS METAL PRODUCERS

Industrial firms are now taking a close look at the ways in which they use energy in their manufacturing plants and mines. Although this has been a normal subject for investigation by the efficiency experts for a long time, they are finding that there are still ways in which energy can be conserved so as to reduce the total quantity of energy required for each operation.

One method of conserving energy is to recapture waste heat. In the past it has not been economic to recapture waste heat in many applications simply because the cost of energy was too low. Now with energy costs increasing, it may be profitable to install the equipment to generate steam from heat that would otherwise be vented. Today more sophisticated equipment is available which can help reduce the peak demands of the manufacturing plants by keeping major equipment off the line for a few minutes at the time of the maximum demand of the plant. Factors of this kind are being more widely used in order to reduce the demand for electric energy.

In other plants better insulation of various types of heat-using equipment has resulted in reduced energy requirements. With prices of all forms of energy advancing, it is good business for the nonferrous metal producers to reexamine every energy use to see if there are ways and means of reducing their total energy requirements.

HELP THAT INDUSTRY REQUIRES FROM GOVERNMENT

Regulatory agencies, both at the federal and state level, appear to be completely preoccupied with the predicament of the household users of energy or of the individual operators of automobiles to the exclusion of the problems of the industrial users of energy. Part of this misdirected attention results from the difficulty curtailing commercial and residential gas loads since shutting off a gas system involves a very complicated process when the gas is to be turned on again and the dangers of explosions from open gas jets must be avoided. Similarly, it is almost impossible to selectively curtail loads on an electric system except very large industrial loads. Nevertheless, the damage to the economy which will result from curtailment falling exclusively upon large industrial users is of sufficient dimension that industrial operators must bring these problems to the attention of government.

Regulatory authorities who are now formulating or have formulated plans for the allocation of inadequate supplies of natural gas, oil, gasoline and diesel fuel or electricity must be made aware of the consequences of exclusively curtailing large industrial loads. It is obviously the responsibility of the management of industrial firms to bring this matter to the attention of the regulators.

This means that each industrial firm which is exposed to potential damage as a result of allocation policies adopted or under consideration by regulatory bodies must call to their attention the effects of industrial energy curtailments, not only upon the operations of the firm, but also upon the effect on the satellite operations of the firm or other firms which use the materials produced by the operation to be curtailed. These effects should be quantified not only in production of materials which will be foregone, but also the potential effects upon the gross national product of the United States. Where possible, data should be also be presented to show the effect of the curtailment upon employment in the affected plants and upon employment in the plants which are dependent upon the producer for supplies. It probably will not be possible to quantify the further effect of the curtailment upon the succeeding group of plants depending upon the same stream of goods. Nevertheless, the potential damage should be called to the attention of the regulatory agencies. The example used earlier in this report of energy curtailments affecting the production of copper, which in turn affects the production of copper wire, which in turn effects the production of electric motors and which in turn affects the production of the myriad of products which require electric motors for their assembly is a prime example which should be raised with the regulatory agencies. Even a casual examination of this chain reaction reveals the possibility of a serious economic depression in the United States growing out of energy shortages which are inadequately handled by regulatory agencies.

The voice of industry should also be heard before the congressional committees whoch are now in the process of formulating national policy with respect to energy use and supply. The point that it is more important to the individual to have a paycheck than to have all the energy he needs to warm or cool his house should be emphasized to the legislative groups which are considering national energy policy. Presenting this point of view is something requiring the cooperation of representatives of both industry and labor to their mutual advantage.

In conclusion, it appears to be clear that the tendency of regulatory agencies and congressional committees to take the easy way out on the allocation of scarce energy supplies, namely to curtail industrial use, must be reversed if the economy of the United States is to survive the rapidly growing shortage of all fuels. While the curtailment of energy supplies to the individual householder and the individual user of motor vehicles is much more complicated and much more difficult than the curtailment of energy supplies to industry, it nevertheless must be attempted and it must succeed if we are to avoid the undesirable economic effects of placing the entire burden of the energy shortage upon industry.

SPECIFIC INSTANCES OF INDUSTRIAL DISRUPTION DUE TO THE ENERGY PROBLEM

Dry year for Pacific northwest hydro power

In the Pacific Northwest an important industrial base is the electro process industries attracted to the region by low-cost, federally-produced hydropower. Northwest aluminum producers make up about 30 percent of U.S. aluminum ingot production. When a dry year curbs the ability of the Columbia River hydroelectric plants to supply all the region's power needs, the region could in the past rely on power from outside to make up much of the shortfall. The region is well interconnected with Montana, Utah, California, and British Columbia. The oil and gas shortage this year prevented these other areas from completely making up the shortfall, and the industries in the Northwest were forced to accept a 14.7-percent cut in their total power load. An estimated 350 workers were laid off and 315 not hired who otherwise would have been hired.

There was a gallant effort on the part of the industrial customers, the Bonneville Power Administration and the local utilities to find oil for power plants in neighboring regions in order to increase their electric generation and thus help overcome the power shortage in the Northwest.

The available makeup energy for the Northwest was purchased at very substantially higher cost than normal supply. During the emergency period the industries have authorized Bonneville Power Administration to purchase supplementary power for them up to an average cost of 12.0 mills per kilowatt hour. Industries pay about 2.2 mills per kilowatt hour for their regular power supplies from BPA. Such cost increases could lead to rises in the price of aluminum since they make themselves felt on all major aluminum-producing companies in the U.S., all of whom have plants in this area.

The international aspects of the energy problem made themselves felt immediately in this instance. One of the regionally interconnected suppliers, British Columbia Hydro and Power Authority, is subject to supply constraints completely beyond U.S. policy jurisdiction. Montana Power Company, another supplier, is heavily dependent upon Alberta gas. The oil being sought for California utilities must come from overseas.

There are also environmental aspects of the Northwest situation. The California utilities can only burn fuels of 0.5 percent sulfur or less. A fossil fuel plant at Centralia, Washington, within the region has only been operating at half capacity because of air pollution restrictions. The gas turbine installations of Portland General Electric Company, another regional supplier, have not received an operating permit from the local air quality regulators.

What is on the surface a regional problem of water scarcity is actually part of a web of interrelationships.

The predicament of southern California utilities

At one point in mid-spring of 1973 the oil shortage in the Los Angeles basin reportedly was so severe that one large Southern California electric utility was said to be preparing procedures for rotating a blackout. A blackout was avoided, but all three of the Los Angeles utilities are making investments to allow them to burn crude oil as well as heavy fuel oil. Los Angeles air pollution regulations restrict sulfur content of fuel oil to 0.5 percent, and this material has been hard to procure because of (1) shortage of refining capacity and (2) shortage of suitable desulfurization equipment. It is thought that crude oil with the low sulfur content required will be easier to obtain. Low-sulfur foreign crudes (again, the international complication enters in) are being sought after by all advanced countries.

Southern California power suppliers are still short of fuel. They currently offer to return one-half of the energy produced from any oil found for them by third parties, assuming transmission is possible.

Aluminum gas shortages

One of the largest aluminum refineries in the country is being subjected to the power shortage described above and in addition to gas curtailment. It has been subject to gas curtailment equivalent to 30 24-hour days at 100-percent curtailment. This gas is of Canadian origin (British Columbia). To maintain output, the company has been forced to import propane from much further away in Canada (Alberta) at 2.5 times the cost of its natural gas.

Tightening supply terms: Raw material shortages

A major timber producer in the Pacific Northwest has been subjected to a change in contract terms under which one of its plants will buy the same energy as previously but at higher cost from a local utility. At two other plants it is subject to interruption of power supply. Gas curtailment at another plant has been made up by substitution of petroleum purchased at much greater cost. Because of the power shortage, its suppliers of chemicals, for example caustics and chlorine, have had difficulty maintaining production. At one of its largest plants the company activated an old generator and marketed part of the power output to local utilities.

Louisville gas and electric

Recently Louisville Gas and Electric Company notified its industrial customers that it will permit no increases in contract volumes above 1972 levels. Unless substitute fuels are available and can be used in the industrial processes involved, expansion of output for industries in the Louisville service area will be impossible.

EMERGING INDUSTRIAL MANAGEMENT OF ENERGY USE: CONSERVATION

There are indications that industry is taking steps to review its energy usage and conserve wherever feasible. Such efforts will help correct the energy supply/demand imbalances, but cannot be expected to cure the problem by themselves. One major chemical company which has an active program of this type underway estimates industry can save 7 to 15 percent of its energy consumption by such methods.

E. I. du Pont de Nemours & Co.,
Wilmington, Del., August 24, 1973.

Jerome L. Klaff,
Chairman, National Commission on Materials Policy,
Washington, D.C.

Dear Mr. Chairman: As you know, Du Pont is a member of the Petrochemical Energy Group (PEG), an ad hoc group of independent petrochemical manufacturers whose principal relation with major oil companies is as customers, as distinguished from other petrochemical manufacturers who are divsions or subsidiaries of major oil companies.

On June 7, 1973, Du Pont's Senior Vice President, David H. Dawson, testified before the Oil Policy Committee on behalf of the nineteen PEG companies and seven other companies with similar concerns but who were not members of PEG. Dr. Dawson's testimony portrayed the plight in which the independent petrochemical industry finds itself in the current energy shortage. His testimony pointed out that many of the petrochemical industry's raw materials, called feedstocks, are made from crude oil in refineries along with other refinery products such as gasoline and fuel oil. He pointed out, however, that these petrochemical feedstocks could also be used for energy purposes and that this was happening as refiners sought to supply their markets for gasoline and heating. For example, propylene is an important petrochemical feedstock used, among other things, to make acrylonitrile which in turn is used to make acrylic fibers. Proplene is made in a refinery. Late this spring, Du Pont was advised by one of its suppliers that propylene deliveries would be reduced because the supplier-refiner intended to maximize gasoline production and needed additional feeds which he normally would have used to make propylene for Du Pont as well as other customers. Now, of course, demand is shifting from gasoline to fuel oil, but the same kind of thing could occur again. For example, last February we were advised by one of our ethylene suppliers that ethylene production would be substantially reduced because the feedstocks used to make ethylene were going to be diverted to maximize fuel oil production.

Currently, propylene is in very tight supply. As a matter of fact, we have heard that some of our competition is allocating acrylonitrile because it can't obtain adequate supplies of propylene from which to make acrylonitrile. Du Pont has found it necessary to import several million pounds of propylene as a direct result of domestic refiners' needs to maximize gasoline production.

Propylene is also involved in another aspect of the energy crisis. Propane is used in the manufacture of propylene. The increased value of propane as fuel has brought upward pressure on the price of propylene and in some instances almost doubled its cost. To us, this is indicative of what the future holds with respect to all materials produced from propane.

Often it is difficult to tell whether the market distortion is because of price controls or because of the energy shortage. For example, benzene is another petrochemical feedstock made in a refinery. It is currently in critically short supply. One reason is that benzene is being siphoned from domestic use to foreign markets in the form of styrene which is made from benzene. This is happening because styrene in the export market brings about 30¢ per pound compared to 7.5¢ to 9.0¢ per pound in the domestic market which is under price control. This impacts on Du Pont because benzene is used to make cyclohexane which, in turn, is used to make nylon. Du Pont purchases large quantities of cyclohexane and because of the benzene shortage, we are becoming increasingly concerned about its continued availability. As a result we have cut back nylon production.

Propylene and benzene are only two examples showing the impact of the energy crisis on the domestic petrochemical industry. We cite them only because they happen to impact directly on Du Pont and, thus, we have detailed information about them. Other members of PEG have reported that some of the traditional feedstock supplies of the independent petrochemical industry made in refineries have been pre-empted and diverted to energy uses. For example, butylenes, like propylene, have been diverted into alkylate for gasoline and are thus available in lesser quantity as raw material for butadiene, which is used in the manufacture of synthetic rubber and nylon fiber. Du Pont makes some kinds of synthetic rubber and has found its ability to supply affected by the shortage of butadiene. Also, the aromatics (benzene, toluene, and xylene) have been retained in gasoline for their contribution to octane rating and thus diverted from the petrochemical industry as raw materials for, among other products, intermediates for man-made fibers. Dr. Dawson's testimony cited numerous other examples of such diversions.

It is important for your Commission to be aware of the fact that dozens of other industries such as agriculture, automobiles, textiles, pharmaceuticals, and plywood employing literally millions of people depend upon a supply of products provided by the petrochemical industry. An interruption of petrochemical production would have a severe impact on other sectors of the nation's economy. For example, farmers need fertilizers and pesticides; food companies need preservatives and packages; automobiles need tires and power lines must be insulated. All these needs are based on petrochemicals. The industry calls these kind of needs the "hidden part of the energy crisis", and is doing everything possible to create an awareness of the importance of the petrochemical industry to the national economy. Very few appreciate, for example, that 78 percent of the nation's rubber is synthetic and based on petrochemicals; that almost half of the fibers we consume are based on petrochemicals and that the ability of the American farmer to produce more food and cotton than any other farmer in the world is greatly dependent upon agricultural chemicals—fertilizers and pesticides which are also based on petrochemicals.

Du Pont is also experiencing increasing interruptions in deliveries of natural gas by suppliers. For example, at our Orange, Texas plant, Du Pont's natural gas supplies are curtailed in accordance with priorities established by the Railroad Commission of Texas, the state regulatory authority for intrastate gas. This curtailment has reduced production at this plant.

At other Du Pont plants, we have found it increasingly difficult to obtain backup fuel supplies. Lack of backup fuel means, of course, that if our fuel supplies are interrupted, for whatever reason, the affected plant shuts down. The economic impact on us and others is obvious.

Finally, as you know, Du Pont for many years has had an extensive program to achieve more effective use and conservation of energy in its own activities. Based on Du Pont's own experience, we believe that a significant conservation effort at an industrial plant can result in a 15 percent reduction in the plant's total energy usage. We would urge that industry give more attention to this aspect of the energy situation.

Very truly yours,

J. M. BRENTLINGER, Jr., *Director.*

GULF OIL CHEMICALS CO.,
Pittsburgh, Pa., August 24, 1973.

Mr. JEROME L. KLAFF,
Chairman, National Commission on Materials Policy,
Washington, D.C.

DEAR MR. KLAFF: It is our understanding that you are preparing a report to the President and the Congress dealing with the impact of hydrocarbon shortages on the petrochemical industry. We further understand that you have solicited comments from companies in this field such as Gulf which would outline specific instances of the effect of such shortages on our businesses.

Enclosed is a memorandum setting forth some general ideas on the above subject. This memorandum points up the potential magnitude of the effect on the economy as a whole which would result from significant and prolonged shortages of petrochemical feedstocks. It also suggests the complexity of this problem and the need for very careful consideration of the total impact of any hydrocarbon allocation procedures which might be implemented.

We are continuing to evaluate this situation and hope to be in a position to submit additional comments to you in the near future. In the meantime, we hope that the enclosed material will be of use to you.

Very truly yours,

E. M. GLAZIER.

Enclosures.

Some Comments on the Need for Adequate Allocations of Feedstock and Fuel for the Chemicals Industry

The petro-chemical industry is the producer of materials going into almost every manufactured product made in the U.S. Shortages in the plastics, elastomers, surface coatings, fibers, etc., made from petroleum can have a rapidly depressing effect on the output of goods, and lead to layoffs of the labor used in their production. It is, therefore, necessary for the healthy growth of the economy that a continued growth in the availability of such materials be planned.

In fact, if normal growth in petro-chemical production cannot take place, this could have the effect of almost bringing to a halt growth in manufacturing, thus limiting increases in Gross National Product as all the industries dependent upon petro-chemical products would be unable to expand their operations and certainly hesitate to invest capital in new equipment in view of this supply constraint.

Some indications of the multiplier effect that the production of petro-chemicals has on the oil used in it, when compared with its fuel use, can be seen in Exhibit I. This exhibit, prepared a few years ago, indicates that the average price of total refinery products at that time was about one cent per pound. Olefins made from this were worth 2.5 cents per pound, and Monomers such as styrene and vinyl chloride about 6 cents per pound, and so on, the value increasing on a trend line basis so that fabricated products average approximately 40 cents per pound. Thus, there is a 400% increase in the contribution to the Gross National Product of oil thus up-graded as compared to its use as fuel.

The other line in the chart shows the number of pounds of processing capacity that can be bought per dollar of investment. Thus, at the refinery level, 100 pounds of product can be produced per $1.00 of investment, or in other words only one cent needs to be invested per pound of material processed. At the other end of the chart it can be seen that each $1.00 of investment only upgrades 2½ pounds of product. In other words, 40 cents worth of equipment must be installed to up-grade the product through that step. It is obvious therefore, that the multiplier effect of the basic investment in an Olefins plant such as that we propose can provide a base for several billion dollars worth of up-grading facilities, thus providing opportunities for capital growth and thousands of new jobs in downstream plants.

Chemicals in recent years have been major contributors to the U.S. balance of payments, and with world wide growth in demand for such products, they can probably be even more important in providing money-earning U.S. exports. Another facet of this picture is the fact that many of the products now made from petrochemicals would, if in short supply, have to be supplemented by natural or synthetic materials which would have to be imported. Examples of this are wool from Australia, rubber from Malaysia, synthetic fibers from Europe, and so forth. Obviously, the cost of importing such materials would be very much higher than importing additional feedstock and fuel for their production in the U.S. The prices of wool imports now range from $1.50 to $3.00 per pound, rubber about 30–41 cents per pound, and synthetic fibers 80 cents to several dollars per pound. Obviously, where shortages cause the import of finished apparel and other goods, the dollar drain is much greater.

Having reviewed above the importance of making possible a continued supply, it is important to review the rates of growth typical in the chemical industry. Perhaps the best indication of actual use of petroleum feedstocks for chemical production is the U.S. Department of the Interior, U.S. Bureau of Mines data on the subject. These indicate that over the last years, 1963–1973, LPG use in chemicals has increased almost 14% per year and other feedstock use has increased 7.0% per year. This compares with a 4.5% per year increase for the total of petroleum primary liquid hydrocarbons consumed in the period. It is obvious, therefore, there should be some special program to allow for this more rapid growth in the chemical sector.

In the fact of uncertainty concerning the availability of feedstocks for chemical production, it would be unlikely to expect the chemical industry to carry out plans for the construction of major new plants necessary to produce the essential chemical building programs from which the necessary supply of plastics, fibers, synthetic rubber, and other chemicals are made. Already the need to consider the processing of liquid feedstocks is making such projects considerably more expensive than plants built in the recent past. Without the assurance of freedom to price the products so as to return an adequate profit, and the assurance of adequate feedstock and fuel supplies upon which to operate such plants, it seems unlikely that sufficient capacity will be planned and built to prevent severe shortages. Therefore, it is important not only that these allocations should be adequate in quantity both for existing and for new plants, but that they should be in some way assured for a certain period to encourage companies to invest the millions of dollars necessary to move forward with well thought-out expansion plans.

In reviewing the history of allocation of imports for chemicals, one is impressed with the fact that perhaps the effort made to tailor the regulations to specific problems of individual companies or groups of companies resulted in a tendency for the regulations to become increasingly complex and difficult to administer. Therefore, we feel that it is important that a relatively simple allocation system for chemical feedstocks and fuels be used if allocation becomes necessary.

We would like to caution, however, that most of the existing petro-chemical plants, and even the plants being designed, have limited flexibility in the nature and range of the petroleum materials which they can efficiently utilize in the production of petro-chemical products. This means that this market is less flexible than those for many fuel applications and projections should be made to make available those required for efficient plant operation. Also, it is felt that there are more viable alternatives in other end use areas which can permit the reduction of use without disturbing the economy; specifically automotive use—for use of gasoline is probably much more elastic without effecting the level of the economy since it is possible to reduce the amount of discretionary use and increase the use of mass transit, car pools, etc. for the necessary commuting without significantly disturbing the economy or affecting the growth of the country.

We have mentioned that specific feedstocks will be required for each petrochemical operation. Exhibit II indicates projections that have been made reflecting some estimates of feedstock use in ethylene production. We believe that even more of the growth will have to come from naphtha and gas oil as LPG looks increasingly as though it will be priced out of the market.

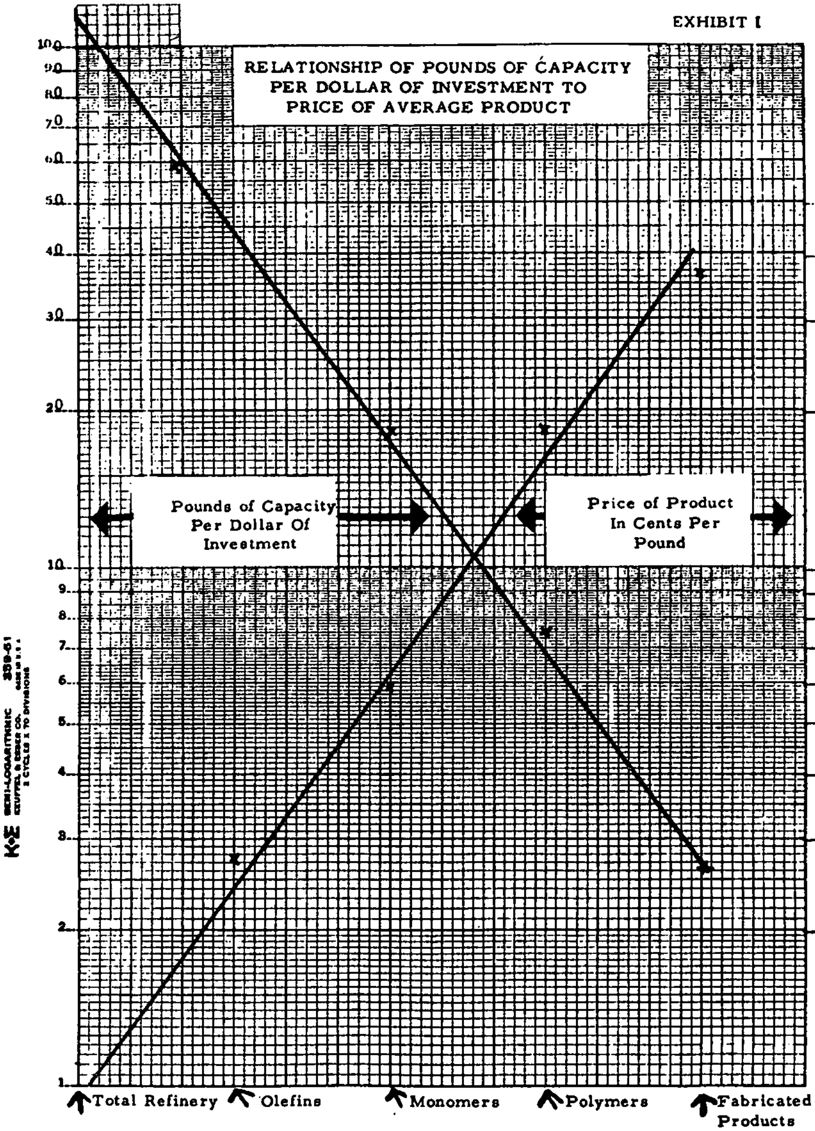
It is very important, therefore, that any allocation program includes adequate provision for these two materials which will be the keystone of growth for this vital industry.

While these materials will have a vital importance for the country's future, they represent only some 5 or 6 percent of the oil run to refineries in the production of petroleum products.

Gulf's proposed new ethylene plant will take a gross of roughly 4% of our refinery runs, but between 25% and 40% will be returned as petroleum products making the net requirement about 3%.

We feel that it would be impractical to solve allocation problems by cutting back on such a small but vital end use area.

EXHIBIT I


RELATIONSHIP OF POUNDS OF CAPACITY
PER DOLLAR OF INVESTMENT TO
PRICE OF AVERAGE PRODUCT
Pounds of Capacity
Per Dollar Of
Investment
Price of Product
In Cents Per
Pound
Total Refinery
Olefins
Monomers
Polymers
Fabricated
Products
100
90
80
70
60
50
40
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20
10
9
8
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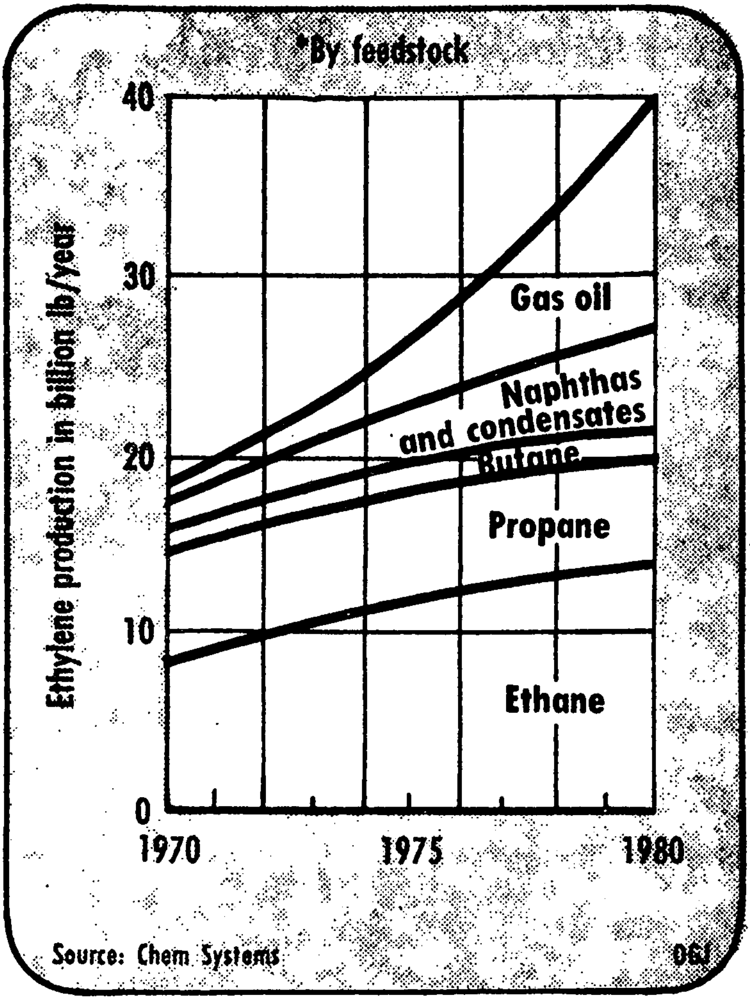
EXHIBIT II

Ethylene production*



Chairman PROXMIRE. Thank you very much, Mr. Boyd.

Mr. Commoner, please proceed.

STATEMENT OF BARRY COMMONER, DIRECTOR, CENTER FOR THE BIOLOGY OF NATURAL SYSTEMS, WASHINGTON UNIVERSITY, ST. LOUIS, MO.

Mr. COMMONER. Thank you, Senator Proxmire. I have turned in a copy of my prepared statement and I would like to submit several articles with it for the record, if that is satisfactory.

Chairman PROXMIRE. That will be printed in full in the record at the end of your oral statement.

Mr. COMMONER. Let me summarize my point of view.

In the first place, I think it is clear to all of us that there is a relationship between the use of resources, the availability of resources and the economic system. What is not so clear is what that relationship is.

A view that has been most commonly expressed in recent years, in the report of the National Commission on Materials Policy as well as in the book "Limits to Growth," is that the operation of the economic system and, in particular, its continued growth is dependent on the availability of resources.

The point of view I want to emphasize here is the reverse; namely, that there have been since World War II very important economic trends which have had a strong and deleterious effect on the balance between demand and supply of resources and on the environmental impact arising from the use of resources.

What I am saying is that both environmental problems and resource supply and demand problems are the consequence of economic policy rather than the reverse.

The reason is that there has been since World War II an intense drive in the economic system to increase labor productivity, which is a chief factor in the profitability of industry. This has led to the introduction of new technologies which are designed to minimize labor input. Unfortunately, these same technologies have also intensified environmental impact, and have reduced the efficiency with which resources, especially of energy, are converted to productive outputs.

You may ask why an environmentalist should be talking in this way. And the answer is fairly simple.

The analysis which I and others have made of the environmental crises shows that behind it lies these changes in technology since World War II.

We have discovered that these changes have increased the amount of pollutants emitted per unit of goods produced, and I can give you a series of examples. Perhaps the simplest example is the relationship between soap and detergent. About 80 percent of the cleaning market has been taken over by detergents from soap since World War II and, as a consequence, every time you wash a shirt you are putting about 20 times more phosphate into the surface water, which is a pollutant, than you did in 1946.

In other words, for the same social value, namely a clean shirt, we are polluting the water 20 times more than we did in 1946.

Another example has to do with bottles. We consume approximately the same amount of beer per capita as we did in 1946, but we now generate five times as many beer bottles to take care of that beer consumption. The reason is that we throw them away, after one use instead of reusing them. Those beer bottles become trash. And the fuel that is used to produce them pollutes the air.

Examples of the main point that I am making: The chief cause of the environmental crisis is a change in the pattern of productive technology such that we incur greater environmental cost per unit of goods produced than we did before.

These same changes have also resulted in a wasteful use of resources, particularly of energy.

To begin I want to use the concept of resource productivity which is analogous to the concept of labor productivity.

Resource productivity measures the economic value we get out of a unit investment of resources. In the case of U.S. manufacturing, using the measure of economic output, value added, we can ask how much value added had been generated per kilowatt hour of electricity. What we discover is that in 1947 this value was 70 cents of value added per kilowatt hour. This is the average for all manufacturing sectors, given in 1958 dollars to account for inflation; but by 1967 it had dropped to 45 cents per kilowatt hour.

In other words, to generate the same economic output for manufacturing we were using more electricity, more resources.

The chief reason is those industries which are least efficient in generating value added from electricity—i.e., those with the lowest resource productivity have grown more rapidly that the more efficient sectors. Among the least efficient industries are chemicals, petroleum refining, paper and pulp, and primary metals.

The motivation has been economic; when you look at the relationship between the decreased efficiency in the use of power and the efficiency with which labor is used; namely, the relationship between labor productivity, you find they are reciprocal. As power productivity in manufacturing has declined, labor productivity has increased, about doubling since 1946.

In other words, because of economic motivations we are displacing workers with energy. This appears to be economically advantageous. It is significant that the four industries with the least productivity when measured in terms of total fuel consumption (that is, the chemical, petroleum, paper, and primarily metals industries) were listed in the recent accounting of profits in industry by Business Week as having the highest increase in profits in 1973 as compared with 1972. Compared with the overall average for manufacturing industries these four industries have very low value added produced per billion Btu's. As well as smaller numbers of workers and total amount of wages per billion Btu's and relatively low wages.

That is, the economic and social value generated by these industries per unit of fuel consumed is very low, and it is these industries which now show the highest rate of profit.

Let me cite one or two other examples. In agriculture, the resource productivity of nitrogen fertilizer (the amount of crop produced per unit of fertilizer used) has decreased by 80 percent since 1946. In other words, due to a change in technology, we are now using five times as much nitrogen fertilizer, to produce the same crop output as we did in 1946. This has been accompanied by the retirement of land for farm use. We have simply displaced land with fertilizer.

The reason for this transformation is quite straightforward. In the corn belt, nitrogen fertilizer represents the most important economic input to the farmer. It pays to use fertilizer rather than land.

In freight transportation we find that railroads are being displaced by trucks and, as a result, there is a sharp decrease in the fuel productivity in moving cargo. It takes four to six times as much fuel to move a ton-mile by truck as it does by railway. This technological change has given us less freight haulage per unit fuel consumed than before, and again the reason is economic; trucklines are more profitable than railroads.

In the case of materials, we see a striking displacement of natural products, such as wood, cotton, and soap, with synthetic materials. Synthetic materials have a lower resource productivity than natural ones. Cotton, for example, is made from carbon dioxide and water, freely available from the environment. On the other hand, a synthetic fiber is made from raw materials derived from petroleum and also, requires fuel for its manufacturing. Therefore to get the same amount of fiber, we now use more resources than we did before. Again the motivation is economic; synthetics are more profitable to produce than cotton.

Also of importance is the fact that the petrochemical industry is designed so that it generates extensive byproducts which, if used as raw materials, cut the cost of production. As a result in many cases the petrochemical industry does not meet demands by generating new products: it generates new products and creates a demand for them. It is because of this process that we are now engulfed with plastic swizzle sticks and wrappings.

Thus, for economic reasons we have made our economy dependent on the intensive use of nonrenewable energy resources. In addition these new technologies have driven the older ones out of the market. Soap has been displaced by detergents, and so on. As a result, in a number of very crucial places in the complex fabric of the Nation's system of production, we have become wholly dependent on fossil fuel.

To emphasize this point, let me again use a corn belt example. Grain drying uses a small percentage of the fuel supply in this country. Nevertheless, it is an important competitor for the fuel it requires. In the last few years the method of harvesting corn has been changed. In the past it had been taken off the stalk as an ear after it had dried naturally on the stalk. Now new harvest combines have been introduced. These take the grain off the ear in a somewhat moist condition so that the grain must be dried artificially by hot air.

This means that the farmer is now dependent on fuel for drying grain at exactly the right week in the fall or his grain will spoil. As a result, grain production has become totally dependent on the availability of propane, which is the only fuel that is practical. That means that the farmer is competing not for fuel, in general, but specifically for propane.

Fifty percent of the propane in the country is consumed for rural uses, including grain drying; 25 percent is used for petrochemicals.

Therefore, the farmer is faced with a serious competitive problem, despite the small amount of energy which is involved in grain drying, compared to the total national fuel budget.

In recent weeks we have seen a good deal of profiteering in the plastics industry. There appears to be a gray market in plastics with prices going up fourfold in a matter of weeks. As a consequence, corn production is forced to compete for high priced propane with swizzle sticks and olive stabbers, putting food production at the mercy of profiteering in plastics.

What I want to emphasize is the economic system has become vulnerable at very important points to manipulations of the supply of energy resources.

It is also important to note, even briefly, the fact the same principle I am discussing here; namely, that economic factors which determine demand, also applies to the question of supply.

Without going into details, it would be a very serious mistake to regard the present shortage of fuel in the United States as evidence that we are running out of domestic supplies of fuel. I have looked very carefully at the record on exploration for domestic oil. It is astonishing to find that in 1957 there was an abrupt reduction in the rate of exploration as measured by the number of exploratory wells drilled as well as the number of geophysical crews put into a field. That curve drops continually over 50 percent since 1957. Not surprisingly, the amount of oil found each year has also decreased.

The ratio between the rate of exploration and the rate of finding oil since 1957 has been constant. In other words, the yield per unit exploration has been constant, and I will assert, based on these data, that the declining development of domestic oil reserves is based on a deliberate decision to cut back on oil exploration. I believe there are good economic reasons for oil companies to engage in such activities abroad rather than in the United States.

The point to be made is that it would mislead the country to say that the present energy crisis means we are approaching the limits of our resources, the limits to growth. Oil is limited, but there is at least 20, perhaps 30 years' supply. Therefore, in 1973 there is no reason for a shortage other than a contrived manipulation of the availability of oil.

The environmental crisis has been the first outward evidence of sweeping changes since World War II in productive technology. These changes have sharply increased the environmental impact of agriculture, industry, and transportation per unit of goods and services produced. The reason for the environmental crisis is not an increase in population, nor an increase in our affluence; it is largely that we have changed the way in which we produce our goods.

These changes have also reduced the efficiency with which we use energy resources. This in turn is the result of unforeseen consequences of technological changes that were introduced for the sake of enhanced labor productivity and profitability. The result has worsened the environmental impact of our productive system, and has increased the demand for resources.

But more seriously, this has rendered the entire fabric of the Nation's productive system vulnerable to uncertainties about the availability and price of energy resources whether real or contrived.

Thus, the corn belt farmer is having difficulty planning for next year because he does not know whether fertilizer and propane will be available or at what price.

The significance of the present energy crisis is not that we are running out of nonrenewable resources. Rather, it is an engineering test of the vulnerability of the economic system. It shows that the transformation of productive technology has made the economic system enormously vulnerable to apparent or real shortages, to increased prices, and to uncertainties in the supply of fuel and other resources. In effect, what has been signaled by the environmental crisis, and demonstrated by the energy crisis, is that in generating the postwar transformation of productive technologies, the economic system has traded, for enhanced short-term gains in profitability, its long-term stability. The joint crises in the environment and energy may be the first signs of a coming crisis of production.

Thank you.

[The prepared statement and articles for the record of Mr. Commoner follow:]

PREPARED STATEMENT OF BARRY COMMONER

It is self-evident that the availability and rate of use of resources is closely related to the operation and growth of the nation's economic system. What is not so clear is the nature of this relationship.

The view that has been most commonly expressed in recent years (for example in the *Report of the National Commission on Materials Policy* and in *The Limits to Growth* by Meadows, *et al.*) is that the operation of the economic system, and in particular its continued growth, is dependent upon (and specifically, limited by) the availability of resources.

The view to be developed in this testimony emphasizes the reverse relationship: i.e., that post-war *economic trends have had a strong—and deleterious—effect on the balance between resource demand and supply, and on the environmental impact arising from the use of resources.* The post-war drive for increased labor productivity (which is a chief factor in profitability) has led to the introduction of new technologies that have been designed to minimize labor input. Unfortunately the new technologies have also intensified environmental impact and have reduced the efficiency with which resources, especially of energy, are converted to productive outputs.

As shown elsewhere (see Barry Commoner, *The Closing Circle*, Knopf, 1971) the first outward symptom of these economically-motivated changes in productive technology has been the environmental crisis, which has sharply intensified the amounts of pollutants emitted into the environment per unit of goods produced. For example, because soap has been displaced by detergents the amount of phosphate that enters surface waters, as a pollutant, per pound of cleaning agent used in the United States—or, per shirt washed—has increased about 20-fold since 1946; similarly, because returnable bottles have been displaced by nonreturnable ones the number of beer bottles used per unit of beer consumed has increased about five-fold since 1946, intensifying by a comparable ratio the environmental impact due to bottles discarded as trash and to the fuel burned in producing them (for details of these and similar examples, see Barry Commoner, *Chemistry in Britain*, Vol. 8, No. 2, Feb., 1972).

Thus the environmental crisis is not so much due to increased population, which has risen about 50% since 1946, or to increased affluence (per capita use of cleaners and beer, for example, has been about constant) but to new productive technologies which have worsened the ratio of pollutants emitted to goods produced.

These same technologies have also been wasteful of resources, especially of energy, as shown by the ratio of economic value yielded per unit energy used. Some examples are the following:

(1) If one measures the economic value to be derived from the use of electricity in U.S. manufacturing industries in terms of *value added*, one can com-

pute the efficiency of use, or the *resource productivity*, of electricity from the ratio: value added/kwhr. In 1947 this ratio was $.70/kwhr; in 1967 it was $.45/kwhr (in 1958 dollars to account for inflation). A chief reason for this decline in resource productivity of electricity is that those manufacturing sectors which are particularly inefficient in their use of electricity (e.g., chemicals, petroleum refining, paper and pulp, primary metals) have grown more rapidly than the more efficient industrial sectors. The motivation has been economic: As power has been introduced into the manufacturing process there has been a comparable *decrease* in labor input; electrons displace people. Thus as *power* productivity (value added/kwhr) has decreased, *labor* productivity (value added/man-hours) has increased (in all U.S. manufacturing, from about $4.00/man-hour in 1947 to about $8.00/man-hour in 1967). As a result inefficient use of energy resources seems to be correlated with profitability. It is significant that four industries that are at the bottom of the list of manufacturing sectors in value added, in jobs and in total wages paid per billion BTU of fuel consumed—petroleum refining, chemicals, primary metals and paper—stand out in recent reports are recording the highest gains in profits in 1973 as compared with 1972; the increases range about 50% (see attached table).

(2) In agriculture, the resource productivity of nitrogen fertilizer—i.e., the amount of crop produced per unit of fertilizer used has decreased by 80% since 1946. Since nitrogen fertilizer is made from natural gas this change has greatly increased the dependency of agriculture on energy supplies. Again the motivation is economic. For example, in corn production investment in nitrogen fertilizer gives a much greater return in income than a comparable investment in land, labor or machinery.

(3) In freight transportation, truck freight has grown much faster than railroad freight (7.0% annual increase as compared with 0.8% annual increase) since 1946. This has caused a large decrease in resource productivity with respect to the use of fuel for freight haulage, since trucks use four to six times more fuel per ton-mile of freight hauled than railroads. Once more the cause of this technological displacement process—and of the worsened resource productivity and environmental impact—is economic, for truck lines are considerably more profitable than railroads, and naturally attract more investment.

(4) In materials used, witness the striking displacement of natural products (wood, cotton, soap) by synthetic ones (plastics, synthetic fibers, detergents).

RELATIONSHIP BETWEEN PROFIT AND ENERGY PRODUCTIVITY

Industry	Percent increase in profit 1973: 1972 [1]	Energy productivity [2]		
		Value added: Fuel energy dollars per 10^9 Btu	Workers: Fuel energy NO/10^9 Btu	Wages: Fuel energy dollars per 10^9 Btu
Chemical	44	7,072	163	1,067
Metals and mining (steel)	54(71)	[3] 5,893	[2] 307	[3] 2,200
Petroleum	47	3,546	65	514
Paper	72	7,069	368	2,322
Average, all manufacturing industries		17,907	954	5,564
Composite, all industries	17			

[1] Computed change for first 9 months of 1973 compared with first 9 months of 1972. The composite value includes service industries as well as manufacturing. From Business Week, Nov. 10, 1973.
[2] Computed from U.S. Census of Manufacturing data for 1967.
[3] These figures are for the manufacturing category "Primary metals"; this corresponds approximately to the Business Week entries for "metals and mining" and "steel."

The synthetic materials have considerably lower resource productivities than the natural ones. While the raw materials for the natural products are freely renewable resources such as water and carbon dioxide, the raw materials for the synthetic products are non-renewable resources: oil and natural gas. While the energy needed to synthesize the natural products is derived, through photosynthesis, from the sun (a renewable resource), the energy needed to manufacture synthetic materials requires further consumption of non-renewable fuels. Again, the driving force in this trend is economic: Production of synthetic products is more profitable than natural ones. Moreover, vertical integration and extensive use of by-products in the petrochemical industry tends to produce low-cost-products that drive natural competitors off the market; hence the plastic swizzle sticks and wrappings that engulf us.

As a result of these technological displacements the productive output of the U.S. economy has become increasingly dependent on non-renewable energy resources. As products and processes that depend on freely available fossil fuel have been introduced, their *economic* advantages over the more efficient produucts and processes which they have displaced (i.e., those of greater resource productivity) have often driven the latter out of the market. As a result, in a number of crucial places the complex fabric of the nation's system of production has become wholly dependent on fossil fuels.

For example, several years ago the older method of harvesting corn—by the ear, after it had dried on the stalk—was replaced in the Corn Belt by combines. These harvest the grain itself, but in a somewhat moist condition—therefore requiring immediate drying to prevent loss of the crop through spoilage. This change has made corn production totally dependent on propane for grain drying—which must be available to the farmer in a given week and at a price that he can afford or the crop will spoil. Similarly synthetic rubber has nearly driven natural rubber off the market, making our total rubber supply wholly dependent on the availability of the petroleum-derived petrochemical raw materials from which it is made.

These changes in the technology of production have made the entire productive system highly vulnerable to shortages in the supply of energy, especially in the form of fossil fuels. The energy problem is translated into a *production* problem; if the farmer cannot obtain propane precisely when he needs it, his crop is ruined. Moreover, even *uncertainties* in the availability and price of propane and nitrogen fertilizer may seriously disrupt planned plantings and reduce agricultural output. In this way a tight situation in overall fuel supply may be far more damaging to production than would be expected from the very small part of the total national fuel budget that is represented by a given productive process such as grain drying. Grain drying does not compete for the *total* fuel supply but for a specific small part of it—propane—in which it *is* an appreciable demand. About one-half of the propane supply is needed for rural use and this must compete with petrochemical demand, which requires about one-fourth of the propane supply. Because of the new productive technologies, corn production must compete for propane with swizzle sticks and olive-stabbers, and food production may be at the mercy of profiteering in plastics.

The foregoing view is also relevant to the problem of energy *supply*. It would be a serious mistake to regard the immediate energy crisis, whether real or contrived, simply as evidence of the depletion of this resource—as a sign that we are approaching the "limits to growth". We are now short of domestic oil not because underground reserves are being used up; we are finding less oil in the United States in each succeeding year not because there is less to be found. Rather, we are finding less oil (and gas) because the effort to find it, as measured by the number of trial wells drilled and the number of geophysical exploration crews in the field, has declined sharply—by about 50%—since 1957. Since the amount of recoverable oil discovered per unit of exploratory activity has remained essentially constant since 1957 this decline cannot be ascribed to a dwindling resource. Rather, there is considerable evidence that *economic* factors—in particular reduced costs and increased profitability of foreign operations—has induced U.S. petroleum companies to reduce domestic exploratory efforts, resulting in a sharp decline in new domestic reserves. Similarly, the failure to develop the resource of solar energy is obviously not due to the depletion of this resource; nor is it due to technical difficulties. Rather, it has simply not paid energy corporations to help develop apparatus such as solar heaters which could greatly reduce the dependency of home heating, for example, on fuel.

In sum, these considerations lead to the following view: The environmental crisis is the first outward evidence of sweeping changes, since World War II, in productive technologies. These changes have sharply increased the environmental impact of agriculture, industry and transportation, per unit goods and services produced. They have also reduced the efficiency with which resources, especially energy, are converted into productive output. All this is the apparently unforeseen consequence of technological changes introduced for the sake of enhanced labor productivity, and profitability.

These changes in productive technology have worsened the environmental impact of the nation's productive system and have increased its demand for resources, especially fossil fuel. But, even more seriously, they have rendered the entire fabric of the productive system vulnerable, at key points, to restrictions and even to uncertainties, whether real or contrived, in the supply and price of energy resources. The significance of the present energy crisis is not that we are in fact now running out of non-renewable energy resources, for this situation, too, appears to be the outcome of deliberate economic policy in the oil industry. The true significance of the present energy crisis is that it is likely to demonstrate just how vulnerable the economic system has become—since its technological base has been transformed by the drive to increase labor productivity and profits—to real or apparent shortages, to increased prices and uncertainties in the supply of fuel and other resources.

In effect, what has been signalized by the environmental crisis, and demonstrated by the energy crisis, is that in generating the post-war transformation of productive technologies the economic system has traded, for enhanced short-term gains in profitability, its long-term stability. The joint crises in the environment and energy may be the first signs of a coming crisis of production.

[From the AIP Journal, May 1973]

"Would you tell me, please, which way I ought to go from here?"

"That depends a good deal on where you want to get to," said the Cat.

"I don't much care where ——" said Alice.

"Then it doesn't matter which way you go," said the Cat.

"— so long as I get *somewhere*," Alice added as an explanation..

"Oh, you're sure to do that," said the Cat, "if you only walk long enough."

Alice in Wonderland
Ch. VI, Pig and Pepper
Lewis Carroll

Alternative Approaches to the Environmental Crisis

Barry Commoner

The author compares the results of two qualitatively different types of analyses of the resource/environmental quality problem: (a) the approach, exemplified by *The Limits to Growth*, which accepts, as given, world statistical summaries of trends in population size, agricultural and industrial production, and rates of pollutant emission; extrapolates these trends into the future; and determines the outcome by means of a computer model that encompasses certain *assumed* interactions among them; and (b) the approach, illustrated in this article, which assembles data on the scale on which, in the real world, the relevant system operates and *derives* from these data the relationships that appear to govern the interactions among the various parameters, leading to generalizations about the mechanisms that mediate the interdependence of human society and the earth's resources.

It is now generally known that the world is in the grip of an environmental crisis. The potential outcome of the crisis is widely recognized: the self-destruction of human civilization. Its basic meaning is increasingly apparent: something is radically wrong with the way in which we use the earth's resources. The kind of action that survival demands is becoming painfully clear: equally radical reorganization of human society to bring it into harmony with the ecological imperative.

It is gratifying to find, in the last few years, that statesmen and industrialists—and, in my opinion more significantly—the general public are now equally concerned with the environmental crisis and anxious to resolve it. Indeed so intense is this concern, and so urgent the pressure for action, that there is now a new danger—that action may precede understanding and compound the present crisis with new blunders. It is with this in mind that I wish, in this presentation, to consider the origins of the environmental crisis, and what we can learn from such an analysis about the kind of action that might begin to resolve it.

One of the perplexing aspects of the environmental crisis is that it encompasses both intensely local issues and sweeping global ones. This concurrence generates serious, disconcerting questions. For example: Does the *world* environmental crisis require that Britain give up its dependence on foreign resources, especially food? How would such a change affect *local* decisions on land use and industrial production? Is a global environmental collapse so imminent as to sweep aside local priorities for environmental improvement? Clearly it does make little sense to consider a local environmental problem wholly apart from the world context. It does, after all, make a difference, let us say to future British architecture and planning, whether new buildings must eschew the use of Canadian aluminum, and automobiles the use of Arabian petroleum, and whether the future population of Britain must, out of global necessity, be reduced to half its present size.

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Credit

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Such issues have been sharply laid before us by the publication, under the sponsorship of the Club of Rome, of *The Limits to Growth* by Meadows et al.[1] The study was designed to analyze the problem on a *world* scale, in the belief that "the essential significance of the project lies in its global concept, for it is through knowledge of wholes that we gain understanding of components and not vice versa.... The report presents in straightforward form the alternatives confronting not one nation or people but all nations and all peoples, thereby compelling a reader to raise his sights to the dimensions of the world problematique." The reader of *The Limits to Growth* is encouraged to look beyond the immediate evidence of environmental degradation—the stagnant water and dying fish, the smog-choked city, the workers unemployed by the closing of a polluting industrial plant—and to consider whether the global trends are "actually so threatening that their resolution should take precedence over local short-term concerns."

This raises a basic issue regarding the analysis of the environmental crisis. All such studies are concerned with how the chief parameters that govern the reciprocal effects of human activities on the earth's resources and environment—such as population, consumption of resources, and emission of pollutants—interact and how these interactions can be redirected to divert us from our present, self-destructive course. On what geographical scale do these factors interact? For example (to introduce a case which is to be analyzed in detail below), if increased food production is achieved by intensified use of nitrogen fertilizer, which in turn exacerbates environmental degradation through the leaching of nitrate into surface waters, do these interactions occur on a global scale, a regional, or national one? And if (as it does in this case) the interaction takes place on a national or smaller scale, what is the meaning of analyses—such as those put forward in *Limits to Growth*—which describe the relationships among world statistics that lump together widely disparate national data on food production, fertilizer use and pollution?

These questions are not readily answered, and in my own opinion it cannot be assumed, a priori, that either computer modeling based on generalized world statistics or direct examination of the relationships, as they actually occur, on their real, rather than statistical, scale, is the more valid analytical technique. We are in the early stages of our effort to understand the environmental crisis, and much can be learned from a direct comparison of alternative approaches.

In this presentation, I propose to compare the results of two qualitatively different types of analyses of the resource/environmental quality problem: (a) the approach, exemplified by *The Limits to Growth,* which accepts, as given, world statistical summaries of trends in population size, agricultural and industrial production, and rates of pollutant emission, extrapolates these trends into the future, and determines the outcome by means of a computer model that encompasses certain *assumed* interactions among them (for it should be noted, from *The Limits to Growth,* that although these interactions are clearly stated, they are nevertheless assumptions rather than conclusions derived from an analysis of the given data); and (b) the approach, illustrated in what follows, which assembles data on the scale on which, in the real world, the relevant system operates, and *derives* from these data the relationships that appear to govern the interactions among the various parameters, leading to generalizations about the mechanisms that mediate the interdependence of human society and the earth's resources. I might anticipate the outcome here by remarking that the two approaches lead to strikingly diverse results.

It is useful to begin with a brief comparison of the basic features of these two approaches to the environmental problem. The approach exemplified by *The Limits to Growth* is based on a mathematical model. This describes a network of relationships among a series of parameters that are involved in the reciprocal relationships between human society and the resources on which it depends. The Meadows study deals with relationships among five parameters: population, food production, industrialization, pollution, and consumption of nonrenewable natural resources. The study is based on the empirical observation, which is generally true on the world scale, that all five of these parameters are increasing in intensity exponentially; ("Nearly all of mankind's current activities, from use of fertilizer to expansion of cities, can be represented by exponential growth curves.") These empirical curves, and various modifications of them, are then used to govern the operation of the computer model, generating thereby a series of predictions of their future course.

Obviously the outcome of these computations is crucially dependent on the structure of the computer program, which expresses the relationships which the investigators believe to govern the numerous interactions among the five parameters. The origin of the relationships used to design the computer model is given in *The Limits to Growth* as follows: "We first listed the important causal relationships among the five levels (i.e., the above parameters) and traced the feedback loop structure. To do so, we consulted literature and professionals in many fields of study dealing with the areas of concern. . . . We then quantified each relationship as accurately as possible, using global data where it was available and characteristic local data where global measurements had not been made."

Thus, the crucial "causal relationships" are determined first—by a method which is specified in no greater detail than that cited above—and the actual data regarding the trends exhibited by the various parameters are *then* inserted into the mathematical model and their interactions computed. Meadows et al. believe that the causal relationships are already known and that "the model is simply an attempt to bring together the large body of knowledge that already exists about cause-and-effect relationships among the five levels . . . and to express that knowledge in terms of interlocking feedback loops." In any case, it would appear that the cause-and-effect relationships embodied in the mathematical model are *not derived from the data* that are used to quantify the relationships, for in that case the entire operation would appear to be a mathematical tautology.

The second approach is, in effect, the reverse of that followed by Meadows et al. Again, one begins with the data that describe the trends among the several parameters. However, care is taken to assemble the data from a specific, real system: the U.S. corn belt, for example. One then derives *from these data* conclusions regarding the causal relationships which have governed their behavior in the past, using this knowledge to describe alternative future courses. In a sense, then, this second approach can be regarded as an empirical test of the validity of "the large body of knowledge that already exists about cause-and-effect relationships," and therefore also a test of the validity of the overall approach adopted by Meadows et al. With this background, we can turn, now, to some specific, illustrative examples.

Environmental pollution resulting from the use of nitrogen fertilizers in food production:

According to Meadows et al. the relevant "causal relationships" are these: population growth stimulates food production, which in turn intensifies agricultural practices, such as the use of fertilizer, leading to increased degradation of the soil and to environmental pollution. It is instructive to compare these relationships with the cause-and-effect relationships that are revealed by the actual data.

The basic data relative to food production and the use of nitrogen fertilizers in the United States are presented in Figure 1. The main trends are self-evident:

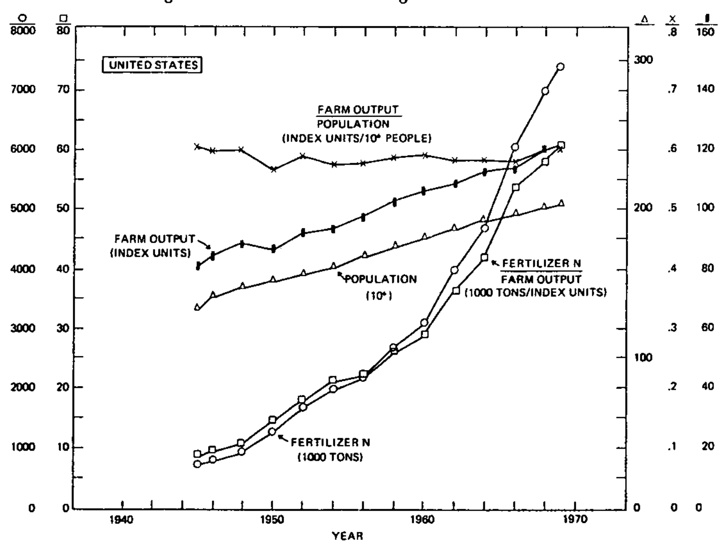

Figure 1 *Fertilizer nitrogen — farm output.*

although the total use of nitrogen fertilizer has increased exponentially since 1945 (which, as we shall see, leads to a corresponding increase in water pollution) no such exponential growth is evident in either total food production, population size, or food production per capita. U.S. population has risen about 43 percent in that period (at a diminishing rate) and total food production has just about kept pace with population growth, so that production per capita has been essentially constant. Thus the exponential increase in fertilizer use is *not* a response to a corresponding increase in the demand for food. (Nor can it be argued that increased food production in the U.S. is a response to the exponential growth of the *world* population, since U.S. agricultural exports have been a constant, and relatively small, fraction of total U.S. agricultural production).

That the exponential growth in fertilizer usage has indeed led to a corresponding trend in levels of pollution is shown in the data of Figures 2 and 3. These relate to the state of Illinois, since national data are not available. Figure 2 shows that, as in the United States as a whole, Illinois nitrogen fertilizer consumption has risen exponentially since 1945. Figure 3 shows as well that the concentration of the resultant pollution of Illinois rivers by nitrate (which stimulates algal overgrowth and increases the risk of methemoglobinemia, in which the blood loses its capacity for oxygen transport, especially in infants) has also risen exponentially since 1945.

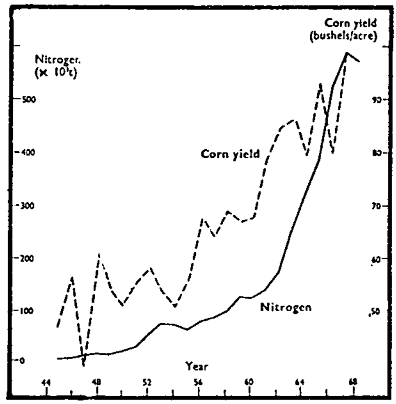

Figure 2 *Corn yield and fertilizer nitrogen application (Illinois) as a function of time.*

Thus, while these data confirm the general conclusion that pollution levels have increased exponentially, they also show that this effect is *not* governed by either a comparable growth in population or in overall food production. In sum, the data do not conform to the cause-and-effect relationship embodied in the world model of Meadows et al. Is there a better explanation?

The foregoing data provide such an explanation. Note in Figure 1 that there is a close parallelism between the exponential growth in fertilizer usage and

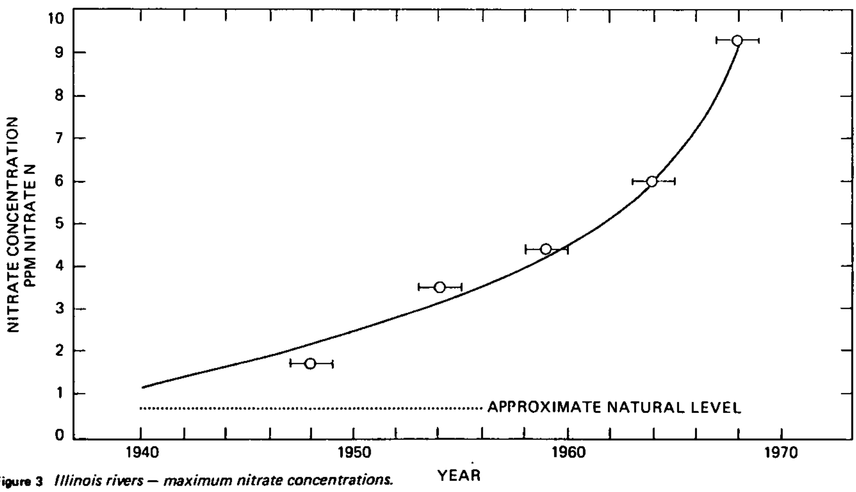

Figure 3 *Illinois rivers — maximum nitrate concentrations.*

another trend: *the amount of fertilizer used per unit food produced.* This parallelism shows that the major cause of the exponential growth in fertilizer use (and in the resultant leaching of nitrate into surface waters as a pollutant) is a specific change in the *technology* of food production—increasing reliance on fertilizer as a source of crop nitrogen—rather than increase in population or in food production per capita.

The operational consequences of the disparity between the "cause-and-effect relationship" assumed by Meadows et al., and that which is evident in the actual data, are considerable. If, as assumed by Meadows et al., nitrate pollution reflects the overall rate of food production, which is in turn driven by the growth of population, then, clearly, control of the pollution problem requires a reduction in population size, in per capita food production, or both. On the other hand, a rather different outcome results if we base our response to the pollution problem on the actual data. This is illustrated by the data of Figure 4, which shows the relationship in the period 1967–1969 between the level of nitrate pollution and the rate of fertilizer application to the land which is drained by various segments of the watersheds in the Central Illinois corn belt. We note at once that nitrate concentration departs significantly from that characteristic of natural waters (0.5-1.0 ppm of nitrate nitrogen) only when the rate of fertilizer application exceeds about 30 lbs N/acre drained. (Since fertilized cropland, which is almost entirely in corn, is about one third of the total acreage, this represents the application of about 90 lbs. of fertilizer N/acre of corn.) As the rate of fertilizer application rises to about 50 lbs/acre drained (or 150 lbs. N/acre of corn) the river nitrate levels rise sharply and approach the limit of acceptability for potable water (for which the water of many of these rivers is used) set by the U.S. Public Health Service—10 ppm of nitrate nitrogen.

This relationship is readily explained by the physiology of plant nitrogen nutrition: up to rates of application of about 90 lbs/acre, fertilizer nitrogen is taken up by the corn crop quite effectively; at higher rates the growth becomes saturated, so that as fertilizer application is increased from about 90 to 150 lbs./acre, the crop yield is increased only 15–20 percent on the average. Thus, the rapid rise in river nitrate when the area is fertilized at rates above 90 lbs. of N/acre of corn is due to the leaching of the unabsorbed fertilizer from the soil into the river. We have carried out direct studies of the source of nitrate leaching from the soil into the rivers (based on nitrogen isotope determination) which directly support this conclusion. (Kohl, Shearer, and Commoner, 1971).

The operational outcome of these considerations

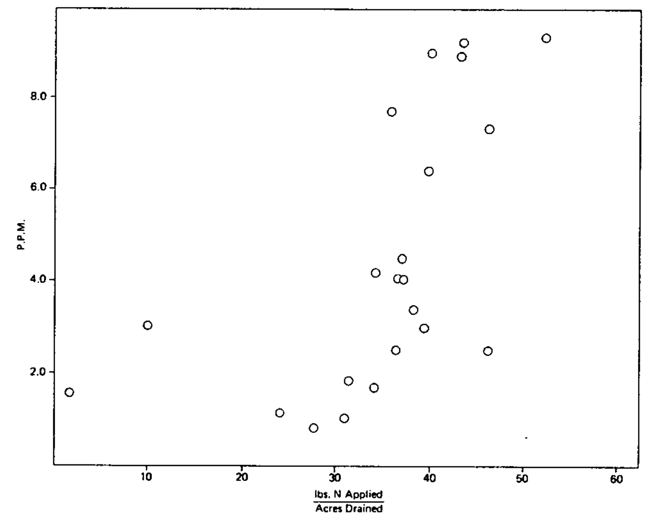

Figure 4 *Average of annual discharge weighted mean* NO_3-N *concentrations 1967–1969.*

is quite straightforward: by reducing the rate of fertilizer application from about 150 lbs. of N/acre of corn to about 75–90 lbs./acre, the nitrate pollution problem could be essentially eliminated—at the cost of about 15–20 percent of crop production. Moreover, by a simple administrative maneuver this reduction in pollution level could be achieved with *no* loss in crop production. In the United States, the rapid growth in fertilizer usage since 1945 has been accompanied by an approximately 16 percent *decrease* in harvested acreage—largely due to the government's program of maintaining farm prices by restricting production. Hence in at least this case (which must be taken seriously in view of the fact that—to my knowledge—it is the only one in which the requisite data are actually available), the exponential growth in pollution levels could be essentially reversed with no change in population size or in per capita food production by the simple (physically, if not economically and politically) expedient of reversing the postwar displacement of land by fertilizer.

It is evident, I believe, that the two approaches to this problem lead to very disparate results. Specifically, the exponential shape of the curve of fertilizer usage (and the comparable increase in nitrate pollution which results) has very different meanings in the two approaches. In the method of Meadows et al. no reason is sought to explain the shape of the curve; but given the nature of the relationships which are programed into the model, the curve is used *as though* its exponential shape was due to an exponential rise in the demand for food. Thus, regardless of the *actual* reason for the shape of the curve, it is used in the model—and therefore affects the outcome of the resultant computations—in a way which *confers* a specific operational meaning upon the curve, a meaning which is necessarily reflected in the computational result. Inevitably, this process yields results in which demand for food takes on an importance that derives from an assumed, rather than demonstrated relationship.

Now, what the *data* show is that the shape of the fertilizer usage curve results from a progressive change in the *technology of food production*, rather than in the amount of food produced. Hence, whatever effect this curve has on the final computational result ought to be ascribed to the technological change rather than to the demand for food. It is difficult to see how the use of this curve in computations of the type reported by Meadows et al. could fail to yield results that are seriously marred by this disparity between the real meaning of the datum and the meaning conferred upon it by the structure of the model itself. It is as though a falsely defined word were used to construct a sentence; obviously the meaning of the sentence is not likely to reflect the real meaning of the word. In a certain sense it is the model, and not the data, that confers meaning on the computational result. Regardless of its true meaning, the word is given a definition by the structure of the sentence.

Automotive lead pollution:

Environmental pollution due to lead provides another illustration of this general conclusion. In the United States, the major source of environmental contamination from lead is the tetraethyl lead added to the high-octane gasoline used in modern high-compression engines. Figure 5 shows that we have in fact experienced the expected, exponential rise in annual consumption of tetraethyl lead (nearly all of which is emitted into the air as a pollutant) since 1945. However, again, the rise in population is too small to account for the increase. In this case, there is a significant increase in "consumption"—here expressed in terms of vehicle-miles/capita. However, there is also a striking increase in the "technology" factor, i.e., in lead consumed/vehicle mile.

In several ways, the data of Figure 5 exemplify the relative importance of the technology factor as compared with both population and "consumption." First, consider the significance of the surprising drop in total lead consumption and in lead/vehicle miles in the period 1958–1962—a change which, in effect, introduced an 8–10 year lapse in the course of the exponential growth in lead consumption—no mean accomplishment on the time scale of the catastrophes predicted by the analysis of Meadows et al. The cause of this effect is evident in the data of Figure 6. This shows that the 1958–1962 period was marked by a temporary reversal in a pervasive trend, in U.S. passenger cars, toward increased horsepower and compression ratios —which correspondingly increases the demand for leaded gasoline. (This lapse was due to the introduction of U.S. "compact" cars to meet foreign competition, cars which after 1962 gradually increased in horsepower and compression ratio, restoring the trend toward increased lead emissions.)

What these data reflect, of course, is the fact that lead emission is a wholly *unnecessary* accompaniment to automotive travel: small, low-compression engines can operate on low-octane, lead-free gasoline and quite successfully provide transport, albeit at some sacrifice of acceleration and high speeds. In the world models of Meadows et al., the rate of emission of a pollutant (lead, in this case,) is generated by the per capita output of industrial production (or, in this case, transportation) and by the growth of the population. The foregoing data lead to a different conclusion regarding this "causal relationship": that the exponential rise in lead pollution since 1945 is largely due to changes in the technology of automotive transport.

Again, the interrelationships revealed by the actual data suggest remedial action quite different from those which emerge from the Meadows study. Specifically, environmental emissions of lead from automotive transport could be *totally* eliminated by the basic redesign of the engine. The same is true of photochemical smog, which is triggered by automotive emission of nitrogen oxides—a product uniquely associated with the modern high-compression engine—and which could be largely eliminated by the simple expedient of returning to pre-1940 low compression designs.

Of course, even thus improved, the internal combustion engine will emit other pollutants, such as carbon monoxide. However, here too a kind of technological change can be effective—in the design of urban areas, for example—to reduce the *need* for automotive travel. Thus, a large part of automobile travel in the United States is simply due to travel between residence and place of work. And the growing separation between places of work residence in U.S. metropolitan areas, is, of course, itself the consequence of the decay of our inner cities. The result is that suburban dwellers need to travel into the city to work, while many ghetto dwellers travel to outlying factories, or to the suburbs as domestic workers. Similarly, the high figures of fuel combustion—and the accompanying environmental pollution—could be drastically reduced in the United States by reversing the present trend to displace railway freight by truck freight, for truck freight uses about six times more fuel per ton mile than railroad freight.

In sum, the actual data show that the exponential increase in fuel consumption and in the emissions of lead and other pollutants from automotive transport reflect changes in automotive technology and in the design of transport systems much more than they do increases in population or in per capita consumption. Therefore, once more, serious doubts arise regarding the significance of predictions generated by a mathematical model in which these same exponential trends are used to quantify a relationship which—contrary to that evidenced in the data themselves—is assumed to reflect chiefly increases in population size and in per capita demand.

Electric Power:

The generation of electricity is a notorious and rather intractable source of pollution; there is always *some* environmental cost associated with the generation and use of electricity, if only from the necessary release of

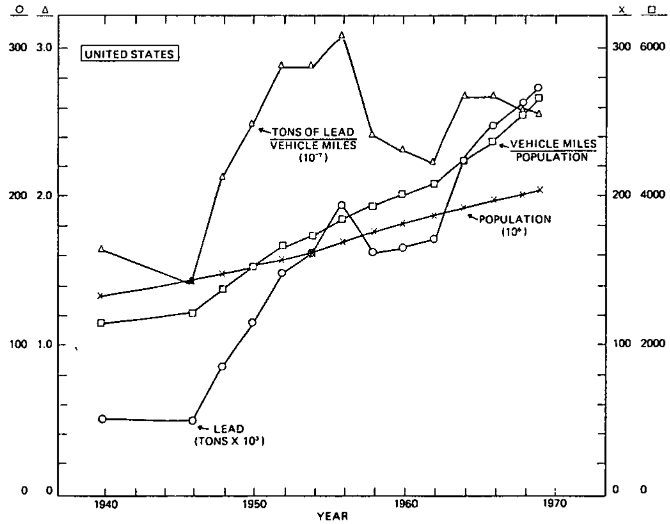

Figure 5 *Tetraethyl lead and land transport.*

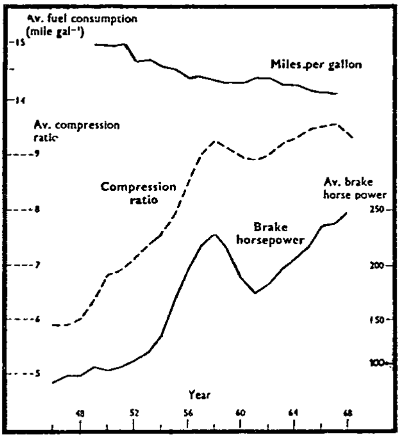

Figure 6 *Temporal trends in automotive compression ratios, brake horsepower, and average fuel consumption in miles per gallon.*

heat to the environment. In the model of Meadows et al. the basic causal relationships are those which relate consumption of goods, industrial activity, and the emission of pollutants. Thus, the exponential rise in consumption of electric power is regarded as a consequence of increased demand for the goods produced by the use of electricity, which is in turn a consequence of increased per capita demand and population growth. Note that this pattern assumes an unchanging relationship between the amount of electricity associated with the production of a given quantity of economic good.

This relationship is readily subject to test.[2] In the case of industrial use of power in the United States, data are available regarding the relationship between the economic good produced by industrial operations (as measured by the term *value added*, which represents the value of the goods sold, less the cost of the necessary materials and power, expressed in 1958 dollars to account for inflation) and the consumption of electric power.

Figure 7 shows that since 1947, for total United States industrial production, value added and electricity consumed have risen exponentially but at somewhat different annual rates. Overall, value added has increased about 2.3-fold, from about $96 billion to about $222 billion (all these figures are computed to 1958 dollars to compensate for inflation); electricity consumed has increased about 3.6-fold, from about 141 billion kwhr to about 506 kwhr. Total resource energy used in industry—that is, the energy content of all fuel used in industry, including that needed to produce electricity—has about doubled in that time. Labor employed in industry follows a distinctly different course; total man-hours expended annually in United States industrial activity increased only 1.1-fold, from 24.3 billion in 1947 to 27.8 billion in 1967.

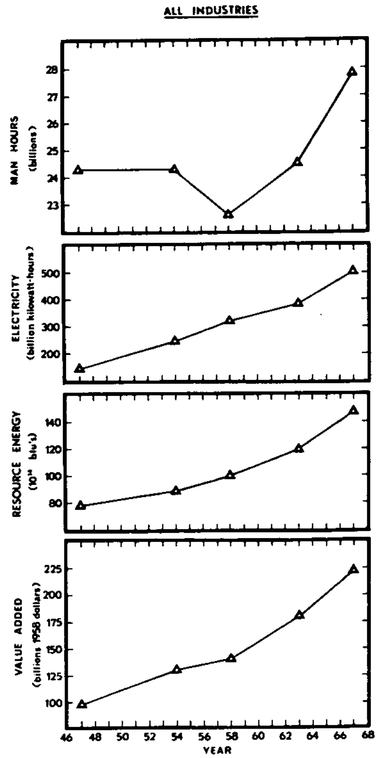

Figure 7 *Use of electrical power by industries.*
Sources: Data from U.S. Department of Commerce, 1971. Man Hours and Value Added, vol. 1, p. 26. Electricity and Resource Energy (except Resource Energy, 1947) SR4, pp. 8-9. Resource Energy 1947, from: Lyon, 1951.

There is a close and useful analogy between the roles of labor and electric power in industrial production. Both are nonstorable entities, which become valuable only in their use; both are consumed in the course of the process in which they are engaged. And, there is a close functional relationship between the roles of labor and electric power in the productive enterprise, since electric power is the most convenient means of substituting for, or amplifying, the muscular power and manipulative capabilities of human beings.

The economic value of labor is usually given by the term *labor productivity* which is measured by value added per man-hour of labor. By analogy with labor productivity, then, we may describe the *power productivity* of an industrial enterprise as the quotient: value added/electricity consumed. Figure 8 shows that both labor productivity and power productivity for all United States industry have exhibited striking changes since 1947, but in opposite directions. There has been a continued increase in labor productivity (although

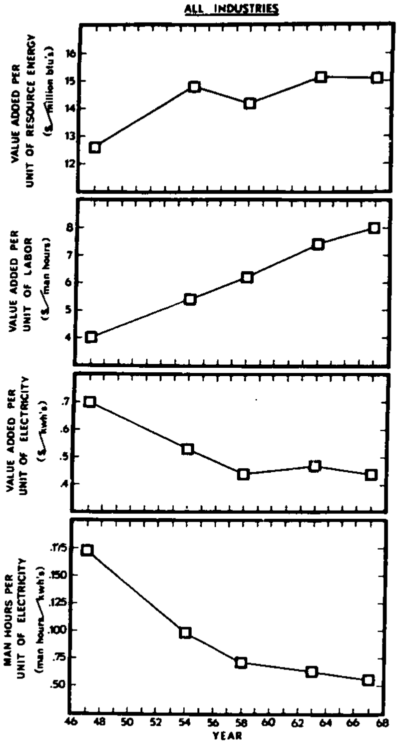

Figure 8 *Labor productivity and power productivity of U.S. industry.*
Source: Computed from data in Figure 7.

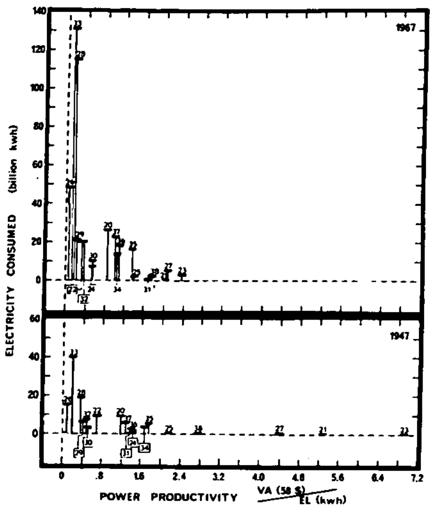

Figure 9 *Power productivity and electric power consumption by 2-digit SIC classification 1947 and 1967.*
Source: Data from Department of Commerce, 1949, 1971.

the rate of increase has been declining in recent years): the overall change is about two-fold in the twenty-year period. In contrast, power productivity declined sharply between 1947 and 1958, remaining more or less constant since then. Overall there has been a 35 percent decline in industrial power productivity since 1947.

Figure 9 shows how different sectors of industry have changed, in respect to power productivity and power consumption, between 1947 and 1967. First it is evident that nearly all sectors have declined in power productivity in that period. In 1947, the highest power productivity (about $6.90 of value added per kwh) was that of the apparel industry. In 1967, that industry was still highest in power productivity, but at the level of $2.40 of value added per kwh. At the same time, partly because of the decline in power productivity and partly because of the increase in total production between 1947 and 1967, the total amount of electricity consumed by that industry increased several-fold. Nearly every industrial sector exhibits these trends.

A second feature illustrated by Figure 9 is that power consumption by the process industries (which have very low power productivities—primary metals (SIC 33), paper and allied products (SIC 26), chemicals (SIC 28), petroleum and coal products (SIC 29) etc.) —contributed much more to the absolute growth of power consumption than group A or B (see Table 1).

Table 1 *The Productivity of Electric Power and Man Hours in Manufacturing*

	Value Added 1958 Dollars x 10^9		Electric Power Used Kwh x 10^9		Electric Power Productivity 1958 Dollars/Kwh		Man-Hour Productivity 1958 Dollars/MH		Resource Energy Productivity 1958 Dollars/10^9 BT		
	1947	1967	1947	1967	1947	1967	1947	1967	1947	1954	1967
23 Apparel	5.87	8.53	0.85	3.61	6.91	2.36	3.24	3.92		173	119
21 Tobacco mfg.	0.85	1.73	0.16	0.85	5.26	2.03	4.28	13.72		79	71
27 Printing & publication	5.62	12.17	1.28	5.82	4.39	2.09	6.33	10.18		173	115
31 Leather & prod.	2.03	2.23	0.57	1.33	3.54	1.67	3.00	4.06		55	53
38 Instruments	1.51	5.44	0.55	3.08	2.77	1.77	3.87	10.27		74	78
25 Furniture & fixtures	1.78	3.54	0.83	2.52	2.16	1.40	3.05	4.94		55	56
GROUP A	*17.66*	*33.64*	*4.24*	*17.21*	*4.17*	*1.95*	*3.88*	*6.35*		*105*	*89*
35 Machinery	10.36	23.61	5.92	17.26	1.76	1.37	4.00	8.48		57	56
34 Fabr. metal prod.	6.51	15.30	3.90	14.76	1.67	1.04	3.84	7.08	38	39	38
24 Lumber wood prod.	3.33	4.22	2.34	7.97	1.43	0.53	2.66	4.32		29	18
36 Elec. equip.	5.11	20.77	3.62	19.20	1.41	1.08	4.00	7.95		46	57
37 Trans. eqp.	7.73	23.89	6.06	23.56	1.28	1.01	3.94	8.70		48	45
20 Food & kd.	12.06	22.57	10.18	26.79	1.18	0.84	5.09	9.99	18	17	21
GROUP B	*45.10*	*110.36*	*32.02*	*109.54*	*1.41*	*1.01*	*4.05*	*8.15*		*33*	*37*
22 Textiles	7.04	6.91	10.04	20.80	0.70	0.33	3.05	4.09	21	16	15
30 Rubber & plastic pro.	1.72	5.77	3.45	10.77	0.50	0.54	4.05	7.07		15	23
32 Stone, clay, glass pro.	3.04	7.07	8.02	20.81	0.48	0.36	3.63	7.45	3	4	5
29 Petroleum & coal pro.	2.63	4.60	6.50	22.28	0.41	0.21	7.44	22.78		4	3
28 Chemicals	7.03	19.97	19.61	116.83	0.36	0.17	7.21	18.39	7	7	6
26 Paper & allied pro.	3.85	8.27	15.39	49.07	0.25	0.17	4.50	7.72	6	7	6
33 Primary metals	7.58	16.94	40.65	131.95	0.19	0.13	3.69	8.11	2	5	5
GROUP C	*32.89*	*69.53*	*103.66*	*372.51*	*0.32*	*0.19*	*4.21*	*8.80*		*6*	*6*
MANUFACTURING	95.65	213.53	139.92	499.26	0.68	0.43	4.07	7.99	11.2	14.4	14.6

Table 1 shows the rate of growth in power consumption of three groups of industries, classified according to power productivity in 1947. The group with the lowest power productivity (0.19 to $0.70/kwh) contributed 75 percent of the growth in power consumption by all manufacturing between 1947 and 1967. However, the contribution of this group of industries to the growth in value added from all manufacturing during 1947 to 1967 was only 27 percent. The contribution to growth in national power consumption by the groups of industries with power productivities between $0.70 and $1.76 was only 22 percent. However, this group of industries contributed 48 percent, by far the largest share to the growth in total value added by industry from the three groups. Finally, the group of industries with power productivities above $1.76 contributed only 4 percent to the growth in power consumption while it contributed 12 percent to the growth in value added by manufacturing.

On the basis of this analysis, it becomes evident that the rapid growth in industrial power consumption *has not been accompanied by comparable growth in the value of the goods produced by industry*, in large part because only a few industries, which contribute a relatively small share of the actual economic growth of industry, account for a good deal of the growth in power consumption. The rapid growth in power consumption is largely due to those industries that use power *least efficiently:* primary metals, chemicals and petroleum products in particular.

Similar relations are evident *within* a single industrial group, such as primary metals. As shown in Figure 10, the major contributors to this group, steel and nonferrous metals (chiefly aluminum), differ considerably in their power productivity. For example, in 1967, the power productivity of steel production was $0.183/kwh, while that of aluminum was $0.013/kwh. Figure 10 also shows that the nonferrous metals, which contribute a significantly smaller share than steel to the total value added by primary metals industries, now consume the largest share of electricity in the group. Again, we find that the industrial activities that are least efficient with respect to the use of power contribute disproportionately to the rapid growth of electricity consumed by industry.

These data illustrate another important trend: the tendency of industries that operate at low power productivities to displace industries which operate at high power productivities. Thus, production of nonferrous metals, especially aluminum, has grown much faster

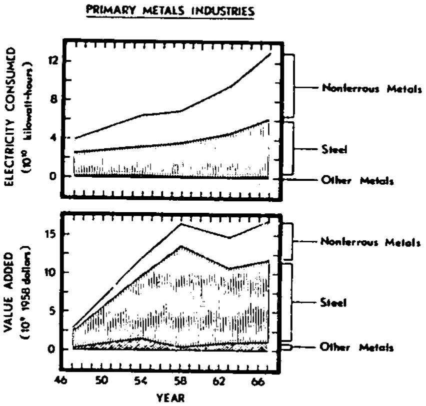

Figure 10 *Primary metals industries.*
Sources: Data from Department of Commerce, 1971 SR4, and Vol. 1 of 1949, 1957, 1961, and 1966.
Steel figures are from SIC 331 and 332.
Nonferrous figures are from SIC 333, 334, 335, and 336. Other is SIC 339.

than steel production, largely because of the replacement of steel (and lumber) products by aluminum ones. In the same way, the growth of the chemical industry—which has a very low power productivity—is largely based on the displacement of a number of natural products, which involve very little power consumption (such as cotton, wood, lumber, and soap made from fat) by synthetic chemical products (synthetic fibers, plastics, detergents).

Thus a good deal of the growth in industrial power consumption is due not so much to the overall expansion of industrial activity, as it is to the introduction of new, power-consumptive products. Since we are concerned with the elasticity of this process, especially the possibility of reversing it, it is important to inquire as to whether these displacements were necessary, because for example, of the depletion of raw materials. Clearly, the foregoing displacements were not *forced*; there is no evidence that aluminum has displaced steel because the latter has been in short supply, or that detergents have displaced soap because we have run out of saponifiable fat (we now export more animal fat than the amount needed to replace United States detergent consumption with soap). In other words, the industrial displacements which have decreased the efficiency of industrial power consumption are, at least in principle, *reversible*, so that savings in industrial power consumption *could* be achieved by reversing the trends which have been under way in the postwar period.

Apart from such displacements, it is also evident that another reason for the declining power productivity of United States industry is the progress of automation—in which hand labor is displaced by machines, nearly always driven by electric power. Thus the sharp decline in power productivity in the apparel industry is obviously due to the considerably increased use in that industry of machines in place of hand labor. This is revealed in the overall statistics for United States industry by the close relation between the decline in power productivity and the increase in labor productivity. This is illustrated in Figure 11, which shows that there is a linear relationship between value added and the product of kilowatt-hours and man-hours expended in industrial production. This means that the increased productivity of labor is proportional to the increase in the amount of electricity consumed, and the decrease in productivity of electricity is proportional to the decrease in the number of man-hours employed.

Again, it is useful to consider the elasticity and reversibility of the increasing consumption of power which is associated with the displacement of labor by powered machinery. Clearly this displacement process was not demanded by the reduced availability of labor, and—apart from the considerable economic consequences, which are discussed below—it could be reversed by the simple expedient of increasing hand labor in place of electric-powered operations.

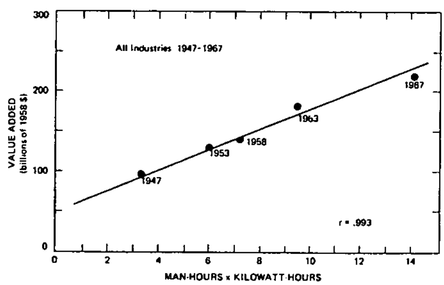

Figure 11 *Declining power productivities accompanies increasing labor productivity in manufacturing.*
Data from all manufacturing indicate that power and labor productivity have been changing according to the following pattern: increased productivity of labor is proportional to the increase in the amount of electricity consumed, and the decrease in productivity of electricity is proportional to the decrease in the number of man hours employed.

It should be apparent from the foregoing considerations that the exponential shape of the curve descriptive of industrial power consumption in the United States has a very complex background. It is, of course, responsive to increases in overall industrial production, but other factors—the displacement of power-thrifty productive enterprises by power-consumptive ones and the general displacement of human labor by electric-driven machines—play equally important roles. At the very least, there appears to be little justification in disregarding the changing intensity of these latter factors in computations of the type employed by Meadows et al.

What elasticity in power demand can be found in the residential power consumption? Table 2 summarizes a tentative effort in this direction. Two methods to achieve power savings are proposed. In those cases (water heating, space heating, cooking ranges, clothes dryers) in which nonelectric appliances exist on the market, the proposed saving is achieved by the very simple expedient of eliminating the electric types. This has the added advantage of saving resource energy as well, since direct heating by local combustion of fuel, for example to produce hot water, uses about 44 percent less fuel than electric heating. The second method of power-saving employed in Table 2 is improved efficiency of power use. In the case of refrigerators and freezers improved efficiency is achieved at the expense of a relatively minor inconvenience—the need to defrost the appliance at intervals. Frost-free types are rather inefficient in converting power to cooling (standard refrigerators use 32.0 percent less electric power than frost-free types) because some power is used for heating in order to melt the frost.

In one important case—air conditioners—appreciable improvement in efficiency is possible with no loss in convenience at all. The relevant evidence is summarized in Figure 12. This reports the cooling efficiencies of various models, of three typical brands, in relation to their cost (as expressed in dollars per BTU of cooling capacity). Efficiency is given as an index number which expresses the cooling achieved per unit of electricity used. Several relationships are evident in Figure 12: (a) There is a considerable overall variation in air conditioner efficiency, from a minimum of about

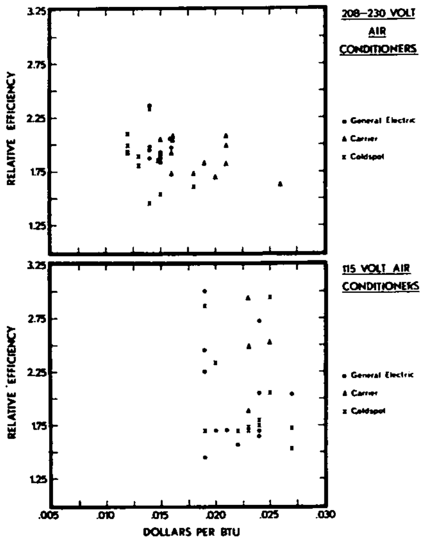

Figure 12 *Relative efficiency and cost per BTU of cooling capacity of various air-conditioner models. Different symbols indicate three different brand names.*

Sources of raw data: Association of Home Appliance Manufacturers, 1971.
Directory of Certified Air Conditioners, no. 4, Chicago, Oct. 15, 1971.
Mr. Ken McFarland Corp., personal communication.

Table 2 *Possible Power Savings in the Residential Sector*

	Percentage of Household with Electric Feature*	1968 Aggregate Electric Consumption (in 10^{12} BTUs)	Possible Percentage Reduction	Method of Power Saving	Reduction in BTUs (Electricity)
Refrigeration	99.7	250	20	Eliminate frost-free refrigeration	50†
Water heater	26.1	223	100	Eliminate electric heaters	223
Space heat	4.8	164	100	Eliminate electric heaters	164
Air conditioner	36.7	154	44	Construct for maximum efficiency	68†
Television	99.0	128	0	Improved installation	0
Cooking (ranges)	47.0	96	100	Eliminate electric ranges	96
Food freezer	27.2	80	16	Eliminate frost-free types	13†
Clothes dryer		51	100	Eliminate electric types	51
Other		244	0		0
		1,390			665

*1969 United States *Statistical Abstract*, p. 704, unless otherwise indicated.
†This denotes a case where savings in energy were obtained by using a more efficient electrical unit.

1.5 to a maximum of 3.0. Variations are greater in 115-volt air conditioners than in 230-volt air conditioners; the latter are clustered in the range of about 2.0. (b) Generally, 230-volt air conditioners are less efficient, but in original purchase price, cost less (per BTU of cooling) than 115-volt air conditioners. Within each voltage type, there appears to be no overall systematic relationship between air conditioner cost and efficiency. However, it might be noted that one recent advertisement for a central air-conditioning unit offers two models—one is advertised as maximally efficient, but presumably expensive; the other is advertised as unusually economical, but presumably less efficient.

The data of Figure 12 show that there are important opportunities for power savings, at no cost in social value, by improving air conditioner efficiency. We estimate that a requirement that all air conditioners be designed to the present maximum efficiency would result in an aggregate saving of about 36 percent in power consumed with no change in cooling output. Improved house insulation could probably increase this saving to about 44 percent.

As indicated in Table 2, by these means, overall domestic power consumption could probably be cut to about half its present value. A good deal of this reduction could be achieved through increased efficiency of air conditioning; this is a particularly important result in view of the critical effects of air conditioning power demands on supply. It is obvious that the proposed changes would increase the domestic demand for fossil fuels, especially gas. The implications of such a shift are discussed below.

Possible elasticity in commercial power consumption has been analyzed in a recent paper by Richard G. Stein (1971), who concludes that in the special case of the modern commercial skyscraper, savings of about 50 percent of operating power requirements could be achieved by proper design (use of windows that open, efficient heating and air conditioning, reduction in excessive illumination). Table 3 is a tentative effort to extend this analysis to the total commercial sector. Total possible savings of about 22 percent of the power used in the commercial sector, or about 4.8 percent of total United States power consumption, are indicated. Note that these savings involve no loss in social value except that involved in the use of power for advertising and display lighting, which, at any rate, are of dubious social value.

In connection with commercial use of power, the matter of lighting is particularly interesting. The total output of electric-powered light has been growing extremely rapidly: between 1948 and 1966 total output increased about 5.5-fold in the United States. What are the values gained from these increases? In most cases lighting is designed to support visual activities; hence we can estimate the efficiency of lighting from the relationship between the light level (which determines the amount of power used) and a measure of visual function, visual acuity. An architectual lighting consultant, Mr. William M. C. Lam of Cambridge, Massachusetts, has analyzed this relationship. In a paper delivered at the national convention of the American Association of School Administrators in February 1964, he described the growth in recommended school light levels, from 3 footcandles up to 1910, to 18 footcandles in 1910–1930, to 30 footcandles in 1930–1950, and to 70–150 footcandles since 1950. He shows that the 30 footcandle standard achieved about 93 percent of the maximum possible visual acuity. The recommended levels after 1950, which increased illumination from 30 footcandles to 70–150 footcandles, achieved only a 3–4 percent increase in visual acuity.

Table 3 *Possible Power Savings in the Commercial Sector*

End Use	Electric Power Used in 1968 10^{12} BTUs	%	Possible Savings: Method	Possible Savings: 10^{12} BTUs	%	Additional Energy Needed 10^{12} BTUs
Total Input*	1,079	100.0		260	22.0	46.2
Water heating*	84	7.8	Changeover to gas†	84	7.8	
Refrigeration*	244	22.6				
Air conditioning*	370	34.3	10% lighting reduction**	37	3.4	
Cooking*	8	0.7	Changeover to gas†	8	0.7	39.5
Other*	373	34.6			10.1	6.7
Lighting**	201	18.7	36% reduction	75	7.8	
Advertising and display lighting**	27	2.5	Total elimination	27	2.5	
Elevators**	40	3.7				
Fans and air handling equipment**	35	3.3	Opening windows**	7	0.6	
Pumps and motors**	18	1.7				
Miscellaneous**	52	4.7				

*Office of Science and Technology, "Patterns of Energy Consumption in the United States," unpublished, 1971.
**Richard G. Stein (1971).
†Edison Electric Institute (New York), "Appliance Comparison References of Electric Energy Consumption with Fuel Use," EEI-9R-309.

Thus for the sake of a negligible improvement of visual acuity, we have undertaken a several-fold increase of power for illumination. In recent years, this trend has intensified considerably. Obviously interior lighting, especially in commercial buildings, schools and the like, leaves considerable room for power savings.

The above potential for power savings in the industrial, residential, and commercial sectors, is summarized in Table 4. Total savings of about 35 percent are indicated, at no cost in goods and services provided by electric power. These data are not to be regarded as definitive, are rather to be viewed as the outcome of a tentative exercise in power-saving. However, the result is informative; it tells us that there is a good deal of elasticity in the relationship between electric power consumption and the resultant production of goods. In particular, the data show that postwar changes in this relationship are significantly affected by concurrent changes in the technology of industrial production, of the design of commercial and residential buildings, and of the design of household appliances. Again we note the failure of a good correspondence between the intensity of productive activity which degrades the environment and the demand for actual goods. And again, this must introduce a serious fault in the results yielded by any mathematical model, which assumes, contrary to the evidence, that this correspondence does, in fact, hold.

The data on power consumption are particularly informative about the considerable internal complexity that lies behind the apparently simple exponential curve that describes the overall trend in power consumption. These complexities not only affect the efficiency with which electric power is used to produce goods—and therefore the amount of environmental degradation that results—but also have similar effects on the rates of depletion of nonrenewable fuel resources. Thus, in the United States, one reason for rapid depletion of gas and petroleum resources has been the relative decline in the use of coal, especially in industrial operations. A secondary consequence is the increase of electric-powered domestic heat sources relative to sources which burn fuel directly, a process which has markedly reduced the overall efficiency with which fuel is used in domestic heating. All these relationships are, so to speak, cloaked by any computation which accepts the exponential curve of power production as given and inquires no further into the *meaning* of its shape.

The foregoing examples are typical of a general process, which largely accounts for the sharp postwar rise in pollution levels in the United States. In that period there has been a striking replacement of natural materials (cotton, wool, silk, wood) by man-made plastic materials; there has been a remarkable increase in the amounts and varieties of other man-made synthetic materials (e.g., detergents, pesticides, herbicides); automobile engines have been redesigned to operate at increasingly higher compression ratios; electric power, generated in very large power plants, has increasingly replaced the geographically spread direct use of fuel in home heating; materials, such as aluminum and certain chemicals, the production of which is intensely power-consumptive, have increasingly replaced more power-sparing materials; at the same time there have been striking changes in agricultural practice, especially the increasing tendency to feed livestock separate from pastures, reduced crop rotation, large increases in the use of inorganic fertilizers, and the massive introduction of synthetic pesticides and herbicides. These changes, which are intense and coincide with the period of rising pollution, provide an important clue to the basic cause of environmental deterioration in the United States: they result from the massive introduction of new technologies, especially in the period following World War II.

These new technologies are drastically unsuited for accommodation by natural environmental processes; they therefore lead to environmental pollution. Manufacture of plastics in place of natural fibers means the use of fuel-generated power (with its attendant pollution) in place of the power of sunlight, absorbed by

Table 4 *Possible Savings of Electricity Consumption in 1970*

Sector	Million KWH Used in 1970	Percent of Total U.S.	Savings: Method	Million KWH	Percentage of Sector	Percentage of Total U.S. Consumption
Industrial	720,000	47	If operated at 1947 rate of power productivity	257,900	35.8	16.8
Commercial	309,900	20	Accounting for Richard Stein's savings estimate	68,100	22.0	4.4
Residential	442,000	29	Accounting for Michael Corr's estimate	212,000	47.9	13.8
Total U.S.	1,531,600	100		537,800		35.0

plants and transmitted by natural (and therefore non-polluting) environmental processes. Synthetic man-made products, such as detergents, plastics and pesticides, which are outside (and therefore incompatible with) the coordinated system of biochemical processes that living things have evolved, are therefore not assimilated by natural environmental cycles; consequently, they accumulate as pollutants. The increased manufacture of synthetic organic chemicals has resulted in increased production of chlorine—an important ingredient in many organic syntheses. In turn, the use of mercury in electrolytic production of chlorine has also increased. This is the source of much of the mercury pollution in United States inland waters. The development of the modern high-compression gasoline engine, with its attendant high temperature, causes oxygen and nitrogen in the air to combine as nitrogen oxides, a substance otherwise rare in nature and not readily accommodated by natural environmental processes. Nitrogen oxides are the basic cause of smog. Intensification of power generation in large electric plants results in the production of several major substances, which are incapable of being accommodated by natural environmental cycles and therefore become pollutants, especially sulfur dioxide, nitrogen oxides, and (in the case of nuclear plants) radioisotopes. The new agricultural techniques have disrupted soil cycles, so that natural soil fertility is reduced and fertilizers—which contribute to water pollution—leach into surface waters. The new pesticides disrupt the balance between insect pests and their natural predators and parasites—with the resultant appearance, increasingly, of insecticide-induced outbreaks of insect pests and the accumulation of insecticides in wildlife and man.

These basic changes in industrial and agricultural production and in transportation account for most of the exponential increase in pollution levels in the United States since 1945. This process—the tendency to displace technologies which are relatively benign environmentally with new ones that sharply increase the ratio of pollution emitted to goods produced—much more than increased population and per capita consumption is the "causal relationship" that couples productive activities to the environment.

A persistent, and crucial, question arises from these considerations: How can we account for the striking tendency of new technologies to be far more stressful toward the environment than the older ones that they replace? This is a complex issue which I have considered in some detail elsewhere (Commoner, 1972). One of the relevant factors needs to be mentioned here. This is the evidence that the chief driving force behind this counterecological trend in the development of modern productive technologies is that production is generally motivated by the desire for short-term gain (in the United States economic system, private profit). As a result, changes in design—whether of industrial or agricultural production, transport, individual buildings or entire urban areas—are governed not by environmental compatability, but by the short-term gains that they promise.

Thus, inevitably, what lies behind the basically scientific and technological issues of the environmental crisis are economic, social, and political ones. And, of course, it is precisely in this realm in which public opinion and social action—which are, or ought to be, the instruments of environmental improvement—must operate. For it is useful to recall at this point that while the principles of science and technology are sufficient to describe the social benefits of a productive process and the social cost of the resultant environmental degradation, no such principle can tell us *where* to strike the balance between cost and benefit. This is necessarily a matter of social judgment. Hence, a method which proposes to elucidate the environmental crisis must be judged not only for its technical accuracy but also with respect to its ability to *inform* society and thereby enhance the opportunities for rational decisions and effective action.

Here, too, the two analytical approaches under discussion are strikingly different. As I have shown in detail elsewhere and have briefly summarized above, the approach which I favor leads to the general conclusion that the exponential course of environmental deterioration is largely due to concurrent changes in the nature of productive technologies. These changes are usually not forced by depletion of resources, nor do they materially enhance per capita consumption, and are therefore, in these material terms, largely reversible, or at least subject to considerable environmentally motivated modification. In turn, as indicated above, it is usually true that the motivation for these counterecological trends in modern technology is economic.

For example, to return to an earlier illustration, such an analysis shows (a) that the exponential rise in nitrate pollution of surface waters in the United States corn belt is the direct outcome of intensified use of inorganic nitrogen fertilizer; (b) that an approximately 50 percent reduction in the rate of fertilizer application, together with the restoration of recently retired acreage to agricultural production, could eliminate the environmental problem at no cost in production; (c) that the foregoing would require certain significant changes in agricultural economics—for example, reversal of crop reduction payments, and a decrease in yield, and therefore in profit, per acre. Note, then, that this approach systematically reveals the chain of cause-and-effect which leads from the origin of the problem, in economic motivation, to its environmental outcome, in nitrate pollution. It helps to lay bare the basic economic issues which, given the realities of social action, *must* be faced if action to relieve the pressure on the environment is to be taken. In this sense, the approach performs not only its technical function of analysis but its social function of revealing where social action can be taken.

In contrast, consider the role played by the economic roots of environmental issues in the approach exemplified by the Meadows study. This is explicitly stated as follows:

> The actual growth of the economy and of the population will depend on such factors as peace and social stability, education and employment, and steady technological progress. These factors are much more difficult to assess or predict. Neither this book nor our world model at this stage in its development can deal explicitly with these social factors.

Note, here, not only that various social factors are excluded from consideration, but that the relatively simple economic factor which appears to play such a general role in the environmental problem—short term gain, or profit—is not even mentioned. And where the report does mention the economic system it is assumed that it is not subject to significant change:

> Let us recognize, however, that the growth rates listed above are the product of a complicated social and economic system that is essentially stable and that is likely to change slowly rather than quickly, except in cases of severe disruption.

Thus, intrinsically embedded in the analytical instrument, which, as indicated earlier, decisively controls the outcome of the analysis—i.e., the structure of the mathematical model—is the *absence of relevant economic and social factors*. Hence, the output generated by the model cannot, in principle, offer a guide to the effect of economic factors on the environmental crisis. The outcome of the analysis is intrinsically incapable of guiding social action toward environmental improvement if the nature of the environmental problem is such as to require social action on the governing economic parameters. Yet, as already indicated (and, as increasingly evident from the conflicts that environmental demands have generated in United States industry), nearly all environmental issues have an economic origin. According to its sponsors, *The Limits to Growth* is designed to guide social action on the environmental crisis. But it is a guide which appears automatically to preclude one major path of action: alteration of the economic system.

Thus, one approach to the environmental crisis tends to open its economic roots to public view, so that the alternative of dealing with the crisis by means of economic change is open to social decision, while the alternative approach forecloses this option.

I am compelled, by these considerations, to conclude this discussion with a value judgment. In my view, it is the obligation of the scientific and technological community to provide society with the information needed to permit a free choice of alternative solutions to social problems which are scientific in their content. The environmental crisis is a major example of such an issue. Among the alternative solutions to the crisis—each of which is grave in its implications for social justice and personal freedom—are actions designed to control the growth of population and personal consumption, or to make the radical economic changes which are required to enforce on technological designs a significant obedience to the ecological imperative. In my view, those of us who essay the difficult task of analyzing the environmental crisis have two overriding obligations. Our obligation to science is to strive for an accurate and meaningful analysis of the crisis. Our obligation to society is to provide, in these efforts, for access to the total range of social actions that hold the promise of survival.

NOTES

1 For all references to the Meadows study in this article, see Meadows et al., 1972.

2 This section on electric power summarizes the results presented in Commoner and Corr (1971).

REFERENCES

Commoner, Barry (1972) "The Environmental Cost of Economic Growth," *Chemistry in Britain* 8, no. 2 (Feb.): 52–65.

——— and Michael Corr (1971) "Power Consumption and Human Welfare." Paper presented at AAAS Symposium on the Energy Crisis, Annual Meeting, Philadelphia, Dec. 29; and as "Electric Power Consumption and Human Welfare: A Selection of Papers on the Social, Technological, and Environmental Problems of Electric Power Consumption," prepared for the Power Study Group of the AAAS Committee on Environmental Alterations and the Electric Power Task Force of the Scientists' Institute for Public Information, unpublished.

Kohl, Daniel H., Georgia B. Shearer, and Barry Commoner (1971) Fertilizer Nitrogen: Contribution to Nitrate in Surface Water in a Corn Belt Watershed," *Science* 174 (Dec. 24): 1311–1334.

Lam, William M. C. (1964) Paper on growth in recommended school light levels, delivered at national convention of the American Association of School Administrators (Feb.).

Meadows, Dennis L. and Donnella H., Jorgen Randers, and William H. Behrens (1972) *The Limits to Growth.* New York: Universe Books.

Stein, Richard G. (1971) "Architecture and Energy." Paper presented at AAAS Annual Meeting, Philadelphia, Dec. 29; and as "Power Consumption in Industry, Commerce, and the Home," prepared for the Power Study Group of the AAAS Committee on Environmental Alterations and the Electric Power Task Force of the Scientists' Institute for Public Information, unpublished.

The Environmental Impact of Chemical Technology [1]

(By Barry Commoner, Director, Center for the Biology of Natural Systems, Washington University, St. Louis, Mo.)

1. INTRODUCTION

The impact of chemical technology on the environment results from the operation of the large scale industries which use that technology for productive purposes. Among them, the petrochemical industry is of particular importance, because it is so heavily based on modern chemical technology, and because its period or rapid growth coincides with the intensification of environmental degradation in the U.S. since World War II. Accordingly, this paper is primarily concerned with an evaluation of the impact of chemical technology as it results from the operation of the chemical industry, particularly the sector based on petrochemicals.

Ideally, in describing the environmental effect of an industry we need to know the nature and amounts of the emitted pollutants and their probable effects on the living constituents of the environment, especially on human health. But even such an accounting would be insufficient to determine the issue of interest, which is: what action, if any, can or should be taken to correct the indicated environmental impact? To make such a decision it is necessary, as well, to relate the deleterious environmental effects of the industry to the social benefits associated with its productive activities, i.e. a cost/benefit assessment must be made. Moreover, where the activity in question yields a product or service that can be provided by some alternative means, environmental cost and social benefits must be compared. The assessment should also include a consideration of the physical, chemical and biological processes that govern the interaction between the given industry and the environment, for such analyses are essential to further our understanding of these problems, which is, as yet, poorly developed. Finally, since social decisions are the ultimate basis of action to correct untoward environmental impact, a similar analysis of the economic and social mechanisms that govern the generation of the industry's environmental impact ought to be included.

We are, as yet, far from achieving this ideal for any single industry or productive activity. However, even a partial analysis of an industry such as petrochemicals is very worthwhile as a means of making a start on this difficult and urgent problem.

As will be shown below, even this kind of partial analysis of the environmental impact of the petrochemical industry reveals that, in comparison with other productive activities, its degradative effect on the environment is extraordinarily intense, and its social benefits are remarkably low. One reason is that there is a tendency *inherent* in the products of petrochemical technology to be toxic or non-biodegradable and therefore incompatible with the natural processes that sustain the integrity of the environment. Another reason is that the production of petrochemicals is particularly extravagent in its use of nonrenewable fossil fuels, relevant to the resultant social benefits. Finally, the petrochemical industry is characteristically *non-innovative* with respect to the end-uses of its products. Typically, the major petro-chemical end-product substitutes for preexisting products which serve a similar function. These are often of equal or better social value, and low in environmental impact because they are of natural origin. Thus, the intense environmental impact of the petrochemical industry cannot be corrected merely by appropriate measures to control waste emissions, for the productive process itself yields relatively low social benefits at high environmental cost. Unfortunately, despite these disadvantages to society there is also inherent in the design of the petrochemical industry a powerful tendency to invade and dominate important sectors of the economy.

In sum, the analysis which follows shows that to ameliorate the intense and socially unrewarding impact of the petrochemical industry on the environment, on health, and on society generally will require that the rapid and continuing growth of this industry be substantially curtailed—a process which will be as difficult as it is important to environmental survival.

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[1] Presented at the American Chemical Society Southeastern Regional Meeting, Charleston, S.C., Nov. 8, 1973.

2. THE RELATION BETWEEN CHEMICAL TECHNOLOGY AND ECOSPHERE

The environment consists of the constituents found on the earth's surface, in the atmosphere, surface waters and the upper layers of soil. This planetary skin, the *ecosphere*, is the habitat of all living things. The life of human beings (and all other organisms) and all human activities depend on the maintenance of the appropriate range of environmental conditions in the ecosphere.

The properties of the ecosphere have gradually evolved during a three billion year period of biological evolution, through the reciprocal interaction of the living and non-living components of the ecosphere. (Thus, the evolutionary emergence of green plants introduced oxygen into the atmosphere, thereby changing its composition and allowing the later appearance of oxygen-using animals.) Hence, the ecosphere is an essential and irreplaceable basis for human existence; all human activities must be compatible with the properties of the ecosphere. Environmental degradation is evidence that they are not.

Chemical technology has created systems of industrial production—an array of man-made chemical constituents and reactions that might be called the *chemical technosphere*—which now coexists with the ecosphere on the earth's surface. However, the petrochemical industry is unique among productive activities: It is based on the production of a large and growing variety of chemical substances which, like those that are decisive in the chemistry of living things, are organic, but which unlike the latter are not produced by living things. There is reason to believe that because of this unique relation between the ecosphere and the chemical technosphere the two are inherently incompatible since chemical substances, particularly organic ones, which are absent from biological systems are, for that reason, frequently toxic and/or non-biodegradable.

The theory viewed from this is of interest. It begins with the observation that the natural biochemical systems characteristic of living things are extremely restricted in the variety of organic substances which they contain, relative to the variety of substances which could be formed by chemical reactions from their constituents.

Thus, although all living things contain considerable amounts of chloride ion and numerous organic compounds that are readily chlorinated (in artificial systems), no *chlorinated organic compounds appear to occur in living things.* Similarly, among many thousands of biochemical constituents which contain nitrogen and oxygen only a few contain the $-N=O$ group. In the same way, despite the presence of some 100 elements in the ecosphere, only about 20 are involved in life processes, many—such as mercury—being excluded. Since biological evolution is a process of trial and error, for which there were enormously frequent opportunities over the three billion year period of evolution, it is likely that a significant number of the organic compounds now *absent* from living things (such as chlorinated compounds) were in fact once produced, but were lost from the evolutionary process because they were incompatible with the overall integrity of the biochemical system. Thus, since many of the enzymatic processes which govern biochemistry depend on sulfhydryl groups, which are inactivated by mercury, the inclusion of the latter in the system of biochemistry was impossible. Also, since the ecosphere operates in closed cycles, every natural biochemical substance is *biodegradable*—i.e., degraded by enzymes produced by living things. In the above sense, then, the synthesis of a substance which is not biodegradable is incompatible with the integrity of the ecosphere, and no such substance is found in living things.

On these grounds it can be expected that many of the products of the petrochemical industry, since they are often, by choice, different from natural organic compounds may be, so-to-speak, "evolutionary rejects" of the natural system and therefore likely to interfere with the latter. Similarly, many petrochemical products (such as plastics) cannot become incorporated into ecological cycles and therefore accumulate as trash—because they are so unlike natural polymers as to resist enzymatic attack. In sum, petrochemicals, precisely *because* they include many man-made organic substances not found in living things have a high risk of interfering with the operation of the ecosphere.

Another important distinction between the petrochemical industry and most other industrial operations, is that in the case of the former a considerable number of substances are released into the environment not only as wastes (i.e., as incidental losses from productive processes), but are *designed, in their use, to be released into the environment.* Such substances include synthetic detergents, insecticides, and herbicides; synthetic solvents and driers used in paints, varnishes and inks; synthetic rubber (worn from tires).

Finally, it should be pointed out that the biological effects of many synthetic organic compounds, which are the chief products of the petrochemical industry, are exceedingly difficult to determine. An important example is carcinogenesis; despite several decades of intensive work, determination that a substance is a carcinogenic hazard to human populations remains a very complex, slow and uncertain process. Yet, as will be shown below it can be assumed that as new petrochemicals are produced, a certain fraction of them will turn out to be carcinogenic (as well as mutagenic and teratogenic). Thus the industry has a tendency to produce substances, some of which are likely to have these serious biological effects, but which can be ascertained to have these effects, or to lack them, only after laborious study.

In sum, from these theoretical considerations it would appear that the petrochemical industry is particularly prone to yield substances which are incompatible with the ecosphere. As is shown below this expectation is borne out by the available evidence, and accounts for the especially intense impact of the petrochemical industry on the environment.

3. EVIDENCE OF THE ECOLOGICAL INCOMPATIBILITY OF PETROCHEMICAL PRODUCTS

Evidence that a particular substance is incompatible with the ecosphere is (a) toxicity to human beings and/or other living organisms; (b) induction of biological changes leading to cancer, mutations or embryonic malformation; (c) nonbiodegradability. Flow charts describing the pattern of production of the chief petrochemicals (each representing at least $10 million in value and in the aggregate comprising about ⅔ of total petrochemical production) are available from the Stanford Research Institute. ("Chemical Origins and Markets"; Flow Charts and Tables; SRI, Palo Alto, 1967). The toxicities (classified as "zero", "slight", "moderate", or "high"—designated in Figure 1 as 0, 1, 2, and 3, respectively) of each of the specific compounds listed in these charts (if known) can be found in Sax's standard handbook on toxicity. ("Dangerous Properties of Industrial Materials", New York, Van Nostrand Reinhold, 1963). Combining these data a new kind of petrochemical flow chart can be constructed (see Figure 1) which shows the levels of toxicity found among the petrochemicals listed in the SRI chart as primary, secondary, tertiary, and quaternary (and beyond) products of the starting materials (crude oil and natural gas). Of a total of 835 specific substances in the chart, 398 (or 48%) are known with respect to local toxocity and 356 (or 43%) are known with repsect to systemic toxicity. Of the substances of known toxicity, only 54 (or 14% of known substances) have *zero* local toxicity and only 9 (or 3% of the known substances) have *zero* systemic toxicity. A total of 139 substances (or 35% of the substances of known local toxicity) have a *high* level of toxicity, and 169 substances (or 48%) of the substances of known systemic toxicity have a *high* level of toxicity. In several major lines of petrochemical products the numbers of moderately and highly toxic substances increases significantly as primary products are converted to secondary ones, the latter to tertiary ones and finally to quaternary (and beyond) products.

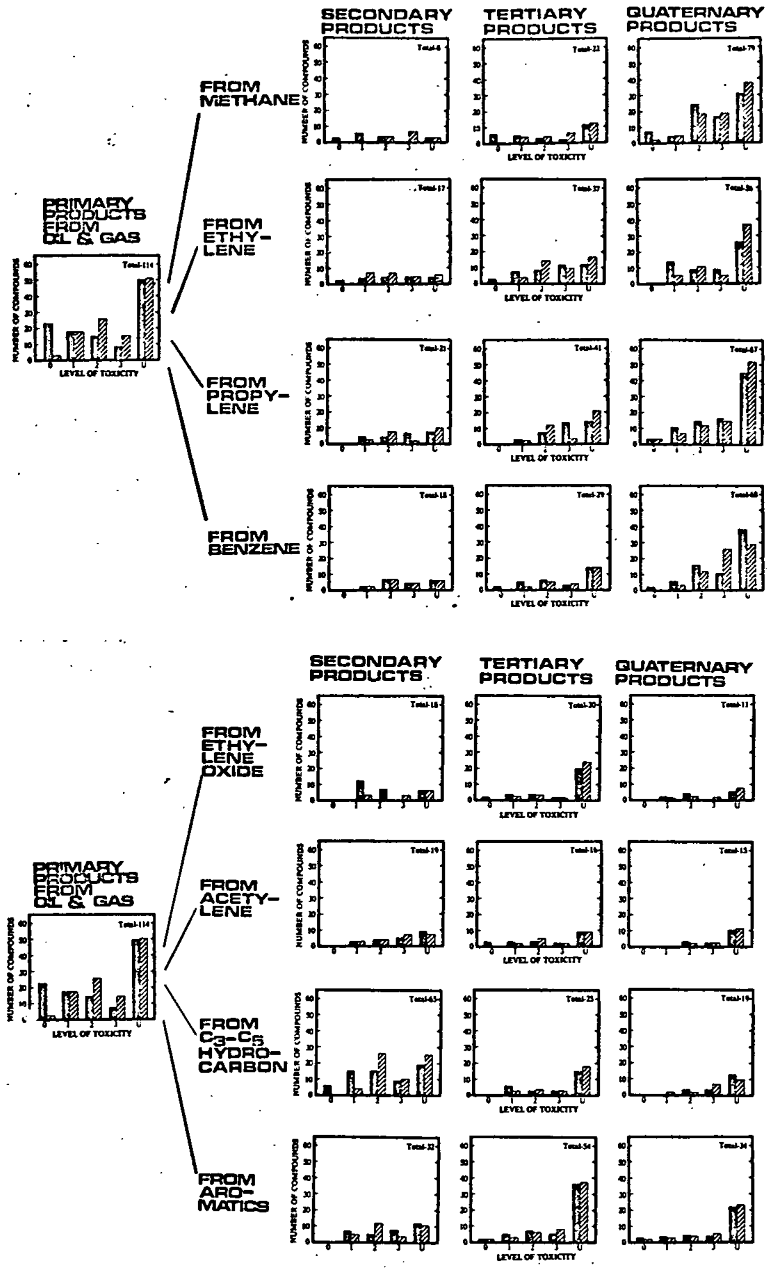

FIGURE 1A AND 1B.—Flow chart for the production of the 115 leading petrochemical products (representing about ⅔ of the bulk and market value of all products) derived from the Standord Research Institute "Flow Chart for Chemical Origins and Markets: Flow Charts and Tables" for 1967. Levels of toxicity are from Sax's classification for the specific substances indicated by the SRI chart: 0, no toxicity; 1, low toxicity; 2, moderate toxicity; 3, high toxicity; U, toxicity unknown; solid bars, local toxicity; striped-bar, systemic toxicity.

Thus Figure 1, which is a kind of "petrochemical toxicity flow chart" shows that as the industry generates an increasing array of substances it also produces a growing risk of toxic effects on living things. In contrast it can be shown (directly and from the relatively small number of species which are toxic or pathogenic to other organisms; see Table I) that only a few percent of *natural* substances are toxic, and that these (in contrast with unnatural toxic substances) usually effect only a limited range of species.

TABLE I.—RELATIVE NUMBERS OF PATHOGENIC SPECIES

Type of organism	Total number of species	Pathogenic species [1]	
		Number	Percent
Higher plants	200,000	200	0.1
Fungi	100,000	150	.01
Bacteria	1,500	100	6.6

[1] I am grateful to my colleague, Dr. James Maniotis, for developing these estimates. It is possible to infer from these data a very rough estimate of the number of natural organic compounds which are toxic to some organisms. The pathogenicity of 1 organism toward another is usually due to the production in the former of 1, or at most a few, substances which are specifically toxic toward the latter (e.g. the botulism toxin). Hence, if as indicated above, there are about 500 species of known pathogenic organisms, and taking into account that the same substance may account for the pathogenicity of several different species, there are probably of the order of about 1,000 natural compounds which are the basis of pathogenicity. This represents perhaps about 1 to 2 percent of the total number of known natural organic compounds. Studies of carcinogenicity of chemical substances provide another source of such data. At present about 10 to 50 natural substances are known to be carcinogenic, although this number is subject to increase. Again, relative to the total number of natural substances, this number is quite small.

Figure 2 provides further evidence of the inherent tendency of organic synthesis to produce substances incompatible with the ecosphere. This shows the constantly increasing numbers of such substances that are found to be neoplastic or carcinogenic. Some 600 such substances are now known, and in recent years the number appears to be increasing at the rate of about ten per year.

Less systematic evidence of the tendency of the petrochemical industry to produce and to release into the environment ecologically damaging materials is provided by the well known effects of tetraethyl lead, synthetic detergents, DDT, PCB's, pthalates and other plastic additives, herbicides, artificial sweeteners and other food additives.

Apart from such toxic effects ecological incompatibility of petrochemical products is evident in the fact that massive amounts of these products—especially plastics, synthetic fibers, PCB's—are not biodegradable and hence accumulate in the environment, or are destroyed by burning, often resulting in air pollution.

In sum, there is considerable evidence that petrochemical products tend to be *inherently* incompatible with the ecosphere, so that the industry must be regarded as a serious potential risk to the integrity of the ecosphere. And, as will be shown below, given the present scale of the industry and the pattern of product use, this potential for damage is, in fact, being realized.

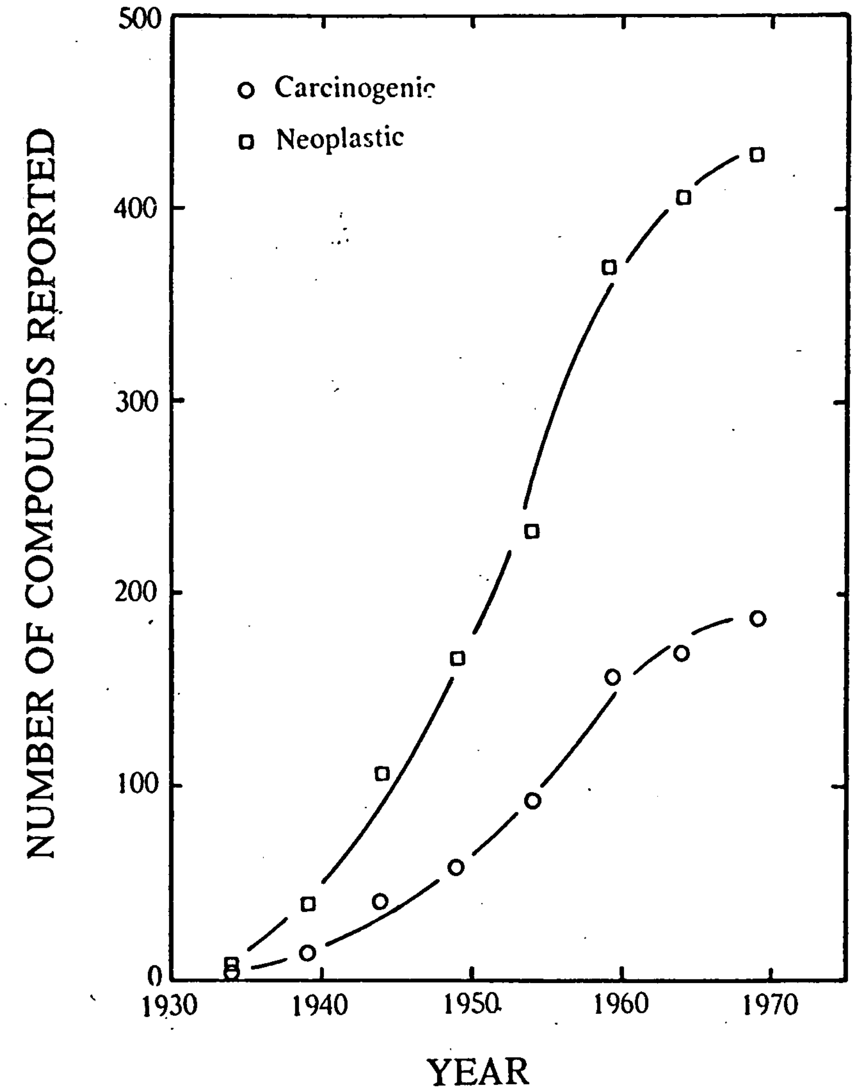

FIGURE 2.—The number of carcinogenic and neoplastic (i.e., causing the formation of non-cancer tumors) compounds plotted against the year of publication of the report which established this property. Data taken from U.S. Public Health Service, "List of Toxic Substances", 1972 edition.

4. THE SCALE OF THE CHEMICAL TECHNOSPHERE RELATIVE TO THE ECOSPHERE

Although, as shown above, there is inherent in the products of the petrochemical industry a considerable tendency toward incompatibility with the ecosphere, this potential will have a significant impact on the ecosphere *only* if the industry operates on a scale sufficient to affect the natural system. Evidence that in a country such as the U.S. a scale sufficient to exert important effects on the ecosphere has in fact now been achieved by the chemical technosphere is the following:

(*a*) Table II shows that the natural ratio of Pb to Cu in the ecosphere (as given by the ratio found in the sector which because of its size is least affected by human activities: the ocean)—.03 ppb Pb/3 ppb Cu—becomes sharply altered in U.S. surface water supplies (.017 ppm Pb/.021 ppm Cu), because the ratio of industrial use of the two metals (about 1:2) is so different from the natural ratio of 1:100.

TABLE II

	Lead	Copper
Concentration in sea water (parts per billion)[1]	0.03	3.0
Concentration in precipitation (parts per million)[2]	.034	.021
Concentration in surface water supplies (parts per million)[2]	.017	.021
Annual industrial consumption (tons)[1]	816,000	1,400,000

[1] From H. A. Schroeder, and D. K. Darrow, Prog. in Anal. Chem. 5, 81 (1973).
[2] U.S. average, 1966–67, from J. P. Lodge, et al., "Chemistry of United States Precipitation," National Center for Atmospheric Research, Boulder, Colo., 1968.

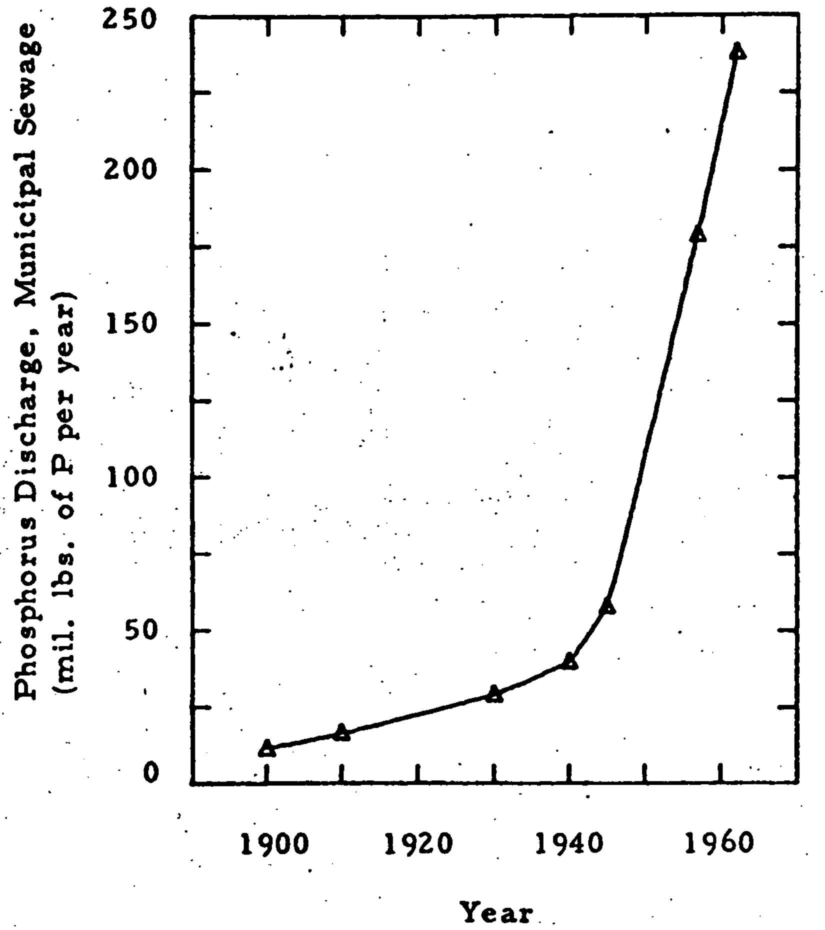

FIGURE 3A.—Phosphorus emitted by United States municipal sewage. Data are from Weinberger, L. W., *et al.* in Hearings before the Subcommittee on Science, Research and Development of the House Committee on Science and Astronautics, *The Adequacy of Technology for Pollution Abatement*, Vol. *II*, U.S. Government Printing Office, Washington, D.C., p. 756.

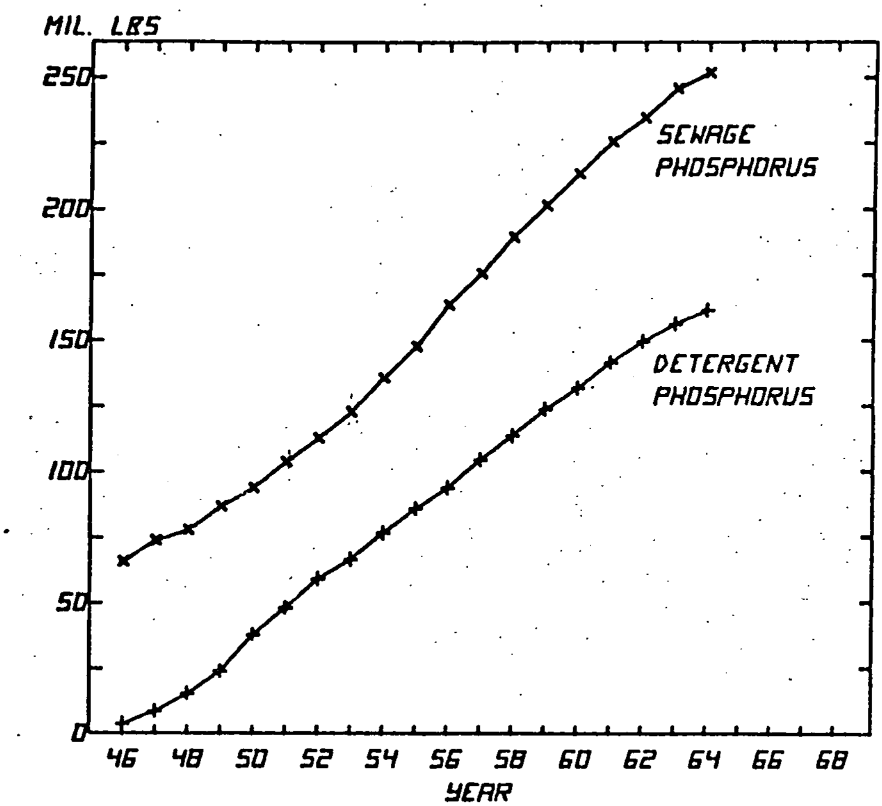

FIGURE 3B.—Concurrent values of phosphorus output from municipal sewage in the United States and phosphorus content of detergents produced. Former values are from Weinberger, L. W., *et al.* (see Legend, Figure 3a Detergent data are based on detergent production (see Legend, Figure 5) assuming an average of 4% P in marketed detergents.

(*b*) Figure 3 shows the effect of a major petrochemical product—synthetic detergents—on the phosphate entering surface waters from municipal sewage systems. The more than seven-fold rise in phosphate emission since 1940, when detergents were introduced into the market (which compares with an approximate doubling in the preceding 30 years), can be wholly accounted for by the phosphate content of detergent sold in the U.S. since 1940.

(*c*) Table III enables a comparison of the intensity of a major source of ecological stress on aquatic ecosystem, annual Biological Oxygen Demand (BOD) from the chemical industry (9,700 x 10^6 lbs.) and from the human population of the U.S. which uses sewers (7,300 x 10^6 lbs.). Apart from the fact that the BOD from the chemical industry (which given the organic nature of most petrochemical wastes must come largely from the petrochemical sector of the industry) is a good deal larger than that due to human wastes, it should be noted that many of the substances contributing to the former, and their degradation products, are toxic while the latter are not. In one recent study 496 different synthetic organic compounds were expected to occur in a particular stretch of river (based on information about industrial emission), and given the earlier evidence, a significant fraction of these must be toxic. Similarly, although only 10% of the organic matter contained in urban air particulates has been identified, the list already includes 55 specific organic substances, nearly all absent from living things. It is also significant that several important non-degradable petrochemicals have now been found widely disseminated in the ecosphere: plastic micro particles in marine plankton hauls; PCB's DDT and pthalates in a very wide range of species and geographic locations.

All of this is persuasive evidence that the chemical technosphere, at least in an industrialized country such as the U.S., has achieved a scale which is sufficient to impinge significantly on the ecosphere. Hence, given this scale of effect, the toxic and otherwise ecologically incompatible potentials inherent in the substances yielded by the petrochemical industry are in fact being realized.

5. RELATION OF THE ENVIRONMENTAL IMPACT OF THE PETROCHEMICAL INDUSTRY TO ITS SOCIAL VALUE

From the foregoing evidence it can be concluded that in a country like the U.S., the petrochemical industry can be expected to have an appreciable deleterious impact on the environment. While ideally one would wish to express this impact in some overall, general integral, this is not possible since the effects are often highly specific and since in any case many of them are still unknown or poorly evaluated (see Figure 1). It is necessary, then, to fall back on those few known environmental effects which have a general influence on the ecosphere, in order to compare environmental impact with other relevant parameters.

Data on two generalized environmental effects are available. One of these is BOD, which represents a serious and easily compared effect on aquatic ecosystems. The second is simply the amount of fuel burned in accomplishing production. The latter has two environmental effects: (a) The combustion of fuel inevitably pollutes the air residues and is a source of heat pollution; (b) Fuel combustion depletes a non-renewable resource, itself a threat to survival, and in advance of that, a source of ecologically deleterious dislocations of production.

As already noted, no environmental impact, such as the above, can be meaningfully evaluated in the abstract. In nearly every case impact on the environment is the unintended, unwanted accompaniment to a socially *useful* process. Hence, environmental impact must be related to the social value of the process which induces the impact. Again, in order to make the necessary comparisons among different products it is important to find general measures of social value. Several are available that are applicable to productive processes such as the petrochemical industry: (a) value added in manufacture; (b) the number of production workers; (c) total wages paid in the industry. Value added is a measure of the economic gain inherent in the production process; it is related to the sale price and therefore to some degree reflects the value of the product to the purchaser. The number of workers involved in the operation expresses its capability of generating jobs, which represents a basic social value; this is also true of wages paid.

Thus it becomes of interest to compare the chemical industry and other productive operations with respect to the ratios of these three parameters of social value to each of the two available parameters of environmental cost, BOD and fuel consumption. These relationships are shown in Tables III and IV.

TABLE III.—RELATION BETWEEN INDUSTRIAL VALUES AND BOD (1964)

Manufacturing sector	BOD (millions of pounds)	Value added (millions of dollars)	Workers (thousands)	Wages (millions of dollars)	Value added dollars per pound	Workers (BOD workers per thousand pounds)	Wages (BOD dollars per pound)
Chemicals and allied products	9,700	19,165.8	479.9	2,927.5	2.0	49.5	0.3
Paper and allied products	5,900	7,805.7	470.8	2,678.3	1.3	79.8	.4
Food and kindred products	4,300	25,053.2	1,095.4	5,367.0	5.8	254.7	1.2
Textile mill products	890	6,671.8	781.7	2,962.9	7.5	878.3	3.4
Petroleum and coal products	500	3,780.4	105.4	743.2	7.5	210.8	1.5
Primary metals	480	16,692.4	973.4	6,577.6	34.7	2,027.9	13.7
Transportation equipment	120	22,733.9	1,119.8	7,771.5	189.4	9,331.6	64.7
Electrical equipment and supplies	70	17,765.4	1,029.9	5,568.9	253.7	14,712.8	79.5
Non-electrical machinery	60	20,302.4	1,108.7	6,982.3	338.3	18,478.3	116.3
Rubber and plastics products	40	4,990.9	340.7	1,798.5	124.7	8,517.5	44.9
All other manufactures	390	61,231.7	4,897.6	22,461.2	157.0	12,557.9	57.5
Total, all manufactures	22,000	206,193.6	12,403.3	65,838.9	9.373	563.786	3.0

Sources: BOD values from "The First Annual Report of the Council on Environmental Quality," Washington, D.C., 1970. All others rrom U.S. Census of Manufacturers.

TABLE IV

	Fuel energy used (10^{15} Btu)	Value added (10^6 dollars)	Workers (thousands)	Wages (10^6 dollars)	Value added: fuel energy (dollars per 10 Btu)	Workers: fuel energy (workers per 10^9 Btu)	Wages: fuel energy (dollars per 10^9 Btu)
Chemicals and allied products	3.33	23,550.1	541.4	3,555.2	7,072	163	1,067
Petroleum and coal products	1.53	5,425.8	99.4	786.4	3,546	65	514
Primary metals	3.39	19,978.2	1,041.5	7,457.3	5,893	307	2,200
Stone, clay, and glass products	1.41	8,333.4	469.3	2,784.1	5,914	333	1,974
Paper and allied products	1.38	9,756.3	507.7	3,205.5	7,069	368	2,322
Food and kindred products	1.07	26,620.9	1,121.7	6,062.6	24,879	1,048	5,666
Transportation equipment	.53	28,173.9	1,336.5	9,918.2	53,159	2,522	18,714
Textile mill products	.46	8,153.2	828.2	3,556.6	17,725	1,800	7,732
Nonelectrical machinery	.42	27,836.4	1,349.0	9,236.1	66,278	3,212	21,991
Fabricated metal products	.40	18,042.6	1,056.9	6,541.6	45,107	2,642	16,354
Electrical equipment and supplies	.36	24,487.3	1,323.8	7,607.0	68,020	3,677	21,131
Rubber and plastics products	.25	6,799.5	410.1	2,312.5	27,198	1,640	9,251
Lumber and wood products	.23	4,973.4	495.7	2,290.6	21,624	2,155	9,959
Printing and publishing	.11	14,355.1	631.6	4,011.3	130,501	5,742	36,466
Apparel and related products	.07	10,064.4	1,200.4	4,340.6	143,778	17,149	62,008
Instruments and related products	.07	6,418.4	265.9	1,569.0	91,692	3,799	22,414
Furniture and fixtures	.06	4,169.5	357.5	1,653.7	69,492	5,958	27,561
Leather and leather products	.04	2,626.5	293.3	1,147.0	65,662	7,333	28,675
Tobacco manufactures	.02	2,032.0	66.2	303.6	101,600	3,310	15,180
All manufactures	14.63	261,983.8	13,955.3	81,393.6	17,907	954	5,564

Source: U.S. Census of Manufacturers.

Table III shows that, compared with other standard sectors of manufacturing, the chemical industry exhibits a very low ratio of social benefit to BOD. Compared with the other sectors of manufacturing the chemical industry yields the poorest ratios of jobs and wages paid to BOD produced and the the second poorest ratio of value added to BOD produced (paper and pulp manufacturing being worse). Value added per unit of BOD produced by the chemical industry is about ⅕ of that for all manufactures; in both workers employed and wages paid per unit of BOD produced, the industry is about $1/10$ as effective as the average for all manufactures.

Table IV shows a similar set of relationships between these social values and fuel consumption. Among all manufacturing industries the chemical industry is the second lowest in value added, number of workers, and in wages paid per unit of fuel consumed, being exceeded only by petroleum refining.

However, it should be noted that in Table IV what is reported is only the amount of fuel *burned* in each given industrial sector. In the case of the petrochemical industry a unique situation arises: In addition to the fuel that is burned a considerable amount is also used as feedstock. For 1967, the chemical industry used in addition to 3.33×10^{15} BTU of fuel for combustion, about 1.8×10^{15} BTU of crude oil and natural gas as feedstock. Therefore, the industry used a total of about 5.1×10^{15} BTU of this non-renewable resource. Thus the chemical industry is in fact, among all sectors of manufacturing, the largest single user of fuel, accounting for about ⅓ of all fuel used for manufacturing and about 7% of the nation's total energy budget.

Thus, these general measures of social value and of environmental cost show that, compared with other productive activities, the chemical industry yields a remarkably low social value relative to the intensity of its environmental impact. It is now recognized that the overall environmental impact of industry must be sharply reduced if we are to survive the environmental crisis. Given that curtailment or elimination of a productive operation is a very effective way of reducing its environmental impact, it would appear that such measures could be used to reduce the environmental cost of the chemical industry at a minimum loss in social benefits, at least as measured by the above values.

6. THE SOCIAL NEED FOR PETROCHEMICAL PRODUCTS

One could argue that despite their poor ratio of certain social values to environmental cost, petrochemicals and other chemical products have an overriding social value, because they provide for needs which cannot be met in any other way. In effect, the *uniqueness* of the social service performed by a product may contribute strongly to its overall social value, regardless of other disadvantages. Obvious examples are highly specific products such as cameras, microscopes, radios and tape recorders; no other products can perform their functions. Less obviously, the same is true of certain essential *generic* products such as clothes, cleaners, or rubber tires. We must inquire, therefore, into the degree to which petrochemical products have social value because of either their specific or generic uniqueness.[1]

A relevant exercise is reported in Table V. Here are listed all of the end uses given for a major segment of petrochemical products—those derived from ethylene—in a standard work on the petrochemical industry by Albert V. Hahn. The list is noteworthy in the extreme scarcity of specific, unique products. Indeed it becomes evident from this list, as from a general inspection of the end-uses of all petrochemicals, that (apart from pharmaceuticals) the industry is quite remarkable for the *non*-uniqueness of its products. Typically a petrochemical product is a substitute for a pre-existing product which performs more or less the same function, where the function itself may be generically unique. Thus cleaners are essential and thereby socially valuable; soap is a product which serves this purpose and while the petrochemical product, detergent, is an alternative to soap in performing this essential service it is not itself unique because soap is an alternative to it. As shown in Table V this type of relationship is typical of all of the major petrochemical products: clothes (natural fibers vs. synthetic ones); shoes (leather vs. plastic); containers (metal or glass vs. plastics); building exteriors (metal, wood, concrete or stone vs. plastics); tires (natural vs. synthetic rubber).

Since petrochemical products are typically *replacements* for pre-existing ones, and given their inherently low social value relative to other products, petrochemical products can be accorded a redeeming social importance only if it can be shown that they have replaced a product which it has become no longer possible to produce.

TABLE V.—ETHYLENE END-USE PRODUCTS; ADVANTAGES AND ALTERNATIVES

End-uses of ethylene petrochemical products [1]	Preexisting alternatives [2]	Secondary end-use advantages of petrochemical product	Possible or improved alternatives to advantages of petrochemical product
Construction:			
Flooring (vinyl)	Wood, tile	Ease of installation and maintenance.	Return to preexisting alternatives.
Weather stripping	Natural fibers	Improved engineering qualities.	Return to preexisting alternatives and change design.
Pipe and fittings	Metallic pipe and fittings	Ease of installation	Return to preexisting alternatives.
Waterproofing	Natural waterproofing products.	Improved engineering qualities.	Do.
Swimming pool liners	Cement pools	Ease of installation	Do.
Windows	Glass	Flexibility of design	Do.
Siding and panels	Wood, tile, brick, steel	Flexibility of design, light weight, ease of handling.	Do.
House furnishings:			
Furniture upholstery	Natural fabrics, leather, caning.	Ease of maintenance	Return to preexisting alternatives and change of design.
Wall covering	Paper, wood panel, grass mat, tile.	Ease of installation and maintenance.	Return to preexisting alternatives.
Shower curtains	Canvas, glass door	do	Return to preexisting alternatives and change of design.
Curtains	Natural fibers	Ease of maintenance, reduced flammability.	Return to preexisting alternatives.
Table cloths, place mats.	Linen, cotton, woven straw, reed, grass.	Flexibility of design	Do.
Closet accessories	Wood and other natural products.	Flexibility of product design	Do.
Garden hose	Rubber and metal piping	Lightness	Do.
Phonograph records	Live music	Instant music	Other recording methods, and encourage live music.

See footnotes at end of table.

[1] Pharmaceutical preparations of unique therapeutic value are the outstanding example of such products among those yielded by the petrochemical industry. Such a product could, indeed, justify an operation which is inefficient in its use of fuel, production of jobs and wages and in its environmental impact. Pharmaceutical products are not considered in this paper because their actual therapeutic values are so variable and difficult to determine that one is not justified in accepting the validity of their use-value with the confidence, let us say, that detergents do in fact clean clothes. In any case pharmaceuticals represent a relatively small segment, in terms of material, of the overall industry.

TABLE V.—ETHYLENE END-USE PRODUCTS; ADVANTAGES AND ALTERNATIVES—Continued

End-uses of ethylene petrochemical products [1]	Preexisting alternatives [2]	Secondary end-use advantages of petrochemical product	Possible or improved alternatives to advantages of petrochemical product
Toys	Wood, paper, cloth, steel, rubber.	Flexibility of design	Return to preexisting alternatives.
Stationary supplies	Wood, metal	do	Do.
Sporting goods	Leather, gut wood, rubber, canvas.	do	Do.
Tools and hardware	Leather, rubber, wood, steel, fabric.	Better insulation, Flexibility of design.	Do.
Credit cards	Cardboard, steel	Flexibility of design	Return to preexisting alternatives and change design.
Automobile furnishings and products:			
Automobile seat covers, upholstery, floor mats.	Natural fabrics, rubber, leather, wood.	Ease of maintenance, flexibility of design.	Return to preexisting alternatives.
Steering wheel	Steel, wood, leather	No apparent advantage	Do.
Antifreeze	Alcohol	Reduced evaporation	Return to preexisting alternatives and reduce auto numbers and mileage.
Brake fluid	Oil	Improved engineering qualities.	Do.
Hydraulic fluid	do	do	Do.
Lead scavenger (antiknock fluid).	None		Change engine design and reduce auto numbers and mileage.
Tubing and hose	Rubber, metal	Improved engineering qualities.	Return to preexisting atlernatives.
Wash-n-wear clothes	Iron, seersucker, etc	No-iron	Return to preexisting alternatives and change style.
Plastic clothes, raincoast, baby pants.	Oilskin, canvas, etc	Improved waterproofing	Return to preexisting alternatives.
Personal consumer products:			
Cosmetics (solvents)	Oils	Flexibility of product design	Return to preexisting alternatives and reduce use.
Disinfectants	Naturally occuring substances, soap.	Improved potentcy	Return to preexisting alternatives and improved sanitation practices.
Detergents	Soap	Allows hard water washing	Return to preexisting alternatives and redesign washing machine plus water softening.
Dry cleaning fluids	None		Change to washable fabrics.
Medical supplies (tubing)	Natural rubber	Improved engineering qualities.	Return to preexisting alternatives.
Food additives (no-cal soft drinks).	Naturally occuring substances.	Flexibility of product design	Do.
Flavors	Natural flavors	Economy and flexibility of product design.	Do.
Communications material:			
Signs	Wood, steel	Increased visability. Flexibility of product design.	Return to preexisting alternatives and reduce advertising.
Paints (solvents)	Natural oils	Improved covering preserving qualities.	Return to preexisting alternatives and reduce air pollution.
Paint removers	Turpentine, heat	Improved efficiency	Return to preexisting alternatives.
Printing ink (solvents)	Natural oils	Increased range of engineering properties.	Do.
Packaging	Paper, cloth, wood, tin	Better advertising, longer shelf life.	Return to preexisting alternatives and reduce amount of packaging, and improved distribution.
Military jet fuel additives	None		Cutback military flights.
Pesticides:			
Herbicides	Biological and cultural controls.	Ease of application	Return to preexisting alternatives and new biological and cultural controls.
Rodenticides	do	do	Do.
Insecticides (DDT)	do	do	Do.
Fungicides	do	do	Do.

[1] This list of ethylene end-use products is adapted from ch. 5, "Ethylene," of Hahn, Albert V., "The Petrochemical Industry: Market and Economics," New York: McGraw-Hill Book Co., 1970. Hahn lists under end-uses, consumer products as well as chemical intermediates which are used as further raw materials. We consider in this table all of the final consumer products which he lists, excepting the 1 pharmaceutical in the original list, aspirin.

[2] This column, like the 2 following, does not pretend to be exhaustive. It is merely a first attempt at understanding the social value of the end-uses of ethylene and the possible alternatives.

Data are available relative to this question. For example, Figure 4 shows that following the introduction of synthetic detergents in the 1940's they captured nearly all of the cleaner market from soap. But this did *not* occur because soap supplies had become inadequate, for as shown in Figure 4, U.S. supplies of saponifiable fat remain adequate to meet the total demand for cleaners. Figure 5 provides some further information on this issue; it shows that per capita consumption of cleaners has remained essentially constant since 1946, so that total demand has only increased with the population (by about 45–50%) since then. Again there is no evidence that soap production could not keep pace with per capita demand. Figure 6 shows that a similar relationship is true of fabrics: Synthetic fabrics have displaced natural ones (cotton and wool), with per capita consumption about constant. There is no evidence that in the period of displacement agriculture could not have met the overall demand for fiber.

The generality of this relationship is shown in Figure 7 which gives the annual rates of increase in output of a series of basic products in the U.S. since 1948. The general picture is clear: pre-existing products which met essential needs for clothes, shoes, cleaners, building materials (i.e., natural fibers, leather, soap, bricks, steel, lumber) have been displaced by their petrochemical competitors (synthetic fibers, plastics and detergents). In a similar sense synthetic nitrogen fertilizer, another major chemical product, has displaced land in food production.

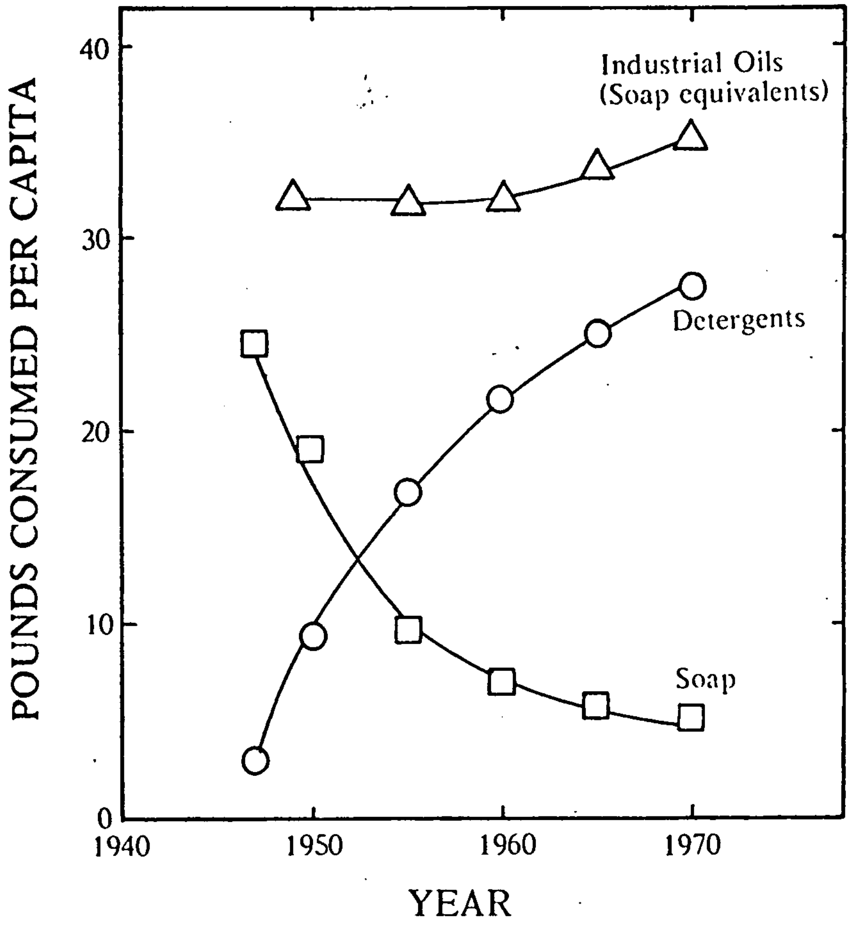

FIGURE 4.—Domestic consumption of detergents, soap, and industrial (saponifiable) oils and fats in the U.S. The latter values have been converted to the equivalent weights of soap that could be manufactured from the oils and fats. Date from U.S. Census of Manufacturers.

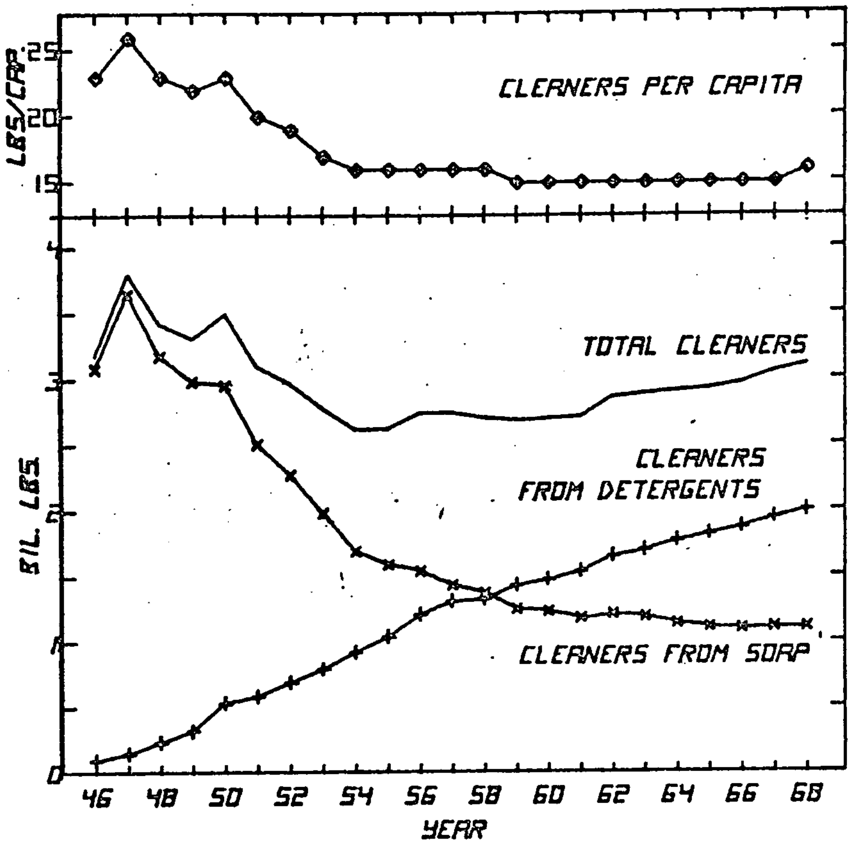

FIGURE 5.—Total soap and detergent production and per capita consumption of total cleaners (soap plus detergent) in the United States since 1946. Data are from *Agricultural Statistics*, U.S. Government Printing Office, Washington, D.C., 1970, p. 149. Detergent data represent actual content of surface-active agent, which is estimated at about 37.5% of the total weight of the marketed detergent.

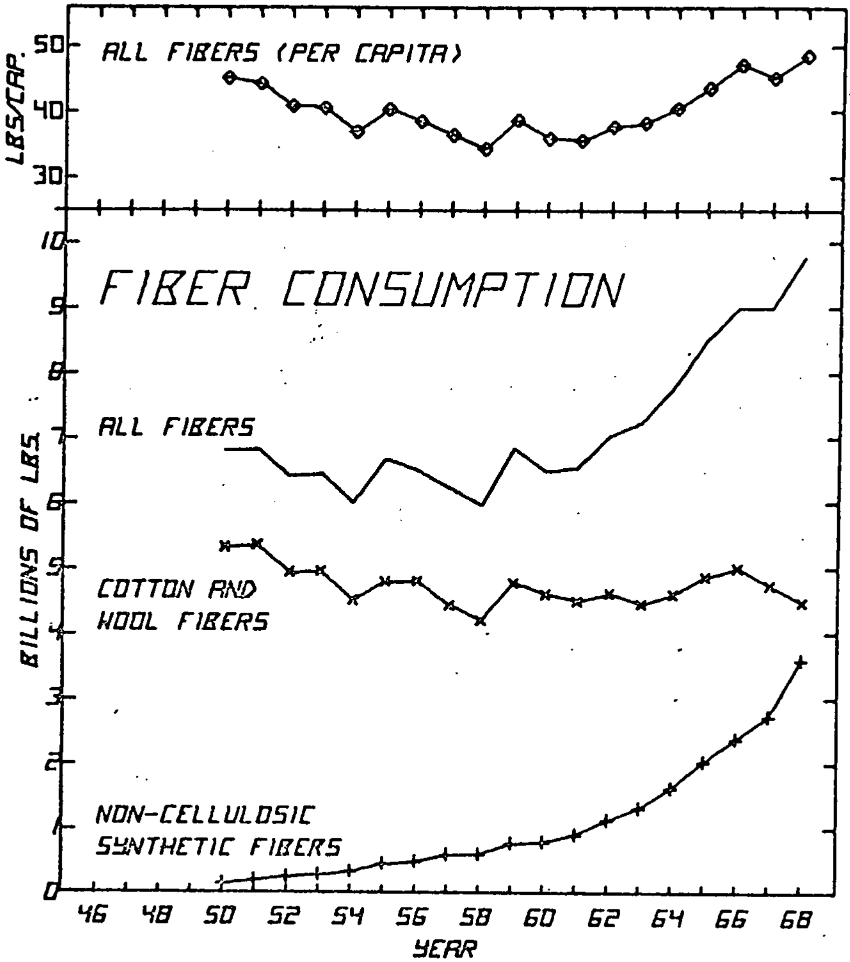

FIGURE 6.—Natural and synthetic fiber production in the United States since 1946. Data are from *Statistical Abstract of the United States*, op. cit., 1962, p. 198; 1966, p. 789; 1970, p. 713.

Synthetic rubber suggests an interesting *apparent* exception to this rule. Natural rubber now meets only three million long tons of a total demand amounting to about eight million long tons. A major reason is the sharp decline in natural rubber production, that occurred when the U.S. dumped its rubber stockpile in 1969, forcing the price of natural rubber to decline from $43/lb. in 1960 to $.23 in 1970. The chief producer of natural rubber, Malaya, suffered a 33% decline in the market value of its crop between 1960 and 1968; as a result plantations were abandoned in Malaya and other rubber-producing countries, leading to their present incapability to meet total world demand for rubber. Nevertheless it appears that the total demand for rubber could be met by plantations. Average yields in Malaya are now about 500 lbs/acre, but new genetic varieties of rubber trees can produce as much as 3.000 lbs/acre and could readily sustain the tripling in natural rubber production to recapture the market from synthetic rubber. This apparent exception only reveals that economic manipulations are capable of enforcing the displacement of a natural product by a synthetic one, and even of temporarily reducing productive capacity for the former.

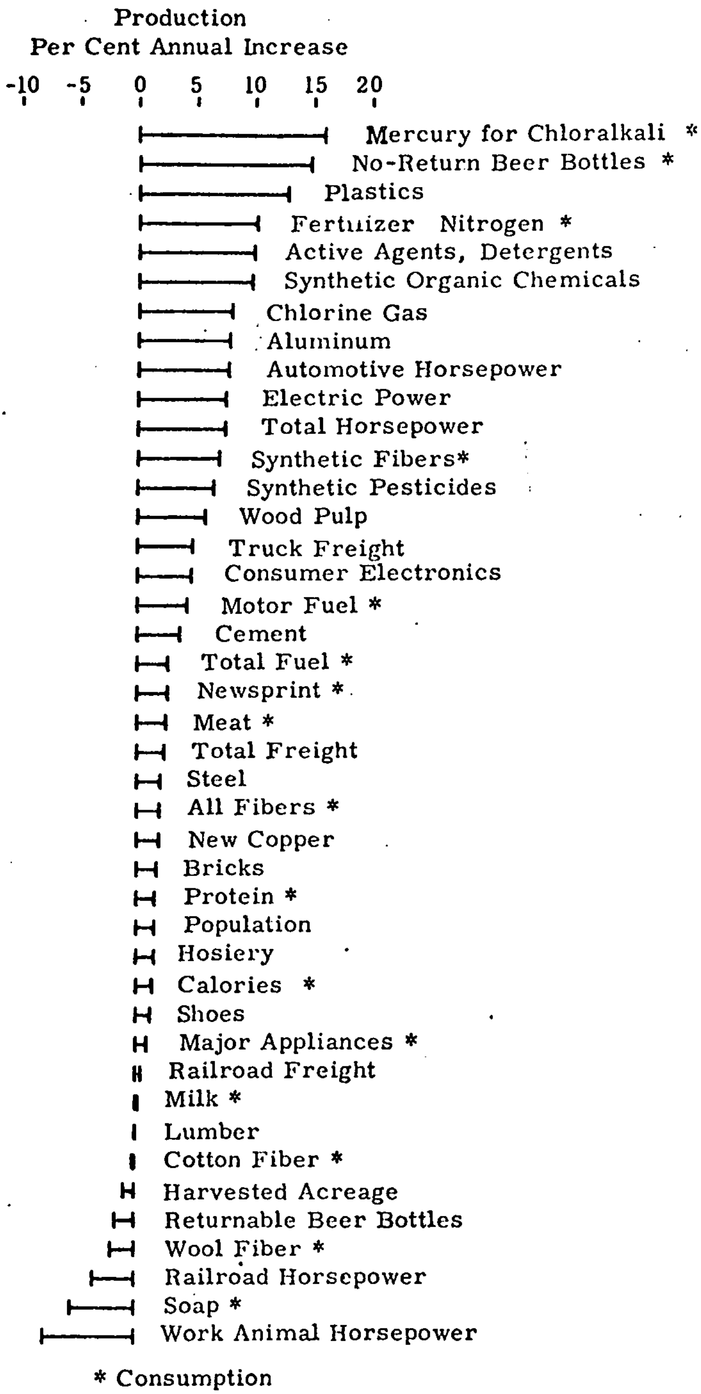

FIGURE 7.—Annual growth rates of production (or consumption) since 1948 in the United States. Annual data are from Statistical Abstract of the United States, op cit., 1948–1970.

In sum, the foregoing evidence shows that a chief reason for the intensification of environmental impact in the U.S. since World War II is that needs for essential goods have since then become increasingly met by petrochemical products which, compared to other alternative products, generate much more intense environmental impacts relative to their social value. A direct way of illustrating this effect is shown in Table VI. This reveals that in the period 1946 to 1968 the environmental cost (as given by the amount of phosphate intruded upon surface waters) per unit of cleaner used has increased nearly 20-fold. In quite practical terms this means that for a given social value—let us say washing a shirt—the environmental cost has been increased 20-fold by the displacement of soap by detergents.

TABLE VI.—DETERGENT PHOSPHORUS ENVIRONMENTAL IMPACT INDEX

	Index factors			Total impact (a×b×c), phosphorus from detergents [2] (10^6 pounds)
	(a)	(b)	(c)	
	Population (thousands)	Cleaners: [1] Population (pounds per capita)	Phosphorus: (pounds per ton of cleaner)	
1946	140,686	22.66	6.90	11
1968	194,846	15.99	137.34	214
1968:1946	1.42	.69 [3] (1.00)	19.90 (13.70)	19.45
Percent increase 1946–68	42	(0)	(1,270)	1,845

[1] Assuming that 35 percent of detergent weight is active agent.
[2] Assuming average phosphorus content of detergents equals 4 percent.
[3] Because of uncerainties regarding the content of active agents in detergents, especially soon after their introduction, the apparent reduction in per capita use of cleaners is not regarded as significant; the numbers contained in parentheses are based on the assumption that this value does not change significantly.

Figure 8 points out that certain special features of petrochemical reactions—namely that they frequently call for the use of chlorinated intermediates—considerably amplifies the already high environmental costs encumbered by the displacement of older products by petrochemical ones. The sharp rise in production of petrochemicals has induced a comparable rise in chlorine production and in the use of mercury in that process—with the resultant contamination of fresh waters in the U.S. by mercury from chlor-alkai plant wastes. This adds to the environmental cost of washing a shirt.

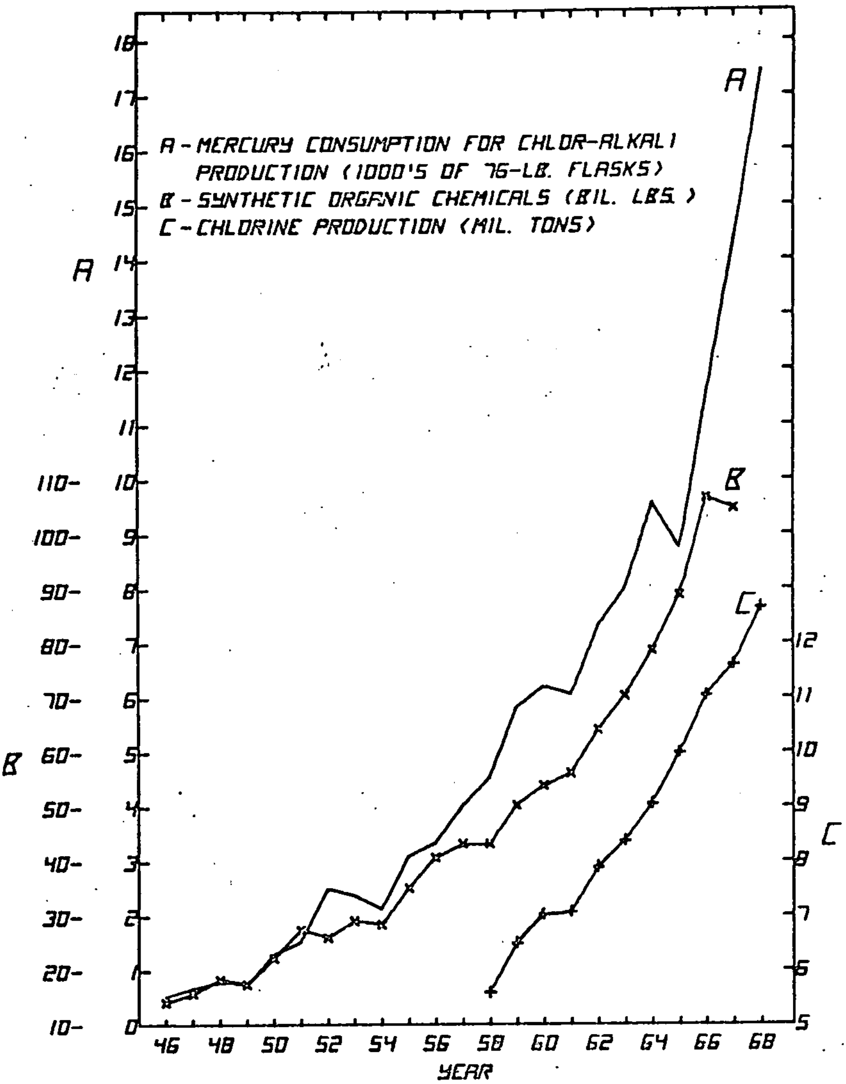

FIGURE 8.—Changes in annual production of synthetic organic compounds and of chlorine gas, and consumption of mercury for chlorine gas production in the United States since 1946. Data are from Bureau of the Census, *Current Industrial Reports, Series M28A Inorganic Chemicals and Gases* and from *Statistical Abstract of the United States*, op cit.

In the foregoing discussion, certain real advantages of petrochemical products over the older ones which they have displaced have, as a first approximation, been ignored. We now return to this question. First it should be stated that certain types of petrochemical products (apart from pharmaceuticals, which, for reasons given earlier are excluded from this discussion) do in fact have unique properties. Thus in certain applications nylon gears will perform in ways that are so superior to metal ones as to enable the construction of a unique mechanism. But such socially valuable uses can account for only a small part of the mass of petrochemical products, which is due largely to synthetic fibers, detergents, plastic wrappings, containers and building materials—all of which are distinctly *not* qualitatively unique in their properties.

Nevertheless, it remains true that many major petrochemical products have advantages of a secondary order (or less) over their pre-existing competitors. Thus, synthetic fabrics do require less ironing and dry more readily than natural ones; synthetic resins impregnated in fabrics eliminates ironing; detergents function more effectively than soap in modern washing machines; synthetic food additives may extend shelf-life. Accepting these advantages as real, and ignoring associated *disadvantages* (for example that resin-impregnated fabrics are hotter and less comfortable than unimpregnated ones or that additives may turn out to be carcinogenic) it is nevertheless true that such advantages are not absolute and can be countered by alternative practices, some of which are set forth in Table V. For example, ordinary cotton shirts can in fact be worn unironed without any sacrifice in social value other than style (this is true in at least certain social circles and could readily become universal through a fairly small change in cultural norms). Or the fabric can be designed to eliminate the need for ironing (seersucker). In the same way instead of extending shelf-life one could develop a system of food distribution efficient enough to provide a constant supply of *naturally fresh* food. Similarly, although present washing machines take advantage of the superior dispersing power of detergents by adopting a design which filters the soiled wash water *through* the clothes (if this is done with soap in the absence of an added dispersing agent, particles are caught in the clothes) this advantage would disappear if the machine were redesigned to avoid this pattern of water movement.

What emerges from these considerations is the conclusion that, with certain exceptions (accounting for only a minor part of production) petrochemical products are typically *not* unique and innovation. Rather, they tend to imitate the function of pre-existing products, but frequently adding a minor, secondary—often trivial—improvement in function or design flexibility which can in turn be readily matched by improving earlier products or practices, or by changing styles or cultural approaches. In effect petrochemical products are often, in a quite meaningful sense, trivial with respect to their enhancement of social use-value. And as we have already seen, as indicated by measures such as value added, jobs, and wages, petrochemical products tend to be very poor sources of social value relative to environmental cost. There appears to be little basis for mitigating this poor standing of petrochemical products on the grounds that they are uniquely capable of fulfilling important, essential social needs.

It might be argued at this point that in relation to the foregoing considerations of the social value of petrochemical products attention should be given to the economies that can result from the introduction of these products. It might be argued, for example, that petrochemical products have made goods available at lower prices and has thereby increased the standard of living. However, the access of consumers to the goods produced by a given society is, of course, totally governed by social decisions. In contrast, the compatibility of a productive enterprise with the ecosphere—which is of overriding importance because production is otherwise impossible in the long run—is based on the appropriate material interaction of the two spheres. Specifically, the difference in biodegradability between wood and polyvinylchloride is an ecological imperative, but the difference in price is subject to human control. On these grounds, in the present discussion an effort has been made to relate social values to the material properties of petrochemical products, rather than to their present relative prices.

7. REASONS FOR THE RAPID GROWTH OF PETROCHEMICAL PRODUCTION

Figure 7 provides striking evidence of the force with which petrochemical products have swept into the market place in the U.S., displacing numerous older products, many made of natural rather than synthetic materials. Yet, as we have seen, compared with the products that they have displaced and with all other sectors of manufacturing, the production of petrochemicals is remarkably low in social value relative to environmental costs. Moreover, these displacements cannot be explained by inadequacies in the supplies of older products relative to demand, nor does the force of the displacement process really reflect the uniqueness of the petrochemical substitutes or any considerable advantages over their competitors.

In a private enterprise economic system, such as that of the U.S., the factor which almost exclusively governs decisions regarding the displacement of one productive process by another is the rate of economic return. For example, we can expect that, on this general principle, the decision by U.S. soap manufacturers to turn increasingly to the manufacture of detergents has been motivated by the expectation that this would yield a higher rate of profit than the manufacture of soap. This expectation is borne out by the available data; as detergents have displaced soap, the rate of profit (before taxes) of the manufacturers (which usually produce *both* types of cleaners) rose from 31% of sales in 1947 (when soap was produced exclusively) to 47% in 1967 (when the industry produced 30% soap and 70% detergents). Similarly the rate of profit from the manufacture of plastics and resins, in 1969, was 21.4% of sales, while the products which these petrochemicals tend to displace, lumber and steel, yielded returns of 15.4% and 12.5% respectively.

This economic advantage is generally true of the manufacture of synthetic chemicals, which in the period 1946–1966 yielded an average return on net worth of 14.7%, as compared with an average return of 13.1% for all manufacturing industries. The unusual profitability of the production of synthetic chemicals from petrochemicals appears to be closely related to the basic structure of the industry, which is typically characterized by relatively high costs of materials, fuel and capital investment and low labor costs. For example, cost accounts for a typical petrochemical, terephthalic acid, are as follows: In a total production cost of $.0985/lb., raw materials cost $.0662, utilities (i.e., energy sources) cost $.0065, plant depreciation (1/10 of total value annually) cost $0.132, and labor cost only $.0009. These economic relationships reflect the distinctive design of the chemical process industries, in which automated flow systems predominate and labor is held to a minimum.

Table VII compares the labor productivity of different sectors of manufacturing. Although, as seen earlier, the chemical industry is among the least efficient sectors with respect to fuel use, it is second only to petroleum refining in the efficiency with which it uses human labor; its labor productivity—$18.39 (1958 dollars) per man-hour—is more than twice the average for all sectors. Since in the U.S. economic system profitability is usually regarded as closely dependent on labor productivity the unusual profitability of the chemical process industries, especially the petrochemicals, is not surprising.

TABLE VII.—LABOR PRODUCTIVITY (1967)

SIC code	Sector of manufacturing	Labor productivity 1958 dollars per/man-hour
29	Petroleum, coal products	22.78
33	Primary metals	8.11
32	Stone, clay, glass products	7.45
28	Chemicals	18.39
26	Paper and allied products	7.72
22	Textiles	4.09
24	Lumber	4.32
20	Food products	9.99
30	Rubber and plastic products	7.07
34	Fabricated metal products	7.08
37	Transportation equipment	8.70
31	Leather products	4.06
35	Machinery	8.48
25	Furniture and fixtures	4.94
36	Electrical equipment	7.95
21	Tobacco manufacturing	13.72
38	Instruments	10.27
27	Printing and publishing	10.18
23	Apparel	3.92
	All manufacturing	7.99

Source: U.S. Census of Manufacturers.

That the cost of raw materials is the predominant factor in determining the cost of a typical petrochemical product has a powerful influence on the industry's pattern of production. Ethylene production provides an instructive example. The feedstock preferred by U.S. plants is butane and propane, while that preferred by European plants is naphtha. This difference has been based on the relative prices of the feedstocks in Europe and the U.S., but also on the values of the by-products of the cracking process which yields ethylene. Moreover, the price at which such a by-product (for example, propylene) can be sold depends on the economics of ethylene production itself. In addition, the value of the by-product is enhanced if it can be sold as a raw material for further processing rather than being burned as a fuel. Thus, the cost of ethylene production can be reduced by about 50% if the cracking by-products are sold as raw materials for further products rather than being burned as fuel. Obviously this places a considerable emphasis on efforts to *find* such uses for by-products in further processing. This sets off an elaborate chain of events. Thus, that propylene produced as a by-product in the manufacture of ethylene can be sold as a raw material for the production of acrylonitrile, which in turn can be converted into a salable end product, acrylic fibers, significantly reduces the cost of producing ethylene. In turn, this reduces the cost of producing ethylene end products, such as polyethylene, which are then in a favorable position, to undersell and displace competitive natural products, such as wool. The resulting increase in production leads to savings in scale, further intensifying the displacement process.

What is crucial in these relationships is that an end-use be found for as many of the by-products yielded at each stage in a petrochemical process. Inevitably this means that by its own internal economic logic, each new petrochemical process generates a powerful tendency toward a rapid proliferation of further products and the displacement of pre-existing ones.

It seems evident that this special characteristic of the petrochemical industry must play a major role in determining the kinds of processes and products which occur in the petrochemical industry. Thus, the pattern of the petrochemical industry is not so much generated by the social *demand* for specified end-products, as it is by the reverse process—i.e. by the generation of *supplies* of new raw materials, for which new salable uses are deliberately sought as a means of reducing the cost of the original process. In this sense, the petrochemical industry tends not so much to serve social needs as to create them.

8. POSSIBLE SOLUTIONS

Given these considerations what can be said about the steps that might be taken to reduce the severe environmental impact of the petrochemical industry and to improve its social value? In principle there are no insuperable barriers to the development of chemical processes which operate in wholly closed systems, so that toxic wastes are kept out of both the workplace and the outside environment. The decision to undertake such an effort is, of course, a matter of justifying its costs. This requires that the cost of containment be compared with the "debt to nature" incurred by environmental and workplace degradation—the costs to society of disease, property damage, and degradation of natural resources due to pollutants. Since such pollution controls involve capital expenditures which, unlike ordinary investments, do not enhance labor productivity they may tend to reduct the rate of return. One may anticipate, therefore, that serious economic difficulties will be encountered in any major effort to redesign petrochemical installations in order to contain wastes.

Nevertheless, basic redesign of petrochemical and all other chemical operations so as to approach as closely as possible, the ultimate goal of total containment is essential. For reasons already given, petrochemical intermediates are *generically* very likely to be toxic or otherwise harmful to the ecosphere. Any industry which proposes to work with such a class of materials ought to accept the task of keeping them contained.

However, for reasons already given, even if totally contained, at its present scale of operations the petrochemical industry would still have a considerable environmental impact relatives to its social value, simply because it is so inferior to alternative products, and to other industrial sectors, with respect to this cost/benefit ratio. And given the growing demand for improved environmental quality and the increasingly intense effects of fuel shortages pressure for improving this situation are likely to mount. The only possible response to this demand, on the part of the petrochemical industry is to curtail production.

The advantages to society of sharply curtailing the production of petrochemicals are clear from the evidence cited earlier: compared with other productive activities petrochemical production is remarkably poor in producing social values (value added, jobs, wages) relative to the cost in environmental degradation; very few petrochemical products have the redeeming feature of uniqueness, which might make them socially valuable despite their other inadequacies; typically petrochemical products are not innovative with respect to their use-value, but serve as substitutes for pre-existing products over which they may have some relatively trivial advantages, that can often be themselves readily matched by other means. In sum, if most products of petrochemistry were withdrawn from the market place, and their functions restored by the products which they have displaced, we would experience very appreciable reductions in air and water pollution and in trash accumulation; many known and potential risks of cancer, mutations and birth defects would be eliminated; very considerable savings in fuel would be experienced (up to 7% of the present national fuel budget); and overall job opportunities and payrolls could be increased. Obviously certain problems, many of them serious, would need to be overcome. We would need to find some means of maintaining certain advantages of petrochemical products—such as no-iron fabrics for example—by changing styles or cultural habits; many objects—furniture, architectural items, utensils—now made of plastics by automatic extrusion processes would have to be made out of other materials, with the use of more hand labor; in order to enable the use of Malayan rubber tires in place of domestic synthetic ones it would probably be necessary to overcome the objections of the Department of Defense; and so on.

Obviously no *scientific* justification for choosing between these alternatives can be offered. What is involved in making such choices are value judgements—cultural, social, economic and political decisions.

Although these will be extremely difficult, certain inherent characteristics of the petrochemical industry, especially as they relate to current changes in petroleum and gas supplies, create a situation in which the internal transformation of the industry and its role in the overall economy may become more feasible. In the U.S., recent shortages in fossil fuels have already begun to have a serious impact on the petrochemical industry. For example, because of the current propane shortage, ethylene production is threatened by the very rigidity inherent in the design of petrochemical processes. Although ethylene can be produced from naphtha, most U.S. plants have been designed to use a propane feedstock because of economic considerations arising from the relative costs of propane and naphtha and from the economic advantages of the yield of specific by-products, such as propylene, which can be sold as raw materials. Thus a shift from propane to naphtha feedstock would necessarily disrupt the extensive pattern of raw materials and end products which has been established in the U.S. Nevertheless such a shift may be necessary given the inevitability of reduced supplies of crude oil and natural gas. At the same time growing public concern with the impact of industry on the environment and working conditions, creates further pressure for change. All this will create opportunities to reconsider the design of the petrochemical industry, its role in the economy, and its overall social utility, even in a country such as the U.S. where it has become so firmly established.

Such considerations are particularly relevant to the transfer of petrochemical processes to developing nations, especially in the tropics. In these instances, the inherent properities of the petrochemical industries appear to be especially unsuitable—i.e. that they are capital- and fuel-intensive rather than labor-intensive and that they tend to minimize the use of materials of biological origin. In developing tropical countries capital and fuel are often in much shorter supply than labor, and materials of biological origin are relatively plentiful. Thus, opportunities for a reexamination of the social value of the petrochemical industry will arise as the developing nations of the world consider the path which they should take toward higher levels of production.

All this suggests that we are approaching a period in which the very design of the petrochemical industry and its place in different social and economic systems needs to be closely reexamined. What we can learn from the environmental impact of the petrochemical industry is that the industry needs to be fundamentally redesigned to fulfill the needs of society rather than its own internal economic logic; and to accord with the imperatives of the ecosphere and of the enhancement of human welfare.

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The environmental cost of economic growth

Barry Commoner

Can we evaluate the environmental costs of economic growth? To put it another way, can degradative ecological changes be related quantitatively to the increased production of economic goods? This complex question has appeared rather suddenly on the horizon of public affairs and, at the moment, suffers from a high ratio of concern to fact. Contributing to our ignorance of the issue is the fact that it does not coincide with the domain of any established academic discipline. Thus, until recently, environmental costs have been so far removed from the concerns of orthodox economics as to have been nearly banished from that realm under the term 'externalities'; and, for its part, the discipline of ecology has maintained a position of lofty disdain for such mundane matters as the price of ecological purity. In this article, Dr Barry Commoner gives a semi-quantitative evaluation of the environmental costs of economic growth in the United States since the 1940s, and, in the light of it, suggests what all modern industrial countries must do in order to survive economically as well as biologically.

The environment is defined as a system comprising the earth's living things and the thin global skin of air, water and soil which is their habitat.

This system, the ecosphere, is the product of the joint, interdigitated evolution of living things and of the physical and chemical constituents of the earth's surface. On the time scale of human life the evolutionary development of the ecosphere has been very slow and irreversible. Hence the ecosphere is irreplaceable; if the system should be destroyed, it could never be reconstituted or replaced either by natural processes or by human effort.

The basic functional element of the ecosphere is the ecological cycle, in which each separate element influences the behaviour of the rest of the cycle, and is in turn itself influenced by it. For example, in surface waters fish excrete organic waste, which is converted by bacteria to inorganic products; in turn, the latter are nutrients for algal growth; the algae are eaten by the fish, and the cycle is complete. Such a cyclical process accomplishes the self-purification of the environmental system, in that wastes produced in one step in the cycle become the necessary raw materials for the next step. Such cycles are cybernetically self-governed, dynamically maintaining a steady state condition of indefinite duration. However if sufficiently stressed by an external agency, such a cycle may exceed the limits of its self-governing processes and eventually collapse. Thus, if the water cycle is overloaded with organic animal waste, the amount of oxygen needed to support waste decomposition by the bacteria of decay may be greater than the oxygen available in the water. The oxygen level is then reduced to zero; lacking the necessary oxygen, the bacteria die and this phase of the cycle stops, halting the cycle as a whole. Evidently, there is an inherent limit to the turnover rate of local ecosystems and of the global ecosystem as a whole.

Human beings are dependent on the ecosphere not only for their biological requirements—oxygen, water, food—but also for resources which are essential to all their productive activities. These resources, together with underground minerals, are the irreplaceable and essential foundation of all human activities.

If we regard economic processes as the means which govern the disposition and use of resources available to human society, then the continued availability of those resources which are derived from the ecosphere, *i.e.*, non-mineral resources, and therefore the stability of the ecosystem, is an essential prerequisite for the success of any economic system. More bluntly, any economic system which hopes to survive must be compatible with the continued operation of the ecosystem.

Because the turnover rate of an ecosystem is inherently limited, there is a corresponding limit to the rate of production of any of its constituents. Different segments of the global ecosystem—*e.g.*, soil, fresh water, marine ecosystems—operate at different intrinsic turnover rates and therefore differ in the limits of their productivity. On purely theoretical grounds it is self-evident that any economic system which is impelled, by its own requirements for stability, to grow by constantly increasing the rate at which it extracts wealth from the ecosystem must eventually drive the ecosystem to a state of collapse. Computation of the rate limits of the global ecosystem or of any major part of it are, as yet, in a rather primitive state. Apart from the foregoing theoretical and as yet unspecified limit to economic growth, such a limit may arise much more rapidly if the growth of the economic system is dependent on productive activities which are especially destructive of the stability of the ecosystem.

Unlike all other forms of life, human beings are capable of exerting environmental effects which extend, both quantitatively and qualitatively, far beyond their influence as biological organisms. Human activities have also introduced into the environment not only intense stresses due to natural agents (such as bodily wastes), but

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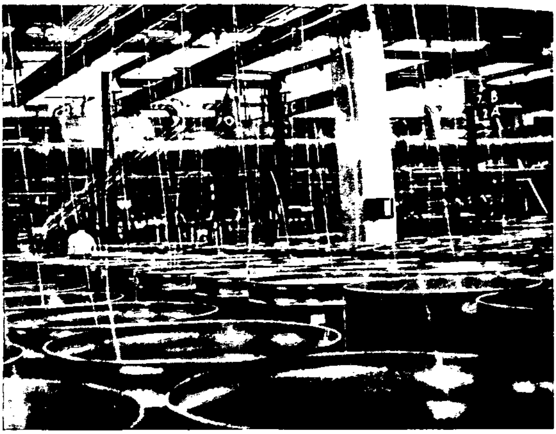


Spinning thousands of miles of man-made fibre a day—synthetic fibres require more energy in production and are themselves ecologically indestructible. (Camera Press)

also wholly new substances not encountered in natural environmental processes — artificial radioisotopes, detergents, pesticides, plastics, a variety of toxic metals and gases, and a host of man-made, synthetic substances. These human intrusions on the natural environment have thrown major segments of the ecosystem out of balance. Environmental pollution is the symptom of the resultant breakdown of the environmental cycles.

The problem

In order to evaluate the cost of economic growth in terms of the resultant environmental deterioration, it is, of course, necessary to define both terms, if possible, in quantitative dimensions that might permit a description of their relationship. The common definition of economic growth would appear to be applicable here—the increase in the goods generated by economic activity. Environmental deterioration is a more elusive concept. On the basis of the foregoing discussion it may be defined as degradative changes in the ecosystems which are the habitat of all life on the planet. The problem is to describe such ecological changes in terms that can be related, quantitatively if possible, to the processes of economic growth—that is, to increased production of economic goods.

To begin with we can take note of the self-governing nature of the ecosystem. It is this property which ensures its stability and continued activity. This basic property helps to define both the process of ecological degradation and the nature of the agencies that can induce it. We can define ecological, or environmental, degradation as a process which stresses an ecosystem so that it reduces its capability for self-adjustment, and which, therefore, if continued can impose an irreversible stress on the system and cause it to collapse.

An agency which is capable of exerting such an effect on an ecosystem must arise from *outside* that system. This results from the cyclical nature of the ecosystem, which brings about, automatically, the system's re-adjustment to any *internal* change in the number or activity of any of its normal biological constituents. For what characterizes the behaviour of a constituent which is part of an ecological cycle is that it both influences and is influenced by the remainder of the cycle. For example, organic waste produced by fish in a closed aquatic ecosystem, such as a balanced aquarium, cannot degrade the system because the waste is converted to algal nutrients, and simply moves through the ecological cycle back to fish. In contrast, if organic waste intrudes upon this same ecosystem from without, it is certain to speed up the cycle's turnover rate, and if sufficiently intense, to consume all the available oxygen, and bring the cycle to a halt.

The internal changes in an ecosystem which occur in response to an external stress are complex, non-linear processes and not readily reduced to simple quantitative indices. The aquatic ecosystem is one of the relatively few instances in which this goal can, to some degree, be approached—in that oxygen tension is a sensitive internal indicator of the system's approach to instability. However, in most cases such internal measures of the state of an ecosystem have not yet been elucidated. Hence, as a practical, but, it is to be hoped, temporary expedient we need to fall back on a measure of the *impact* on the ecosystem of an external degradative agency as an index of environmental quality. This expedient has the virtue of enabling the quantitative comparison of the effects of ecological impacts of different origins, a matter of particular importance in connection with their relation to economic processes. Later, when the necessary ecological information becomes available, such data can be translated to the resultant internal changes.

Thus, in this article, the environmental cost of a given economic process will be represented by its *environmental impact*, a term which has the dimensions of the amount of an agency external to the ecosystem which, by intruding upon it, tends to degrade the system's capacity for self-adjustment.

Turning to the possible environmental impacts that may result from *human* activity, we find the situation somewhat complicated by the special role of human beings on the earth. In one sense, human beings are simply another animal in the earth's ecosystem, consuming oxygen and organic foodstuff and producing carbon dioxide, organic wastes, heat and more people. In this role, the human being is a constituent part of an ecosystem and therefore in terms of the previous definition exerts no environmental impact on it. However, a human population has a zero environmental impact only as long as it is in fact part of an ecosystem, which is the case, for example, if food is acquired from soil which receives the population's organic waste. If a population is separated from this cycle, for example, by settling in a city, their wastes are intruded, with or without treatment, into surface waters. Now the population is no longer a part of the soil ecosystem, and the wastes become *external* to the *aquatic* system on which they intrude. An environmental impact is generated, leading to water pollution.

On the basis of these considerations, people—viewed simply as biological organisms—generate an environmental impact only in so far as they become separated from the ecosystem to which, in nature, terrestrial animals belong, as is, of course, nearly universally true in the United States. The intensity of this environmental impact is generally proportional to the population size.

All other environmental impacts are generated, not by human biological

Table 1. Post-war increases in pollutant emissions.

Pollutant	Year	Annual production Amount	Year	Amount	Increase (%)
Inorganic fertilizer nitrogen	1949	0.91 × 10^6 t	1968	6.8 × 10^6 t	648
Synthetic organic pesticides	1950	286 × 10^6 lb	1967	1050 × 10^6 lb	267
Detergent phosphorus	1948	11 × 10^6 lb	1968	214 × 10^6 lb	1845
Tetraethyl lead**	1946	0.048 × × 10^6 t	1967	0.25 × 10^6 t	415
Nitrogen oxides**	1946	10.6*	1967	77.5*	630
Beer bottles	1950	6.5 × 10^6 gross	1967	45.5 × 10^6 gross	595

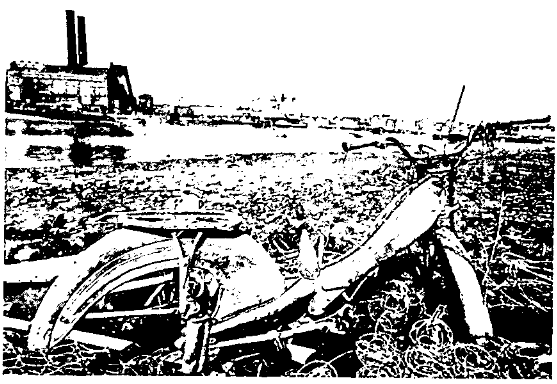
* Dimension = NO_x (ppm) × gasoline consumption (gal × 10^{-6}); estimated from product of passenger vehicle gasoline consumption and ppm of NO_x emitted by engines of average compression ratio 5.9 (1946) and 9.5 (1967) under running conditions, at 15 in manifold pressure. NO_x emitted: 500 ppm in 1946; 1200 ppm in 1967.
** Automotive emissions.

activities, but by human *productive activities*, and are therefore governed by economic processes. Such impacts may be generated in several different ways. First, certain economic gains can be derived from an ecosystem by exploiting its biological productivity. In these cases, a constituent of the ecosystem which has economic value—for example, an agricultural crop, timber or fish—is withdrawn from the ecosystem. In so far as the withdrawn substance or a suitable substitute fails to return as nutrient to the ecosystem from which it was removed it constitutes a drain on that system which cannot continue indefinitely without causing it to collapse. Examples of such effects are the destructive erosion of the soil following excessive exploitation, and the incipient destruction of the whaling industry due to the extinction of whales.

Environmental stress may also arise from an intrusion of opposite sign—that is the amount of some component of the ecosystem is augmented from outside that system. This may be done either for the purpose of disposing of waste or in order to accelerate the system's rate of turnover and thus increase its yield. Examples of these effects are the intrusion of sewage into surface water, and the intensive use of fertilizer nitrogen in agriculture. In the latter case, following a reduction in the nitrogen available from the soil's natural store of nutrient (its organic humus) due to a period of over-exploitation through uncompensated crop withdrawal, *i.e.* a stress of the type described above, the nitrate level is artificially raised by adding fertilizer to the soil's ecological cycle. Because of the low efficiency of nutrient uptake by the crop's roots, which is in turn a result of inadequate soil oxygen due to reduced porosity stemming from the decreased humus content, a considerable portion of the fertilizer leaches from the soil into surface waters—where it becomes an external stress on the aquatic ecosystem, causing algal overgrowths and the resulting breakdown of the self-purifying aquatic cycle.

Apart from the above stresses—which represent the impact of externally altered concentrations of natural ecosystem constituents — environmental impact may be due to the intrusion into an ecosystem of a substance wholly foreign to it. Thus, DDT has a powerful environmental impact in part because it readily upsets the naturally balanced ecological relations among insect pests, the plants they attack, and the insects which, in turn, prey on the pests. DDT-induced outbreaks of insect pests often result. In general, there is a considerable risk of environmental pollution whenever productive activity introduces substances which are foreign to the natural environment.

Low tide on the river—a waste of mud, muck and 7000 tons of driftwood to clear every year. *(Camera Press)*



We turn now to the practical problem of evaluating the environmental cost of economic growth. The most general theoretical aspect of this problem has already been alluded to. Given that the global ecosystem is closed, and that its integrity is essential to the continued operation of any conceivable economic system, there must be an upper limit to the growth of productive activities on the earth.

However, such a theoretical statement is hardly an effective guide to practice. The chief reason is that the theory fails to specify the time scale in which the ecological limitation on economic growth is likely to take effect. For one can readily grant the truth of such an abstract theorem—for example, that economic growth will eventually be limited by the extinction of the sun—and disregard its practical consequences because of the rather long time scale involved, in this case some billions of years.

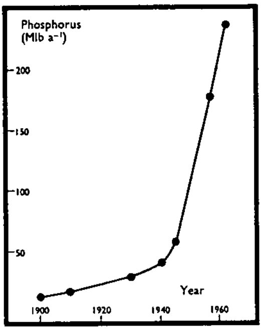
Accordingly it would seem useful to make the problem more concrete by examining the relationship between economic growth and environmental impact in the real world. And since growth is, of course, a time-dependent process, this suggests the value of an historical approach.

Origins of environmental impacts

The American Association for the Advancement of Science committee on environmental alterations, in collaboration with Corr and Stamler, has attempted to describe the origins of environmental impacts in the United States.[1] The results of their initial efforts are described here. Most US pollution problems are of relatively recent origin. The post-war period, 1945–46, is a convenient benchmark, for a number of pollutants—man-made radioisotopes, detergents, plastics, synthetic pesticides and herbicides—are due to the emergence, after the war, of new productive technologies. The statistical data available for this period in the US provide a useful opportunity to compare the changes in the levels of various pollutants with the concurrent activities of the US productive system that might be related to their environmental effects.

Although we lack sufficient comprehensive data on the actual environmental levels of most pollutants, some estimates of historical changes can be made from intermittent observations, and from computed data on emissions of pollutants from their sources. Some of the available data are summarized in Table 1, which indicates that since 1946, emissions of pollutants have increased by 200–2000 per cent. For phosphate, which is a pollutant of surface waters, and enters mainly from municipal sewage, data on the long term trends are available; these are shown in *Fig. 1*.[1] In the 30-year period between 1910 and 1940, phosphorus output from municipal sewage increased gradually from about 17 Mlb a^{-1} to about 40 Mlb a^{-1}. Thereafter the rate of output rose rapidly; so that in the 30-year period 1940–70 phosphorus output increased to about 300 Mlb a^{-1}.

It should be noted that these are data regarding the computed *emission* of pollutants, which are not necessarily descriptive of their actual concentrations in the environment or of their ultimate effects on the ecosystems or on human health. Numerous, complex and interrelated processes intervene between the entry of a pollutant into the ecosystem and the expression of its biological effect. Moreover, two or more pollutants may interact synergistically to intensify the separate effects. Most of these processes are still too poorly understood to enable us to convert the amount of a pollutant entering an ecosystem to a quantitative estimate of its degradative effects. Nevertheless it is self-evident that these effects have increased sharply, along with the rapid rise of pollutant levels, since 1946. Since pollutant emission is a direct measure of the activity of the source, it is a useful way to estimate the contributions of different sources to the overall degradation of the environment.



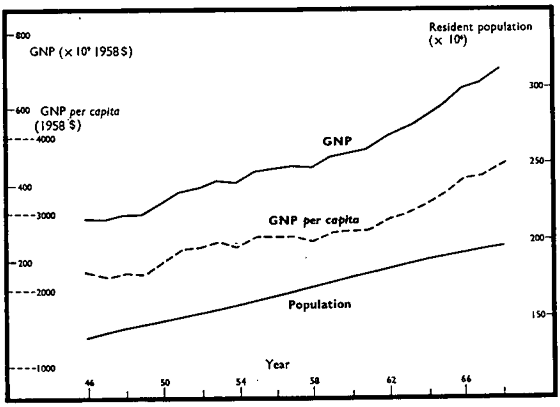
If we define the amount of a given pollutant introduced annually into the environment as the *environmental impact* (*I*), we can relate this value to the effects of three major factors that might influence it by the following identity:

$$I = \text{Population} \times \frac{\text{Economic good}}{\text{Population}} \times \frac{\text{Pollutant}}{\text{Economic good}}$$

Population refers to the size of the US population in a given year, economic good refers to the amount of a designated good produced (or where appropriate, consumed) during the given year, and pollutant refers to the amount of a specific pollutant (defined as above) released into the environment as a result of the production or consumption of the designated good, during the given year. This relationship enables us to estimate the contribution of three factors to the total environmental impact: (*a*) the size of the population; (*b*) production or consumption *per capita*, *i.e.* 'affluence'; (*c*) the environmental impact, *i.e.* amount of pollutant, generated per unit of production or consumption, which reflects the nature of the productive technology.

Fig. 1. (Left) *Phosphorus emitted by US municipal sewage.*[11]

Fig. 2. (Below) *Changes in population, Gross National Product (reduced to 1958 dollars) and GNP* per capita *for the US since 1946.*[12]



Since we are concerned with identifying the sources of the sharp increases in the environmental impacts experienced since 1946, it is of interest to examine the concurrent changes in the nation's productive activities. The most general data relevant to these changes are presented in *Fig. 2*. In the period 1946–68 US population increased, at an approximately constant rate by about 42 per cent; GNP (adjusted to 1958 dollars) increased exponentially by about 126 per cent; GNP *per capita* also increased approximately exponentially by about 59 per cent.

We can see at once that, as a first approximation, the contribution of population growth to the overall values of the environmental impacts generated since 1946 is of the order of 40 per cent. In most cases, this represents a relatively small contribution to the total environmental impact, since as indicated in Table 1, these values increased by 200–2000 per cent during the period.

In order to evaluate the effects of the remaining factors it is useful to examine the growth rates of different sectors of the productive economy. For this purpose, a series of productive activities which are likely to contribute significantly to environmental impact and are representative of the overall pattern of the economy have been selected. From the annual production (or where appropriate, consumption) data for the US as a whole, the annual percentage rates of increase or decrease have been calculated. The results of these computations are presented in *Fig. 3*, from which it is possible to derive certain useful generalizations about the pattern of US economic growth. Productive activities fall into three main groups.

First, production and consumption of certain goods have increased at an annual rate about equal to the annual rate of increase of the population, so that *per capita* production remains essentially unchanged. This group includes food, fabric and clothing, major household appliances and certain basic metals and building materials, including steel and copper, and brick. In effect, for these basic life necessities, average affluence has remained essentially unchanged.

Secondly, the annual production of certain goods has decreased since 1946, or has increased at an annual rate below that of the population. Horsepower produced by work animals is the extreme case; it declined at an annual rate of about 10 per cent. Other items in this category are saponifiable fat, cotton fibre, wool fibre, lumber, milk, railroad horsepower, and railroad freight. These are goods which have been significantly displaced in the pattern of production during the course of the overall growth of the economy. Cultivated farm acreage also declined.

Thirdly, there are the productive activities which have increased at an annual rate in excess of that exhibited by the population. Certain of the rapidly increasing productive activities are substitutes for activities that have declined in rate, relative to the population. These generally represent technological displacement of an older process by a newer one, with the sum of goods produced remaining essentially constant, *per capita*, or increasing. These displacement processes include: natural fibres (cotton and wool) by synthetic fibres; lumber by plastics; soap by detergents; steel by aluminium and cement; railroad freight by truck freight; harvested acreage by fertilizer; returnable by non-returnable bottles.

Others of the rapidly growing productive activities evident in *Fig. 3* are secondary consequences of displacement processes. Thus the displacement of natural products by synthetic ones involves the use of increased amounts of synthetic organic chemicals, so this category has increased sharply. Moreover, since many organic syntheses require chlorine as a reagent, the rate of chlorine production has also increased rapidly. And because chlorine is efficiently produced in a mercury electrolytic cell, the use of mercury for this purpose has increased at a very considerable rate. Similarly, the rapidly rising rate of power utilization is, in part, a secondary consequence of certain displacement processes, for a number of the new technologies are more power-consumptive than the technologies which they replace.

There is a third group discernible among the rapidly growing productive activities (*Fig. 3*). These are neither displacements of older technologies, nor *sequelae* to such displacements, but true increments in *per capita* availability of goods. An example of this category is consumer electronics—radios, television sets, sound equipment *etc.* Such items represent true increases in affluence.

Impact of economic growth

Given the foregoing conclusions, we can now rephrase the original question as: What are the relative costs, in intensity of environmental impact, of the several distinctive features of the growth of the US economy from 1946 to the present? Reasonably complete quantitative answers to this question are well beyond the present state of knowledge. In most cases it is possible to provide only an informal, qualitative, description of the changes in environmental impact which have been induced by the post-war transformation of the economy; although some quantitative evaluations in the form of environmental impact indices and a few partial environmental impact inventories can be constructed. As shown below, such evidence leads to the general conclusion that in most of the technological displacements which have accompanied the growth of the US economy, the new technology has an appreciably greater environmental impact than the technology which it has displaced, and that the post-war technological transformation of productive activities is the chief reason for the environmental crisis that we have at present.

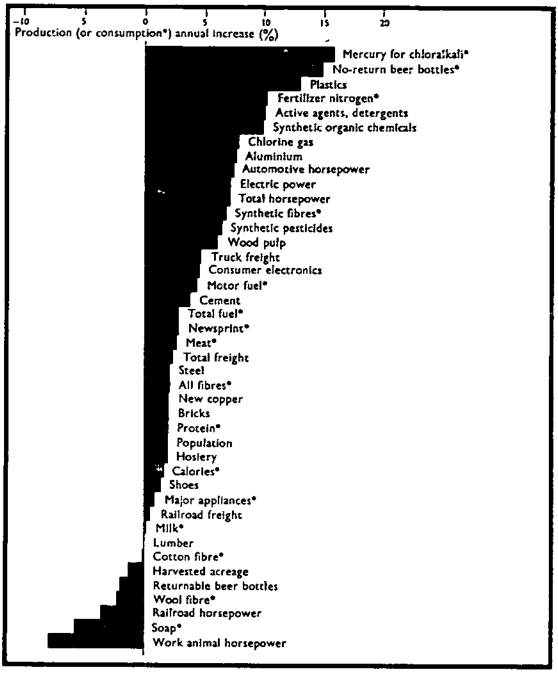


Fig. 3. Annual growth rates of production or consumption in the US.[13]

Agricultural production. Agricultural production, as measured by the US Department of Agriculture crop index, has increased at about the same rate as the population since 1946 (*Fig. 3*). However, the technological methods for achieving agricultural production have changed significantly in that period. One important change is illustrated by *Fig. 4*, which shows that although agricultural production *per capita* has increased only slightly, harvested acreage has decreased, and the use of inorganic nitrogen fertilizer has risen sharply. This displacement process of fertilizer for land leads to a considerably increased environmental impact.

The relevant ecological situation is as follows.[3] Nitrogen, an essential constituent of all living things, is available to plants in nature from organic nitrogen, stored in the soil in the form of humus. Humus is broken down by bacteria to release inorganic forms of nitrogen, eventually as nitrate.

The latter is taken up by the plant roots and reconverted to organic matter, such as the plant's protein. Finally the plant may be eaten by a grazing animal, which returns the nitrogen not retained in the growth of its own body to the soil as bodily wastes.

Agriculture imposes a negative drain on this cycle; nitrogen is removed from the system in the form of the plant crcp or of the livestock produced from it. In ecologically sound husbandry, all the organic nitrogen produced by the soil system other than the food itself—that is, plant residues, manure, garbage—is returned to the soil, where it is converted by complex microbial processes to humus and thus helps to restore the soil's organic nitrogen content. The deficit, if it is not too large, can be made up by the process of nitrogen fixation in which bacteria, usually in close association with the roots of certain plants, take up nitrogen gas from the air and convert it into organic form. If the nitrogen cycle is not in balance, agriculture 'mines' the soil nitrogen, progressively depleting it. This process does more than reduce the store of organic nitrogen available to support plant growth, for humus is not only a nutrient store. Due to its polymeric structure humus is also responsible for the porosity of the soil to air. And air is essential to the soil, not only as a source of nitrogen for fixation, but also because its oxygen is essential to the root's metabolic activity, which in turn is the driving force for the absorption of nutrients by the roots. In the US, for example in Corn Belt soils, about a half of the original soil organic nitrogen has been lost since 1880. Naturally, other things being equal, such soil is relatively infertile and produces relatively poor crop yields. However, beginning after World War 2, a technological solution was intensively applied to this problem: sharply increasing amounts of inorganic nitrogen were applied to the soil in the form of fertilizer. Annual nitrogen fertilizer usage in the US increased by an order of magnitude during the period 1946–68.

In effect, nitrogen fertilizer can be regarded as a substitute for land. With the intensive use of fertilizer it is possible to accelerate the turnover rate of the soil ecosystem, so that each acre of soil produces more food than before. The economic benefits of this new agricultural technology are appreciable, and self-evident. However, the economic advantage may be counterbalanced by the increased impact on the environment. This arises because, given the reduced humus content of the soil, the plant's roots do not efficiently absorb the added fertilizer. As a result an appreciable part leaches from the soil as nitrate and enters surface waters where it becomes a serious pollutant. Nitrate may encourage algal overgrowths, which on their inevitable death and decay tend to break down the self-purifying aquatic cycle.

Excess nitrate from fertilizer drainage leads to another environmental impact, which may affect human health. While nitrate in food and drinking water appears to be relatively innocuous, nitrite is not, for it combines with haemoglobin in the blood, converting it to methemoglobin—which cannot carry oxygen. Unfortunately nitrate can be converted to nitrite by the action of bacteria in the intestinal tract, especially in infants, and can cause asphyxiation and even death. On these grounds, the US public health service has established 10 ppm of nitrate nitrogen as the acceptable limit of nitrate

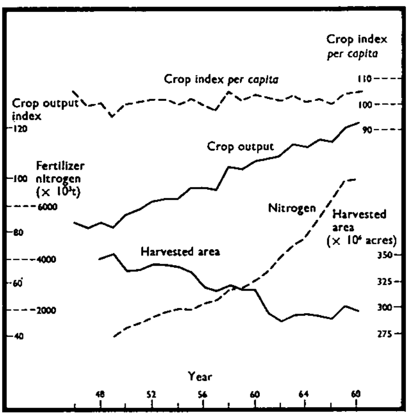
Table 2. Environmental impact index for fertilizer nitrogen.

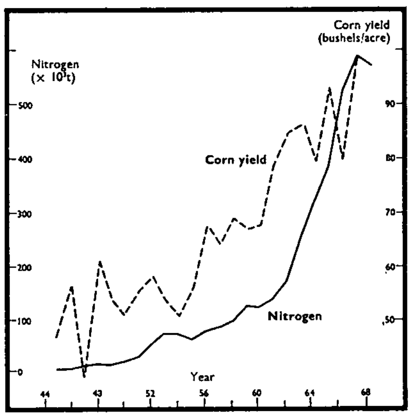
	1949	1968	1968/1949	Increase (%)
Index factors				
(*a*) Population (× 10³)	149 304	199 846	1.34	34
(*b*) Crop production / Population (prod. units *per capita*)	5.43 × 10⁻⁷	6.00 × 10⁻⁷	1.11	11
(*c*) Fertilizer nitrogen / Crop production (t per prod. unit)	11 284*	57 008	5.05	405
Total index (*a* × *b* × *c*) Fertilizer (× 10³ t)	**914**	**6841**	**7.48**	**648**

* The crop output index is an indicator of agricultural productivity with the 1957–59 average = 100.

Fig. 4. (Left) *Changes in total crop output (as determinted by US Department of Agriculture crop index, 1957–59 = 100), in crop output* per capita, *in harvested acreage and in annual use of inorganic nitrogen fertilizer in the US since 1946.*[14]

Fig. 5. (Right) *Corn yield and nitrogen usage for the State of Illinois, 1944–1968.*[5]





in drinking water. In a number of agricultural areas in the US, nitrate levels in water supplies obtained from wells, and in some instances from surface waters, have exceeded this limit. Our own studies in the area of Decatur, Illinois, show quite directly that in the spring of 1970 when the city's water supply, which is derived from an impoundment of the Sangamon River, recorded 9 ppm of nitrate nitrogen, a minimum of 60 per cent of the nitrate was derived from inorganic fertilizer applied to the surrounding farmland.[4]

The effect of this change in agricultural technology is evident from Table 2, which compares the influence of the several relevant factors on the total environmental impact due to fertilizer nitrogen in 1949 and 1968. During that period the total annual use of fertilizer nitrogen, *i.e.* the total environmental impact, increased 648 per cent. The influence of population size increased by 34 per cent; the influence of crop production *per capita* (affluence) increased by 11 per cent; the influence of the change in fertilizer technology increased by 405 per cent. Clearly the last factor dominates the large increase in the total environmental impact of fertilizer nitrogen. Specifically, it should be noted that in 1949 about 11 000 t fertilizer nitrogen were used per unit crop production, while in 1968 about 57 000 t nitrogen were employed for the same crop yield. This means that the efficiency with which fertilizer nitrogen contributes to crop yield has declined fivefold. Obviously an appreciable part of the added nitrogen does not enter the crop and must appear elsewhere in the ecosystem.

The biological basis for this effect is shown in *Fig. 5*, which compares the corn yield in the State of Illinois, with the concurrent amounts of nitrogen fertilizer added to the soil.[5] This shows that as fertilizer levels increased, the yield per acre rose, but eventually levelled off due to the natural limits of plant growth. Thus, between 1962 and 1968, fertilizer usage doubled, but crop yield rose only about 10–15 per cent. Clearly at the higher levels of fertilizer usage an increasingly small proportion of the fertilizer contributes to the crop. The remainder leaches into surface waters. Thus, this innovation in agricultural technology sharply increases the environmental stress due to agricultural production.

Pesticides have created a similar situation. This is shown by the changes in the environmental impact index of pesticides between 1950 and 1967 (Table 3). In that time there was a 168 per cent increase in the amount of pesticides used per unit crop production, as a national average. By killing off natural insect predators and parasites of the target pest, while the latter often becomes resistant to the insecticides, the use of modern synthetic insecticides tends to exacerbate the pest problems that they were designed to control. As a result increasing amounts of insecticides must be used to maintain agricultural productivity. Insecticide usage is self-accelerating—resulting in both a decreased efficiency and an increased environmental impact.

Another technological displacement in agriculture is the increased use of feedlots for the production of livestock in preference to range feeding. Range-fed cattle are integrated into the soil ecosystem; they graze the soil's grass crop and restore nutrient to the soil as manure. But when cattle are maintained in huge pens, where they are fed on corn and deposit their waste intensively in the feedlot itself, the waste does not return to the soil. Instead it drains into surface waters where it adds to the stresses due to fertilizer nitrogen and detergent phosphate. The magnitude of the effect is considerable. At present, the organic waste produced in feedlots is more than the organic waste produced by all the cities of the US. Again, the newer technology has a serious environmental impact, and in this case has displaced a technology with an essentially zero environmental impact.

Textiles. *Figure 6* describes changes in textile production since 1946. While total fibre production *per capita* has remained more or less constant, natural fibres (cotton and wool) have been significantly displaced by synthetic ones. This technological change considerably increases the environmental impact due to fibre production and use.

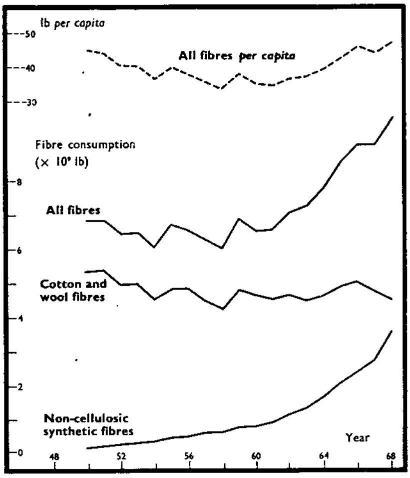
One reason is that the energy required for the synthesis of the final product, a linear polymer (cellulose in the case of cotton, keratin in the case of wool and polyamides in the case of nylon) is greater for the synthetic material. Although quantitative data are not yet available, this is evident from the comparison of two productive processes, shown in Table 4. Nylon

Table 3. Environmental impact index for synthetic organic pesticides.

	1950	1967	1967/1950	Increase (%)
Index factors				
(*a*) Population (× 10³)	151 868	197 859	1.30	30
(*b*) Crop production / Population (prod. units *per capita*)	5.66×10^{-7}	5.96×10^{-7}	1.05	5
(c) Pesticide consumption / Crop production (× 10³ lb per prod. unit)	3326	8898	2.68	168
Total index (*a* × *b* × *c*) Synthetic organic pesticides (×10⁶ lb)	**286**	**1050**	**3.67**	**267**

Table 4. Cotton and nylon: environmental characteristics.

	Cotton	Nylon	Comparative environmental impact
Raw materials	CO_2, H_2O	Petroleum	Cotton, renewable. Nylon, non-renewable
Process	$CO_2 + H_2O$ (light) ↓ Glucose ↓ Cellulose (70–90 °F) Cultivation, ginning, spinning, require power	Petroleum (distil) ↓ Benzene (550 °F) ↓ Cyclohexane (300 °F) ↓ Cyclohexanol (200–400 °F) ↓ Adipic acid (600–700 °F) ↓ Adiponitrile (200–250 °F) ↓ Hexamethylenediamine ↓ Nylon 610 Distillation and other purification at most of above steps; power required to operate process	Fuel combustion and resultant air pollution: nylon probably greater than cotton
Product	Cellulose	Polyamide	Cellulose wholly biodegradable, polyamide not degradable



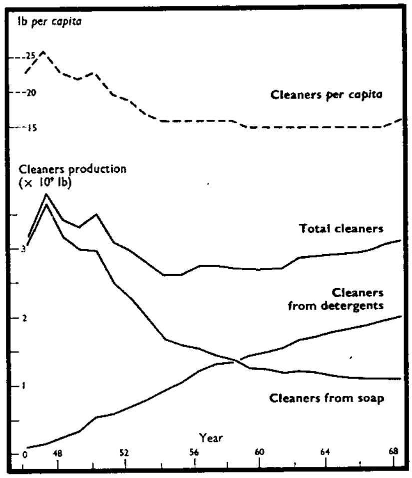


Fig. 6. (Left) *Natural and synthetic fibre production in the US since 1946.*[15]

Fig. 7. (Right) *Total soap and detergent production and* per capita *consumption of total cleaners (soap plus detergent) in the US since 1946.*[14] *Detergent data represent actual content of surface-active agent, which is estimated at about 37.5 per cent of the total weight of the marketed detergent.*

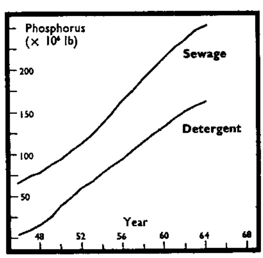
production involves as many as 10 steps of chemical synthesis, each requiring considerable energy in the form of heat and electric power. In contrast, energy required for the synthesis of cotton is derived, free, from a renewable source—sunlight—and is transferred without combustion and resultant air pollution. Moreover, the raw materials for cellulose synthesis are carbon dioxide and water, both freely available renewable resources, while the raw material for nylon synthesis is petroleum or a similar hydrocarbon—non-renewable resources. Thus it seems that the environmental stress due to the production of such an artificial fibre is probably well in excess of that due to the production of an equal weight of cotton. This is only an approximation, for we need far more detailed, quantitative estimates, in the form of the appropriate environmental impact indices, that would also take into account the fuel and other materials used in the production of cotton.

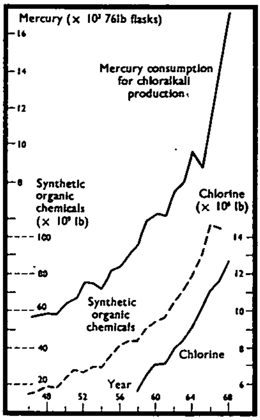
Because a synthetic fibre such as nylon is unnatural, it also has a greater impact on the environment as a waste material, than do cotton or wool. The natural polymers in cotton and wool are important constituents of the soil ecosystem. Through the action of moulds and decay bacteria they contribute to the formation of humus. In this process cellulose is readily broken down. Thus, in nature, cellulose and keratin are *not* wastes, because they provide essential nutrients for soil microorganisms. Hence they cannot accumulate.

The contrast with synthetic fibres is striking. The structure of nylon and similar synthetic polymers is a human invention and does not occur in natural living things. Hence, unlike natural polymers, synthetic ones find no counterpart in the armamentarium of degradative enzymes in nature. Ecologically, synthetic polymers are literally indestructible. Hence, every bit of synthetic fibre or polymer that has been produced on the earth is either destroyed by burning—and thereby pollutes the air—or accumulates as rubbish. One result, according to a recent report, is that microscopic fragments of plastic fibres, often red, blue or orange, have now become common in certain marine waters.[6] For technological displacement has been at work in this area too; in recent years natural fibres such as hemp and jute have been nearly totally replaced by synthetic fibres in fishing operations. A chief reason for this use of synthetic fibres is that they resist degradation by moulds, which, as already indicated, readily attack cellulosic net materials such as hemp or jute. Thus, the property which enhances the economic value of the synthetic fibre over the natural one—its resistance to biological degradation—is precisely the property which increases the environmental impact of the synthetic material.

Detergents. *Figure 7* shows that synthetic detergents have largely replaced soap in the US as domestic and industrial cleaners, with the total production of cleaners *per capita* remaining essentially unchanged. Soap is based on fat, which is reacted with alkali to produce the end product. Being a natural product, fat is extracted from an ecosystem (for example, that represented by a coconut palm plantation), and when released into an aquatic ecosystem after use, soap is readily degraded by the bacteria of decay. Since most municipal wastes are subjected to treatment which degrades organic waste to its inorganic products,

Fig. 8. Concurrent values of phosphorus output from municipal sewage in the US and phosphorus content of detergents produced.[17]





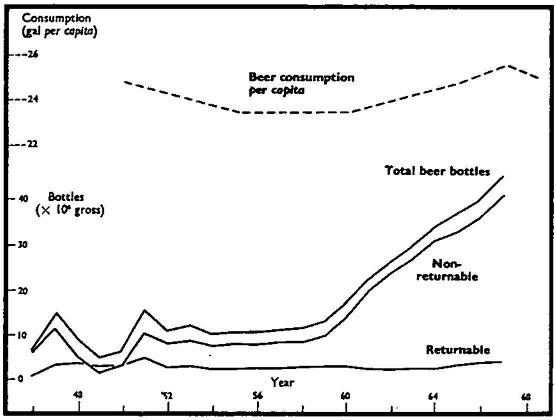


Fig. 9. (Left) *Changes in annual production of synthetic organic compounds and of chlorine gas, and consumption of mercury for chlorine gas production in the US since 1946.*[18]

Fig. 10. (Right) Per capita *consumption of beer and production of beer bottles in the US.*[19]

in practice, the fatty residue of soap wastes is degraded by bacterial action within the confines of a sewage treatment plant. What is emitted to surface waters is only carbon dioxide and water. Hence, there is little or no impact on the aquatic ecosystem due to biological oxygen demand arising from soap wastes. Nor is the product of soap degradation, carbon dioxide, usually an important ecological intrusion since it is in plentiful supply from other environmental sources, and in any case is an essential nutrient for photosynthetic algae.

Compared with soap, the production of synthetic detergents is a more serious source of pollution. Once used and released into the environment, detergents generate a more intense environmental impact than a comparable amount of soap. Even the newer detergents which are regarded as degradable because the paraffin chain of the molecule (being unbranched, in contrast with the earlier non-degradable detergents) is broken down by bacterial action, nevertheless leave a residue of phenol which may not be degraded and may accumulate in surface waters. Phenol is a rather toxic substance, being foreign to the aquatic ecosystem.

Unlike soap, detergents are compounded with considerable amounts of phosphate in order to enhance their cleansing action and as a water softener. Phosphate may readily induce water pollution by stimulating heavy overgrowths of algae, in the same way as nitrate. *Figure 8* shows that nearly all of the increase in sewage phosphorus in the US can be accounted for by the phosphorus content of detergents. Since soap is quite free of phosphate, the environmental impact due to phosphate is clearly a consequence of the technological change in cleaner production.

The change in the environmental impact index of phosphate in cleaners between 1946 and 1968 is shown in Table 5. In this period the overall environmental impact index increased 1845 per cent. The increase in the effect of population size was 42 per cent; the effect of *per capita* use of cleaners did not change; the technological factor, *i.e.* that due to the displacement of phosphate-free soap by detergents containing an average of about 4 per cent phosphorus, increased about 1270 per cent. The relative importance of this change in cleaner technology in intensifying environmental impact is quite evident.

Table 5. Environmental impact index for phosphorus from detergents.

	1946	1968	1968/1946	Increase (%)
Index factors				
(*a*) Population (× 10³)	140 686	194 846	1.42	42
(*b*) Cleaners* / Population (lb *per capita*)	22.66	15.99	0.69 (1.00)†	(0)
(c) Phosphorus / Cleaners (lb per t cleaner)	6.90	137.34	19.90 (13.70)	(1270)
Total impact (*a* × *b* × *c*) Phosphorus from detergents** (× 10⁶ lb)	11	214	19.45	1845

* Assuming that 35 per cent of detergent weight is active agent.
** Assuming average phosphorus content of detergents is 4 per cent.
† Because of uncertainties regarding the content of active agent in detergents, especially soon after their introduction, the apparent reduction in *per capita* use of cleaners is not regarded as significant; the numbers in parentheses are based on the assumption that this value does not change significantly.

Secondary environmental effects of technological displacements. Increased production of synthetic organic chemicals leads to intensified environmental impacts in several different ways. This segment of industry has heavy power requirements; and in contributing to increased power production the industry adds to the rising levels of air pollutants that are emitted by power plants. In addition, organic synthesis releases into the environment a wide variety of reagents and intermediates, which are foreign to natural ecosystems and often toxic, thus

Table 6. Environmental impact index for beer bottles.

	1950	1967	1967/1950	Increase (%)
Index factors				
(*a*) Population (× 10³)	151 868	197 859	1.30	30
(*b*) Beer consumption / Population (gal *per capita*)	24.99	26.27	1.05	5
(*c*) Beer bottles / Beer consumption (bottles per gal)	0.25	1.26	5.08	408
Total index (*a* × *b* × *c*) Beer bottles (× 10³)	6540	45 476	6.95	595

generating important, often poorly understood, environmental impacts. An example is the enormous loss of fish and plant damage resulting from release of organic wastes, insecticides and herbicides to surface waters or the air.

Perhaps the most serious environmental impact attributable to the increased production of synthetic organic chemicals is due to the intrusion of mercury into surface waters. This effect is mediated by chlorine production. Chlorine is a vital reagent in many organic syntheses—about 80 per cent of present chlorine production finds its end use in the synthetic organic chemical industry. A considerable proportion of chlorine production is carried out in electrolytic mercury cells; until recent control measures were imposed on the industry, about 0.2–0.5 lb of mercury were released to the environment per ton of chlorine manufactured in this way. This means, for example, that the substitution of nylon for cotton has generated an intensified environmental impact due to mercury, for nylon production involves the use of chlorinated intermediates. The rapid, parallel rises in production of synthetic organic chemicals, of chlorine, and of the use of mercury for the latter, is illustrated in *Fig. 9*.

The displacement of steel and lumber by aluminium adds to the burden of air pollutants, for aluminium production is extremely power consumptive. Per lb of aluminium produced, about 29 860 BThU are required to generate the necessary electricity whereas only about 4615 BThU are used per lb of steel produced. Cement, which tends to displace steel in construction, is also extremely power consumptive. The production of chemicals, aluminium and cement account for about 28 per cent of the total US industrial use of electricity.

Packaging. The displacement of older forms of packaging by 'disposable' containers, such as non-returnable bottles, is another example of the intensification of environmental impact due to the postwar pattern of economic growth. This is illustrated in *Fig. 10* and Table 6. There has been a very striking increase in environmental impact due to beer bottles, which are not assimilated by ecological systems and are, in their manufacture, quite power consumptive. The major factor in this intensified environmental impact is the new technology—the use of non-returnable bottles to contain beer—rather than affluence with respect to *per capita* consumption of beer, or increased population. A recent study shows that the total expenditure of energy—for bottle manufacture, processing, shipping *etc.*—required to deliver equal amounts of fluid in non-returnable bottles is 4.7 times that for returnable ones.[7]

Automotive vehicles. Finally there is the problem of assessing the environmental impact of changes in patterns of passenger travel and freight traffic since 1946. Particularly important has been the increased use of automobiles, buses and trucks.

The environmental impact of the internal combustion engine is due to the emission of nitrogen oxides, carbon monoxide, waste fuel and lead. The intensities of these impacts, as measured by their levels in the environment, are a function, not only of the vehicle-miles travelled, but also of the nature of the engine itself—*i.e.* technological factors are relevant as well.

The technological changes in automotive engines since World War 2 have worsened environmental impact (*Fig. 11*). Thus, for passenger automobiles, overall mileage per gallon of

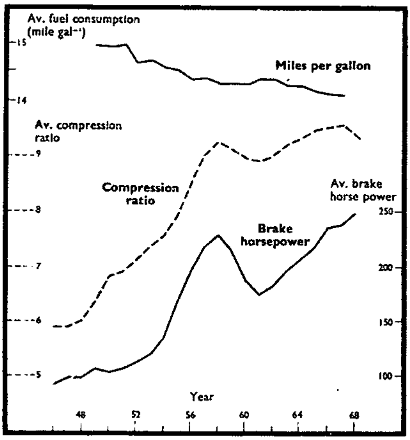


Fig. 11. (left) *Average characteristics of passenger car engines in the US since 1946.*[20]

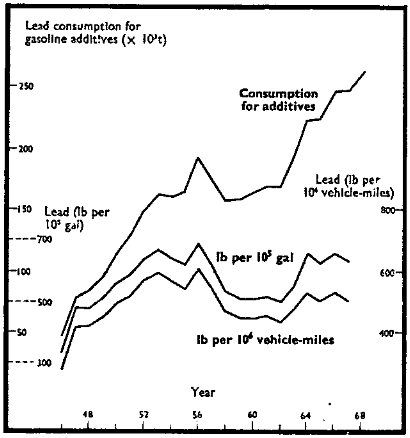


Fig. 12. (right) *Lead emissions from tetraethyl lead in gasoline in the US since 1946.*[21]

fuel declined from 14.97 in 1949 to 14.08 in 1967, largely because average horsepower increased from 100 to 240. Another important technological change was in average compression ratio, which increased from about 5.9 to 9.5 This engineering change has had two important effects on the environmental impact of the gasoline engine. First increasing amounts of tetraethyl lead are needed as a gasoline additive in order to suppress the engine knock that occurs at high compression ratios. As shown in *Fig. 12*, annual use of tetraethyl lead has increased significantly in 1946–68. Essentially all of this lead is emitted from the engine exhaust and is disseminated into the environment. Since lead is not a functional element in any biological organism, and is toxic, it represents an external intrusion on the ecosystem and generates an appreciable environmental effect.

A second consequence of the increase in engine compression ratio has been a rise in the concentration of nitrogen oxides emitted in engine exhaust. This has occurred because the engine temperature increases with compression ratio. The combination of nitrogen and oxygen, present in the air taken into the engine cylinder, to form nitrogen oxides is enhanced at elevated temperatures. Through a series of light-activated reactions, involving waste fuel, nitrogen oxides induce the formation of peroxyacetyl nitrate, the noxious ingredient of photochemical smog. Smog of this type was first detected in Los Angeles in 1942–3; it was unknown in most other US cities until the late 1950s and 1960s, but is now a nearly universal urban pollutant. Peroxyacetyl nitrate is a toxic agent to man, agricultural crops and trees; it has probably increased by about an order of magnitude in 1946–68.

The environmental impact indices for nitrogen oxides and lead are shown in Tables 7 and 8 respectively. The total environmental impact for nitrogen oxides increased by about 630 per cent between 1946 and 1967. The technological factor (the amount of nitrogen oxides emitted per vehicle-mile) increased by 158 per cent, vehicle-miles travelled *per capita* increased by about 100 per cent, and the population factor by about 41 per cent. In the case of tetraethyl lead, the largest increase in impact is in vehicle-miles travelled *per capita* (100 per cent), followed by the technological factor (83 per cent) and the population factor (41 per cent). Thus the major influences on automotive air pollution are increased *per capita* mileage (in part because of changes in work-residence distribution due to the expansion of suburbs) and the increased environmental impact per mile travelled due to technological changes in the gasoline engine.

A similar situation obtains with respect to overland shipments of intercity freight. Here truck freight has tended to displace railroad freight. And again the displacing technology has a more severe environmental impact than does the displaced technology. This is evident from the energy required to transport freight by rail and truck: 624 BThU/t-mile by rail and 3462 BThU/t-mile by truck. It should also be noted that the steel and cement required to produce equal lengths of railroad and expressway differ in the amount of power required in the ratio 1 to 3.6. This is due to the rather power consumptive nature of cement production and to the fact that four highway lanes are required to accommodate heavy truck traffic. In addition, the divided roadway requires a 400 ft right-of-way while a train roadbed needs only 100 ft. In all these ways, the displacement of railroads by automotive vehicles, not only for freight, but also for passenger travel, has intensified the resultant environmental impact.

Table 7. Environmental impact index for nitrogen oxides (passenger vehicles).

	1946	1967	1967/1946	Increase (%)
Index factors				
(*a*) Population (× 10^3)	140 686	197 849	1.41	41
(*b*) Vehicle-miles / Population	1982	3962	2.00	100
(*c*) Nitrogen oxides* / Vehicle-miles	33.5	86.4	2.58	158
Total index (*a* × *b* × *c*) Nitrogen oxides*	10.6	77.5	7.3	630

* Dimension = NO_x (ppm) × gasoline consumption (× 10^6 gal). Estimated from product of passenger vehicle gasoline consumption and ppm NO_x emitted by engines of average compression ratio 5.9 (1946) and 9.5 (1967) under running conditions at 15 in manifold pressure: 1946, 500 ppm NO_x; 1967, 1200 ppm.

Table 8. Environmental impact index for tetraethyl lead.

	1946	1967	1967/1946	Increase (%)
Index factors				
(*a*) Population (× 10^3)	140 686	197 859	1.41	41
(*b*) Vehicle-miles* / Population (miles *per capita*)	1982	3962	2.00	100
(*c*) Tetraethyl lead** / Vehicle-miles (lb per 10^6 vehicle miles)	300	630	1.83	83
Total index (*a* × *b* × *c*) Tetraethyl lead (× 10^3 t)	48	247	5.15	415

* Passenger vehicles only. ** Weight refers to lead content.

Environmental impact inventory

The above analysis represents only small fragments of a complex whole. What is required is a full inventory of the various environmental impact indices associated with the productive enterprise and the identification of the origins of these impacts within the production process and of the ecosystems on which they intrude. Such an assemblage of data, representing an *environmental impact inventory*, is derived below as an exploratory exercise with reference to a productive item for which a certain amount of the data happen to be available—the production of chlorine and alkali by chlor-alkali plants employing mercury electrolytic cells.

The required data include (*i*) the environmental impact indices associated with the input goods, chiefly, electric power, salt and mercury; (*ii*) the environmental impact indices representative of the process wastes and the properties of the ecological systems which are affected by them; (*iii*) the environmental impact indices representative of the ecologically significant wastes associated with the process output goods (chlorine and alkali) and the environmental fate of this material. Thus, the production of one megawatt of electricity by fossil-fuel burning plants results in the release of 34.20 lb sulphur oxides to the atmosphere. Since 4300 kWh is consumed by a mercury cell chlor-alkali plant, per ton of chlorine produced, on the average, 147 lb sulphur oxides are released to the environment per ton of chlorine produced. In this way the corresponding values for other power-plant pollutants—nitrogen oxides, dust—can

Table 9. Environmental impact inventory for chlor-alkali production by means of mercury electrolytic cells.

	Production process	Relevant ecological systems**	Environmental impact (per t chlorine produced)
Input goods*	Electric power (4300 kWh/t Cl)	Air	SO_x: 147.1 lb NO_x: 29.4 lb Particulates: 5.9 lb Mercury: 0.004 g Heat: 5.51 × 10^6 BThU
		Surface waters	Heat: 16.56 × 10^6 BThU
Production process step*	H_2 gas ventilation	Air	Mercury: 17–35 g
	H_2 condensate, wash water	Surface waters *via* settling pond or drainage system	Mercury: 35–121 g
	Brine sludge removal	Surface waters	
	Anode sweepings removal	Soil *via* land fill	Mercury: 6–97 g
Output goods*	Selected alkali-using goods (soap, lye, cleansers, pulp and paper)	Air Surface waters	Mercury: 1–5 g
			Total mercury: 59–258 g/t chlorine

* Only a few of the actual items are shown, for purposes of illustration.
** In an actual index, reference would be made to a standardized description of each of the indicated relevant ecological systems.

also be computed.

The major ecologically-significant waste from chlor-alkali production is mercury metal. Two studies provide data on the amounts of mercury released to the air, to surface waters or buried in land-fill, per ton of chlorine produced. For example, per ton of chlorine produced, about 17–35 g mercury vapour is emitted to the air as waste. Chemical engineering data indicate a total 'mercury loss' of 0.2–0.5 lb per ton of chlorine for the process. This agrees rather well with the total losses to the environment estimated directly by the above studies: 0.13–0.57 lb mercury per ton of chlorine.

The present data indicate that as much as 20 g mercury may become incorporated in the alkali produced in the course of producing a ton of chlorine; this alkali is used in 42 separate products. From an input-output analysis of the chlor-alkali industry one could construct a comprehensive matrix for the movement of mercury contained in alkali through various manufacturing processes into the environment. Recently, economic input–output methods (Leontiev and Isard) have been adapted to include environmental externalities.[8] For the present purposes we shall restrict the analysis to a group of products—wood pulp and paper, soap, lye and cleansers—which use about 26 per cent of the alkali output. Hence, we may estimate that of every 20 g mercury which goes into alkali, 26 per cent or 5 g appears in these products. Their environmental fates are known: waste water containing cleansers goes into waterways, as do the fluid wastes from pulp and paper production; paper is eventually burned, releasing its mercury to the air as vapour.

The ecological data relevant to an environmental impact inventory for chlor-alkali production are just beginning to be investigated. When metallic mercury is dumped into surface waters it sinks into the bottom mud, as droplets. There it may be acted on by certain species of bacteria which convert the mercury to an organic form, methyl mercury. While metallic mercury does not dissolve in water, methyl mercury does. Hence in this form the mercury is readily taken up by living organisms in the water, ultimately contaminating fish that may be eaten by people. In recent months it has been found that mercury wastes from a number of chlor-alkali plants have caused mercury levels in fish in adjacent surface water to exceed acceptable public health limits. Emitted into the air, mercury may be taken up directly by human beings through absorption in the lungs, or may be washed down into soil and water by precipitation—and thus enter into these ecosystems. Very little is known about the ecological transfer of mercury in the soil as yet. Finally, since mercury is very volatile, when heated (as in an incinerator) it is vaporized and emitted into the air. A recent study shows that St Louis domestic incinerators emit about 2–3000 lb mercury into the air annually. Much of this originates in the incineration of paper and wood pulp products.

On the basis of such data one can now produce (in a quite incomplete and tentative form) an environmental impact inventory for chlor-alkali production. This is presented in Table 9.

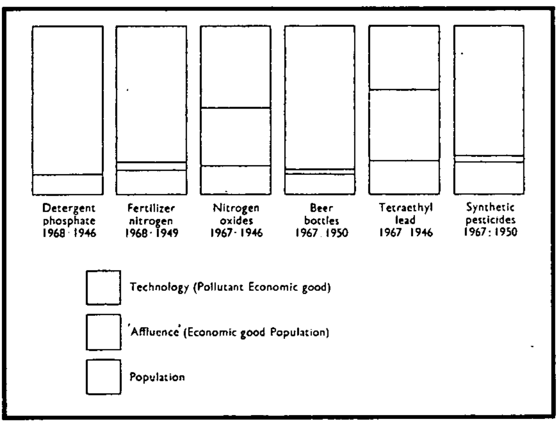
Some conclusions

The data that have been presented reveal a functional connection between economic growth—at least in the US since 1946—and environmental impact. It is significant that the range of increase in the computed environmental impacts agrees fairly well with the independent measure of the actual levels of pollutants occurring in the environment. Thus, the increase in environmental impact index for tetraethyl lead computed from gasoline consumption data for 1946–67 is about 400 per cent; a similar increase in environmental lead levels has been recorded from analyses of layered ice in glaciers.[9] Similarly, the 648 per cent increase in the 19-year period 1949–68 in the environmental impact index computed for nitrogen fertilizer is in keeping with the few available large-scale field measurements. Thus, field data show that nitrate entering the Missouri River as it traversed Nebraska in the six-year period 1956–62 increased a little over 200 per cent.[10] The environmental impact indices computed for several aspects of automative vehicle use are also in keeping with general field observations. It is widely recognized that the most striking increase among the several aspects of environmental deterioration due to automative vehicles, is in the production of photochemical smog. Since 1942 it has increased, nationally, by probably an order of magnitude, appearing in nearly every major city and even in smaller ones in the last five years. However, in the period 1946–68 total use of automotive vehicles, as measured by gasoline consumption, increased by only about 200 per cent—an increment too small to account for the concurrent rise in the incidence of photochemical smog. It is significant that this disparity between the observed increase in smog levels and the increase in vehicle use is accounted for by the environmental impact index computed for nitrogen oxides, the agent which initiates the smog reaction, for that index increased by 630 per cent in 1946–67.

These agreements with actual field data support the conclusion that the computations represented by the environmental impact index provide a useful approximation of the changes in environmental impact associated with the relevant features of the growth of the US economy since 1946. In particular, we can place some reliance on the subdivision of the total impact index into the several factors: population size, *per capita* production or consumption and the technology of production and use.

It is of interest to make a direct comparison of the relative contributions of increases in population size and affluence, and of changes in the technology of production, to the increases in total environmental impact which have occurred since 1946. The ratio of the most recent total index value to the value of the 1946 index (or to the value for the earliest year for which the necessary data are available) is indicative of the change in the total impact over this period of time. The relative contributions of the several factors to these total changes is then given by the ratios of their respective partial indices. *Figure 13* reports such comparisons for the six productive activities evaluated. The population factor contributes only between 12 and 20 per cent of the total change in impact index. For all but the automotive pollutants, the affluence factor makes a rather small contribution—no more than 5 per cent—to the total changes in impact index. For nitrogen oxides and tetraethyl lead from automotive sources, this factor accounts for about 40 per cent of the total effect, reflecting a considerable increase in the number of vehicle-miles travelled *per capita* since 1946. The technological changes in the processes which generate the various economic goods, contribute from 40–90 per cent of the total increases in impact.

Fig. 13. Relative contributions of several factors to changes in environmental impact indices. The contributions of population size, affluence (production per capita*) and technological characteristics (amount of pollutant released per unit production) to the total environmental impact indices were computed as shown in the text. Each bar is subdivided to show the relative contributions of the several factors to the ratio of the total impact index value for the later year to the value for the earlier year.*



In evaluating these results it should be noted that automotive travel is itself strongly affected by a kind of technological transformation: the rapid increase of suburban residences and the concomitant failure to provide adequate railroad and other mass transportation to accommodate this change. That the overall increase in vehicle-miles travelled *per capita* since 1946 (about 100 per cent) is related to increased residence–work travel incident upon this change is suggested by the results of a 1963 survey. It was found that 90 per cent of all automobile trips, representing 30 per cent of total mileage travelled, are 10 miles or less in length. The mean residence–work travel distance was about 5.5 miles. Thus, it is probably appropriate to regard the increase in *per capita* vehicle-miles travelled by automobile as not totally attributable to increased affluence, but rather as a response to new work–residence relationships which are costly in transportation.

During the period from 1946 to the present, pollution levels in the US have increased sharply—generally by an order of magnitude or so. It seems evident from the data presented above that most of this increase is due to one of the three factors that influence environmental impact—the technology of production—and that both population growth and increase in affluence exert a much smaller influence. Thus the chief reason for the sharp increase in environmental stress is the sweeping transformation in production technology. Productive activities with intense environmental impacts have displaced activities with less serious environmental impacts; the growth pattern has been counter-ecological.

This conclusion is easily misconstrued to mean that technology is therefore, *per se*, ecologically harmful. That this interpretation is unwarranted can be seen from the following examples.

Consider the transformation of the present, ecologically-faulty, relationship among soil, agricultural crops, the human population and sewage. Suppose that the sewage, instead of being introduced into surface waters as it is now, whether directly or following treatment, is instead transported from urban collection systems by pipeline to agricultural areas, where—after appropriate sterilization procedures—it is incorporated into the soil. Such a pipeline would reincorporate the urban population into the soil's ecological cycle, restoring the integrity of that cycle, and incidentally removing the need for inorganic nitrogen fertilizer—which also stresses the aquatic cycle. Hence the urban population is then no longer external to the soil cycle and is therefore incapable either of generating a negative biological stress upon it or of exerting a positive ecological stress on the aquatic ecosystem. But note that this state of zero environmental impact is not achieved by a return to 'primitive' conditions, but by an actual technological advance—the construction of a sewage pipeline system.

Or consider the example provided by the technological treatment of gold and other precious metals. Gold is, after all, subject to numerous technological manipulations, which generate a series of considerable economic values. Yet we manage to accomplish all of this without intruding more than a rather small fraction of all the gold ever acquired by human beings into the ecosphere. Because we value it so highly very little gold is 'lost' to the environment. In contrast, most of the mercury which has entered commerce in the last generation has been disseminated into the environment, with very unfortunate effects. Clearly, given adequate technology—and motivation—we could be as thrifty in our handling of mercury as we are of gold, thereby preventing the entry of this toxic material into the environment. Again what is required is not necessarily the abandonment of mercury-based technology, but rather the improvement of that technology to the point of satisfactory compatability with the ecosystem.

Generally speaking then, it would appear possible to reduce the environmental impact of human activities by developing alternatives to ecologically-faulty activities. This can be accomplished, not by abandoning technology and the economic goods which it can yield, but by developing new technologies which incorporate not only the knowledge of the physical sciences but ecological wisdom as well.

From the foregoing considerations, a number of conclusions can be drawn.

1. The deterioration of the environment, whatever its cost in money, social distress and personal suffering, is chiefly the result of the ecologically-faulty technology which has been employed to remake productive enterprises.

2. The resulting environmental impacts stress the basic ecosystems which support the life of human beings, destroy the 'biological capital' which is essential to the operation of industry and agriculture, and may, if unchecked, lead to the catastrophic collapse of these systems.

3. The environmental impacts already generated are sufficient to threaten the continued development of the economic system—witness the current difficulties in the US in siting new power plants at a time of severe power shortage, the recent curtailment of industrial innovation in the fields of detergents, chemical manufacturing, insecticides, herbicides, chlorine production, oil drilling, oil transport, supersonic aviation, nuclear power generation, industrial uses of nuclear explosives—all resulting from public rejection of the concomitant environmental deterioration.

What has been the actual cost of the degradation which has been the response of the environmental system to the intensified impacts upon it? This is, of course, a very difficult question. As indicated earlier, the theory which links environmental impact to ecological effect is for the most part poorly developed. At the same time there are formidable difficulties confronting the economist who attempts to return the 'externalities' represented by ecological damage to the realm of economic evaluation. These efforts, which appear to be developing increasingly useful information, need not be reviewed here. For there is, I believe, a simpler and more direct way to express the cost to the economic system represented by environmental deterioration.

It seems to me that a meaningful way to evaluate this cost is along the following lines. Given conditions 1, 2 and 3 above, it seems probable, if we are to survive economically as well as biologically, that much of the technological transformation of the US economy since 1946 will need to be, so to speak, redone in order to bring the nation's productive technology much more closely into harmony with the inescapable demands of the ecosystem. This will require the development of massive new technologies including: systems to return sewage and garbage directly to the soil; for the replacement of synthetic materials by natural ones; to support the reversal of the present trend to retire soil from agriculture and to elevate the yield per acre; for the development of land transport that operates with maximal fuel efficiency at low combustion temperatures; to enable the sharp curtailment of the use of biologically active synthetic organic agents. In effect what is required is a new period of technological transformation of the economy, which reverses the counter-ecological trends developed since 1946. We might estimate the cost of the new transformation, from the cost of the former one, which must represent a capital investment in the range of hundreds of billions of dollars. To this must be added, of course, the cost of repairing the ecological damage which has already been incurred, such as the eutrophication of Lake Erie—again a bill to be reckoned in the hundreds of billions of dollars.

The enormous size of these costs raises a final question: Is there some functional connection in the economy between the tendency of a given productive activity to inflict an intense impact on the environment (and the size of the resultant costs) and the role of this activity in economic growth? For it is evident from even a cursory comparison of the productive activities which have rapidly expanded in the US economy since 1946 with the activities which they have displaced, that the displacing activities are also considerably more profitable than those which they displace. The correlation between profitability and rapid growth is one that is presumably accountable by economics. Is the additional linkage to intense environmental impact also functional, or only accidental?

It has been pointed out often enough that environmental pollution represents a long-unpaid debt to nature. Is it possible that the US economy has grown since 1946 by deriving much of its new wealth through the enlargement of that debt? If this should turn out to be the case what strains will develop in the economy if, for the sake of the survival of our society, that debt should now be called? How will these strains affect our ability to pay the debt—to survive?

References

1. B Commoner, M. Corr and P. J. Stamler, *Environment*, 1971, **13**, 2.
2. L. W. Weinberger, D. G. Stephan and F. M. Middleton, *Ann. N.Y. Acad. Sci.*, 1966, **136**, 131.
3. B. Commoner, in *Global effects of environmental pollution* (ed. S. Fred Singer). Dordrecht-Holland: Reidel, 1970.
4. D. H. Kohl, G. B. Shearer and B. Commoner, *Isotopic analysis of the movement of fertilizer nitrogen into surface water*. In press 1971.
5. J. H. Dawes, T. E. Larson and R H. Harmeson, *Proc. 24th Annual Meeting, Soil Conservation Society of America*, Ft Collins, Colorado, 1968, p 94.
6. See note in *Marine Pollution Bulletin*, February 1971, **2**, 23.
7. Bruce Hannon (University of Illinois, Urbana), personal communication.
8. See, for example, W. Isard *et al.*, *Papers of the Regional Science Association*, 1969, **21**, 79.
9. C. C. Patterson, *Environment*, 1967, **10**, 72.
10. B. Commoner, *Environment*, 1967, **10**.
11. L. W. Weinberger *et al.* in Hearings before the Subcommittee of Science, Research and Development of the House Committee on Science and Astronautics, *The adequacy of technology for pollution abatement*, vol. 2, p 756. Washington: US Government Printing Office.
12. Department of Commerce, *Statistical abstracts of the United States*, p 5. Washington: US Government Printing Office, 1970. Department of Commerce, *The national income and product accounts of the United States 1929–1965*, p 4. Washington: US Government Printing Office, 1966.
13. *Statistical abstracts of the United States, 1948–1970* (cf. ref. 12).
14. *Agricultural statistics*, 1967, 531, 544, 583; 1970, 444, 454, 481. Washington: US Government Printing Office.
15. *Statistical abstracts of the United States* (cf. ref. 12), 1962, 198; 1966, 789; 1970, 713.
16. *Agricultural statistics* (cf. ref. 14), 1970, 149.
17. L. W. Weinberger *et al.* (cf. ref. 11) Detergent data are based on detergent production assuming an average of 4 per cent phosphorus in marketed detergents.
18. Bureau of Census, *Current industrial reports, series M28A, inorganic chemicals and gases*. *Statistical abstracts of the United States* (cf. ref. 12).
19. *Statistical abstracts of the United States* (cf. ref. 12), 1951, 792; 1955, 833; 1970, 12.
20. Gasoline consumption data from *Statistical abstracts of the United States* (cf. ref. 12). Brake horsepower and compression ratio data from *Brief passenger car data*, 1951 and 1970. Ethyl Corporation.
21. *Minerals Yearbook, 1947–1968*. *Statistical abstracts of the United States* (cf. ref. 12).

Chairman PROXMIRE. Thank you very much, Mr. Commoner.
Mr. MacDonald, please proceed.

STATEMENT OF GORDON J. F. MacDONALD, HENRY LUCE PROFESSOR OF ENVIRONMENTAL POLICY AND STUDIES, DARTMOUTH COLLEGE, HANOVER, N.H.

Mr. MACDONALD. Mr. Chairman, if you would permit, I would like to enter my prepared statement into the record as given to you and attempt to summarize it.

My comments are based both on the National Academy of Sciences Study——

Chairman PROXMIRE. That will be done. Your statement will be printed in full in the record at the end of your statement.

Mr. MACDONALD. Thank you.

The National Academy of Sciences study on man, materials and the environment and the report by the National Commission on Materials Policy form the basis of my prepared statement.

I would like to begin by emphasizing what I think is really the fundamental conclusion reached by the Commission's study, which is contained in the first of the three policy directives. It is quoted by Mr. Boyd and I would like to quote it again because I think it is of very great significance; it is to "Strike a balance between the need to produce goods and the need to protect the environment by modifying the materials system so that all resources, including the environment, are paid for by the user."

I think this policy guidance, which we can summarize by saying the user should pay, is essential if the price mechanism of our economy is to work efficiently and effectively.

I also would like to commend the Commission for the position it has taken with respect to the use of emission charges as a means of improving environmental quality.

As you know, while I was on the Council on Environmental Quality, we attempted to develop a legislative proposal for a tax on sulfur oxide. This has not progressed very far in the legislative process, but it is an essential first step in establishing this as a mechanism which can very effectively help to improve environmental quality.

The next feature of both the academy tudy and the Commission report which deserves attention, is the emphasis on resource recovery. In the country today we produce something like 4½ billion tons of waste material, the majority of which is from agricultural and mining waste, but about 230 million tons are produced in the municipal sector alone.

These waste materials, as has been pointed out in these studies, form a very valuable resource that is not being used sufficiently or effectively. In fact, the disposal of the municipal waste costs the economy today about $4½ billion; one-half of it is a direct municipal expenditure and the other half borne by the private sector is, of course, passed on.

If our waste production continues to increase at current rates, by the year 2000 municipalities will be faced with an expenditure of something on the order of $15 billion a year in addition to their already beleaguered budgets.

The Commission's report points out that an attempt to reuse some of these materials which have passed through the waste streams would have very important environmental benefits. There would be less use of energy, less use of water, less use of natural resources, as well as a decreased pollutant load on the environment.

There are secondary effects associated with resource recovery which I think are significant and must not be forgotten. If you use less energy the secondary effect of coal mining and oil production are lessened. There is also less disruption of esthetic values and wildlife habitats than is associated with virgin mineral extraction and so on.

Another important feature of resource recovery, of course, is that you lessen the wasteful use of land and landfills and other means of disposing of urban waste.

This is further emphasized in one mechanism that had been considered as appropriate for disposing of urban waste, that of dumping materials in the oceans. Both the ocean dumping legislation and international conventions adopted suggest this is no longer a possibility that will be available to our urban centers.

If you look at the problem of resource recovery, you quickly come to the conclusion that it is an economic problem.

If present policies—as they are applied to resource recovery—continue, recycling will not increase, and the total percentage of recycled material entering the production process will actually decrease.

In order for recycling to become an integral part of the production and consumption cycle, the cost of recycling must be favorable at every point in the cycle. For a municipality or business, the net cost of recycling must be less than the net cost of disposal. For a paper or steel producer, the wastepaper or steel must be as cheap or cheaper than the trees or the iron ore; and, if the private sector is to be involved in recycling of municipal waste, there must be a sufficient rate of return to make investments in this area competitive with other investment opportunities.

I do not believe that at present the economics of projected recycling approve it as opposed to a loss.

Even if recycling today looks economical, I doubt that it would be instituted on a large scale. Today, disposal costs for a municipality may run somewhere around $7½ a ton. Even if the recycling brought in moneys to offset this cost for the institutional barriers, the fact that one can be confident of the disposal costs and not confident of the recycling technology would work against the use of any such new technology.

In summary, I think the work of the Commission and that of various other studies clearly demonstrate recycling is marginally competitive at best with the most costly disposal systems, assuming current price levels for waste materials.

There are, of course, numerous barriers to the establishment of a resource recovery industry. The Federal stacks policy has fostered the trend toward the more efficient use of virgin resources by strengthening the economic advantages of virgin over secondary materials. The most striking advantage arises, of course, from the mineral depletion allowance. Mineral producers not only receive a percentage depletion allowance on their resources for extracting metals but they can also elect to recoup certain capital costs as a current deduction thereby reducing their current tax liability.

The depletion allowance varies with respect to materials but it is clear that in many areas this depletion allowance puts the virgin material producer at a significant advantage over those who use secondary materials. For example, if there is a 20 percent depletion allowance one can sell a good at $83 rather than a $100 in order to bring back the same return on an investment, providing one were using secondary materials.

I am not so politically naive to suggest that the depletion allowance should be abolished at the present time or decreased in any substantial way in the short term, although I do believe many of the reasons which led to the provision of these allowances no longer exist.

What are the realistic alternatives to developing resource recovery and making use of that fundamental law of nature which states materials can be used over and over again?

One is no Federal action. I consider this an unrealistic alternative because of the pressing nature of the problem from a number of points of view, environmental, energy, land use and municipal resources. Furthermore, the simple fact of the matter is that the Federal Government is already deeply involved in how materials are priced.

Second, a proposal that has been suggested from time to time is the direct use of Federal funds. The use of the direct subsidy for recycling plants is a possibility. However, construction grants and direct payments to secondary dealers and users, I think, would be economically inefficient; they would require a large new bureaucracy and, in the end, would be far more costly than the proposal I will advance.

A third possibility is the use of regulatory authority. A number of States have adopted regulatory measures to encourage return of beverage containers and such. The administrative problems associated with these regulatory measures are piling up, and I am very familiar with those from resulting legislation in the State of Vermont.

Finally, there is the possibility of incentives to the private sector. I assert that successful resource recovery strategy must be based on the market mechanism. Regulatory approaches suggested to date are only piecemeal and do not promise to be as effective as a direct economic incentive.

Specifically, the proposal I would like to advance today, and one that has been discussed from time to time, is a tax incentive to encourage the private sector to become involved in the recycling of waste material and to make solid waste and resource recovery more profitable and competitive with current means of disposal. In this context I mean by resource recovery, both the recovery of materials of various sorts such as steel, aluminum, glass, and paper for reuse and the recovery of energy contained within the waste products.

The proposal would involve legislation authorizing a resource recovery tax credit to provide a direct offset against taxes to any manufacturing firm utilizing materials that have passed through the consumer waste stream. I would suggest that initially the tax offset should be 15 percent of the price paid for materials derived from waste material that has passed through the consumer system. It would not apply to waste generated within the industry itself.

In particular, the tax offset would apply to urban waste and other postconsumer waste products. Because of the experimental nature of such a proposal, the tax credit would be discontinued after 10 years subject to reexamination by the Congress. This tax credit would apply to the major items contributing to solid waste including paper, glass, aluminum, steel, and textiles, as well as to organic materials and other waste that could be used as an energy resource. It would not apply to semiprecious metals such as lead, copper, and other elements whose high price already insures a fairly active secondary market.

The advantages of such a proposal are that it would encourage the development and implementation of the technology required for resource recovery. The research and development, I think, could be carried out in the private sector provided the profit motives generated in part by the tax offset existed. And further, the secondary industry could develop at a pace required to meet industrial demands.

Clearly, there would be a number of other social benefits alleviating some of the problems to which I have referred. There would be advantages in maintaining our total resource position. Energy and water conservation would rule, and there would, I think, be important effects on reduced air and water pollution.

One can make attempts at estimating what such a tax offset would cost the Federal Government. My best guess is that initially it would probably mean a loss in revenue of something on the order of $200 million a year. This, I would argue, would be much more than offset by benefits to the society in lowered municipal waste disposal costs, lowered costs in the environment, and so forth.

This is a very rough outline of a proposal I think should be examined in great detail. I would be derelict if I did not mention some of the uncertainties associated with it. What would be the effect on the virgin materials industry? In view of the present technologies and the vertically integrated structure of many manufacturing industries and the total volumes of materials required, I would suspect that at least for the short term such a tax proposal would have a relatively small effect. A second weakness that has not been studied in sufficient detail is the possibility for windfalls. A third difficulty involves the administration of such a tax proposal. And American industry in many ways is already overwhelmed by the paperwork requirements imposed by the Federal Government. The proposed tax incentive would indeed lead to further requirements together with some Federal or State means of insuring that materials labeled as having gone through the consumer streams have indeed done so.

However, I would note in passing that our experience in Government has been that we have been far better in tax collection than in regulation. However, I do believe the drawbacks I mention are real and they do need further examination. They do not negate the thesis that there is an urgent requirement to put the resource recovery industry on a competitive basis with the industries that exploit, develop, and use our irreplaceable natural resources.

I would like to end by touching on another issue that poses a different kind of problem. Our increasingly complex technology referred to by Mr. Commoner produces materials that to an increasing extent contain potentially toxic and hazardous compounds and elements. The microcomputers displayed on page after page of advertising contain components made up of such elements as gallium, arsenic, elemental silicon, cadmium, and other potentially toxic materials. In the end these products or components of products enter into the waste stream.

If these potentially toxic elements end up in the landfill or are incinerated or are disposed of by conventional methods, they enter into the environment and can be accumulated therein.

Their total volume at present is not sufficient to represent an immediate threat to the health of man or to the health of the environment, but as we look ahead, I think we should recognize they could become potential environmental hazards.

Furthermore, they are an important resource in material terms.

I see two approaches to the problem. One is an attempt to obtain from industry an agreement to place a deposit or an item high enough so the return of the product to the manufacturer would be insured and the materials contained within the product reused. The difficulty with this proposal, based on voluntary action, is the very large number of individual manufacturers in such industries as microcomputers, television photography, and so forth. Furthermore, a substantial fraction of these products is produced abroad.

An alternative approach is through legislation requiring a deposit equal to about 20 percent of the value of the product as a means of encouraging the customer to return that product for future recycling.

As I say, this is only a small problem at the present. I think it is a problem that is going to grow in the future, a problem resulting from the fact we will be producing more products for the consumer market that contain within them hazardous and potentially toxic materials of one sort or another. I think we should anticipate that problem and insure that these materials are recycled through the industry and not end up in the environment.

In summary, I believe that the emphasis given by both the Academy study and the Commission study on the resource recovery aspects of our materials problem is very important and should receive your careful attention.

Thank you very much.

[The prepared statement of Mr. MacDonald follows:]

PREPARED STATEMENT OF GORDON J. F. MACDONALD

Mr. Chairman, members of the subcommittee, I very much appreciate the opportunity to appear before you and comment on some aspects of the National Academy of Science's study on "Man, Materials and the Environment" and on the comprehensive report prepared by the National Commission on Material Policy. The Commission with a mandate to examine means by which we can conserve materials and enhance the environment inherited a charge of almost incredible complexity. In discharging its responsibilities the Commission drew on a number of outside investigations, including that of the National Academy of Sciences. I believe the Commission has taken on this responsibility and produced a document presenting and detailing a number of far-ranging and innovative recommendations for the future.

I would like to begin by emphasizing a fundamental conclusion of the Academy's study which was adopted by the Commission. I consider this conclusion to be the *most* fundamental issue in dealing with questions of energy, environment and materials. In its first of three directives for policy makers (pages 1–4), the Commission states that in order to secure a sufficient supply of materials while managing and conserving the physical basis of our natural life we should, and I quote, "Strike a balance between the 'need to produce goods' and the 'need to protect the environment' by modifying the materials system so that all resources including environmental are paid for by the user." This policy guidance, which can be put concisely in the form *the user should pay*, is essential if the price mechanism of our economy is to work efficiently and effectively. Further, I commend the Commission for the position it developed with respect to the placing of taxes or user charges on pollutants emitted into the environment, a view strongly endorsed by the Academy study. As you may know, I worked while on the Council on Environmental Quality on developing a legislative proposal for a tax on sulfur oxide emissions. While this proposal has not as yet progressed far in the legislative process, I believe its eventual enactment would represent a first step in facing a problem of how to translate the principle *the user should pay* into legislation. In my testimony this morning I will attempt to focus on economic issues with respect to materials. I doing so, I will have little to say about energy, not because energy and its efficient use are not critical problems, but because I believe that insufficient attention has been focused on what may eventually become problems as critical as that of energy today.

Energy and materials differ in a fundamental way because of the laws of science. Aside from radioactivity an element does not lose its identity. It may be changed chemically or physically, but it is still there. This fundamental physical law means that elements can be recovered and reused over and over again. This is not true of energy. Everytime one uses energy, energy is wasted in such a way that it cannot be recovered. There is no such thing as a perpetual motion machine.

The fundamental physical law of the conservation of mass makes the issue of resource recovery of paramount importance. In 1970 some 4.5 billion tons of waste material were produced by all activities in the United States. The overwhelming percentage (92) was from mining and agriculture. While much can be done from recovery and re-use of these wastes, I will center my attention on the re-use of the some 230 million tons of municipal waste, the disposal of which costs the country something on the order of $4.5 billion annually. Of this, one-half is a direct municipal expenditure. The other half of the cost is incurred by the private sector, although they obviously charge either the municipalities or the citizens directly for their services. If the current annual four percent rate of growth of generation of waste continues and the proportional cost of collection and disposal goes up at the same rate, the total annual expenditure for waste collection and disposal by our local government would reach $15 billion by the year 2000, a dramatic increase in the budgets of our already beleaguered cities.

The report of the National Commission on Materials Policy and the Academy's study in particular documents that resource re-use offers significant environmental dividends. In such material areas as paper, ferrous metals and glass; air and water pollution are reduced and less water, natural resources and energy are consumed when materials that have gone through the consumer cycle are substituted for virgin materials. Further, there is a potential for a partial substitution for fossil fuels through the burning of organic waste. The latter use of waste carries with it significant environmental benefits. For example, resource recovery for energy use would cut the damages of strip mining and subsidence from abandoned mines as well as the acid drainage and sediment from those sources. Resource energy recovery would also cut air pollution because the sulfur content of waste derived from urban areas is low while particulate matter can be controlled with existing technologies.

There are many other factors of an environmental character which favor recycling. These include: the secondary effects of coal mining and oil production to produce energy are lessened since recycling in general requires lesser amounts of energy, there there is less disruption of aesthetic values and wildlife habitants than is associated with virgin mineral extraction, and groundwater pollution and decreased property values resulting from dumping in landfills decline as materials are re-used.

One major benefit of resource recovery, of course. is that we reduce the requirement for disposal in landfills and by incineration. Inadequately managed landfills are ugly, breed rats and disease and often pollute groundwater. Approximately, 40,000 acres of often valued land must be allocated annually for solid waste disposal. Furthremore, the open burning of solid waste results in about five percent of the total weight of all air pollution emissions.

Because of these facts there is little reason to doubt that increased resource recovery could result in significant environmental improvements. In addition we must over the long term consider the availability of our resources. Any step towards resource re-use will lessen our dependence on minerals imported from abroad.

With the clear advantages to the increased use of secondary or recovered resources, why has there been over the past twenty years a percentage decrease in the use of many secondary materials as compared with virgin materials.

Increased resource recovery is limited by a number of technological, institutional and economic barriers. The Commission's report explores these barriers in some detail. In my comments I wish to emphasize the economic barriers and to discuss with you a specific proposal that could assist in breaking down existing economic impediments to increased resource recovery.

The economics of recycling are particularly crucial in looking towards the future. If present policies persist, recycling will not increase. Indeed it will probably decrease as the percentage of production if costs of resource recovery continue to exceed the costs of other alternatives. Because recycling must become an integral part of the complex production, consumption and disposal cycle; the costs of recycling must be favorable at each of the critical points in the cycle. For a municipality or business, the net cost of a recycling system must be less than the net cost of disposal. For the paper or steel producer, the waste paper or steel must be as cheap or cheaper than trees or iron ore. Finally, if the private sector is to be involved in the recycling of municipal waste, there must be a sufficient rate of return to make investments in this area competitive with other investment opportunities.

Clearly the economics in recycling vary greatly depending upon a wide range of variables. For example, the location of the plant and transportation costs have a major impact. While land disposal may look favorable for a municipality, it becomes less favorable if long-range hauling is required as nearby land is devoted to other uses. This last point is exacerbated by the clear recognition that ocean dumping does not provide the ultimate means for disposal of urban wastes of coastal cities. In sum, the overall economics are different in each situation. However, I believe certain generalities can be drawn.

A number of studies, including those reviewed by the Commission, show that at present, the economics of projected recycling technology show net costs rather than net profits. Resource recovery technologies for paper, aluminum, ferrous metals and glass require a large investment and the fixed costs of operation are quite high in relation to total costs. Available and projected technologies to achieve the most favorable economics would require that these systems be operated 24 hours a day at near capacity to minimize costs and maximize saleable product output. Sophisticated management would be needed to operate the systems and the economics would depend heavily on the efficiency of the unit process. Perhaps most important are prices that recovered resources will command in the marketplace.

Even if a recycling system appears economical, there still are impediments to its adoption. Disposal costs of $7.50 per ton, which may be appropriate for a very long haul of land disposal would be viewed very differently than would recycling at a net cost of $7.50 per ton. The former costs have been borne out by years of experience while the net costs for recycling systems are projected largely from pilot plant projects without operating experience or actual knowledge of the problems that would be encountered with the use of recovered resources. Thus, even in the most favorable instances, recycling is only comparable in cost to disposal with great uncertainties surrounding both cost and profits of recovered materials.

In summary, the work of the Commission and that of various other studies clearly demonstrate that recycling is marginally competitive at best with the most costly disposal systems assuming current price levels for waste materials. Greater recycling, however, would depress these prices. At existing prices, moreover, it is not economical for manufacturers to enter new areas for substituting waste for virgin materials. Only a significant increase in disposal costs or decrease in the cost of processing waste can bring about a sustained and significant increase in resource recovery.

I have alluded to the many reasons for economic barriers to increased recycling. In addition there are institutional barriers. First, for more than one hunded years industries have depended upon virgin materials and have improved the techniques for extracting virgin materials and converting them into final products. As a result, we have developed large, complex and highly efficient processes many of which are near the source of raw materials such as the vertically integrated glass and steel industries. By contrast there has never been a sufficient quantity of waste of adequate quality to represent a major resource input. Coupled with the fact that industries do not have an incentive to take into account many of the external costs of production such as waste disposal, pollution and other environmental damages, the market for waste material has declined.

The economic forces tend to be contradictory. Recycling will become attractive to localities and private entrepreneurs if prices for waste are high compared with disposal cost. On the other hand, if prices are high, then waste materials are less attractive to the user, the steel mill. This dilemma can only be resolved by examining the Federal role in the present price differential between virgin and used materials.

Federal tax policy has fostered the trend to more efficient use of virgin resources by strengthening the advantage of virgin over secondary materials. The most striking advantage arises from the mineral depletion allowance. Mineral producers not only receive a percentage depletion allowance on their resources for extracting metals, but they can also elect to recoup certain capital costs as a current deduction thereby reducing their current tax liability. Deductions eventually may exceed the cost of the property since they are based on the income from the property rather than on actual investment and are calculated on an arbitrary percentage basis. As result percentage depletion allowances make it probable that claims will continue indefinitely so long as the property produces income.

Coke and iron lessors may treat much of the property as capital gains which has a lower tax rate than ordinary corporate tax rates. There are also less significant tax incentives for exploration and development activities. At present the percentage depletion allowance for iron is 15 percent, aluminum is 22 percent, glass is 14 percent and coal is 10 percent. The significance of the depletion allowance can be illustrated by considering income of $100 from property under resource development. Under regular tax provisions, without a depletion allowance, the taxable income would be $100 and the Federal tax at a 50 percent rate would lead to income after taxes of $50. With a depletion allowance provision of 20 percent, the $100 is first reduced by $20 leaving a taxable income of $80 and an income after taxes of $60, or a greater net income of 20 percent as compared to regular tax treatment.

This tax treatment allows virgin materials to be sold cheaper than in the absence of the tax provision. For example, the depletion allowance permits a $50 after-tax profit from the sale of virgin materials at only $83 instead of at $100 sales price that would be needed for the sale of waste materials. In other words, given the same cost of producing the virgin materials a 20 percent depletion allowance permits roughly a 17 percent reduction in the selling price without reducing the profit to the producer. Other factors also decrease the cost of virgin compared to secondary materials. For example, current freight rates for scrap steel are high on a per ton basis when compared with rates for virgin ore, adding to the economic disadvantage of scrap use. However, these differential rates can be dealt with through the regulatory mechanisms of the Interstate Commerce Commission and certainly should be.

I will now turn to my proposal for dealing with the economic advantages provided users of virgin material as a result of the depletion allowance. I am certainly not so politically naive as to suggest that the depletion allowances be abolished or decreased in any substantial way, although I do believe many of the reasons that led to the provision of these allowances no longer exist.

What are the realistic alternatives?

(1) No Federal action. I consider this to be an unrealistic alternative because of the pressing nature of the problem from any of a number of points of view, environment, energy, land use and resource availability. Further, the simple fact is that the Federal Government is already deeply involved in how materials are priced.

(2) Direct use of Federal funds. The use of a direct subsidy to recycling plants is a possibility. However, construction grants and direct payments to secondary material dealers or users would appear to be highly inefficient, would require a large administrative staff, and in the end I believe would be far more costly than the proposal I will make.

(3) The use of regulatory authority. Some use of regulatory authority has been suggested to encourage recycling including the banning of one-way bottles, requiring bounties on automobiles or a requirement by law as the minimum recycling requirements. Oregon and Vermont both have a mandatory deposit approach to beverage containers, considering these to be primarily a litter, rather than a resource, problem. Already administrative problems are piling up, and I consider this only a band-aid when compared to the far more important question of resource recovery.

(4) Incentives to the private sector. Successful resource recovery strategy must be based on the market mechanism. Regulatory approaches suggested to date

are only piecemeal and do not promise to be as effective as a direct economic incentive.

Specifically, the proposal is for tax incentives to encourage the private sector to become involved in the recycling of waste material and make solid waste and resource recovery more profitable and competitive with current means of disposal. In this context I mean by resource recovery both the recovery of materials of various sorts such as steel, aluminum, glass and paper for re-use and the recovery of energy contained within the waste products.

The proposal would involve legislation authorizing a resource recovery tax credit to provide a direct offset against taxes to any manufacturing firm utilizing materials that have passed through the consumer waste stream. I would suggest that initially the tax offset should be 15 percent of the price paid for materials derived from waste material that has passed through the consumer system. It would not apply to waste internally generated within an industry.

In particular the tax offset would apply to urban waste and other post-consumer waste products. Because of the experimental nature of such a proposal, the tax credit would be discontinued after ten years subject to re-examination by the Congress. This tax credit would apply to the major items contributing to solid waste including paper, glass, aluminum, steel and textiles, as well as to organic materials and other waste that could be used as an energy resource. It would not apply to semi-precious metals such as lead, copper and other elements whose high price already insures a fairly active secondary market. Furthermore, the tax credit would not apply to whole parts of manufactured products such as the bumper or radiator of an automobile.

The purpose of the tax proposal would be to reverse the uneconomic position of secondary materials and assure adequate markets for them. The provision of such a tax credit would be of benefit to industry if it used maximum quantities of waste available. In a real sense the tax credit would in part and only in part offset the advantages now given to virgin materials through the depletion allowance.

An additional benefit from the enactment of such a proposal would encourage the development and implementation of the technology required for resource recovery. This research and development should and undoubtedly would be carried out in the private sector provided the profit motives generated in part by the tax offset existed. Further, the secondary industries could develop at a pace to meet industrial demands. Recycling technology implementation would move ahead as industrial demand guarantees markets as industries themselves begin to handle what are now municipal problems. Indeed tax incentives will provide a mechanism to assure private sector involvement rather than inefficient municipal operation.

In addition to the direct benefits in solid waste management, a number of other social benefits would result. In general resource recovery will result in resource, energy and water conservation as well as positive and important effects on reduced air and water pollution. These externalities are not included in the current prices of the products made from virgin materials but represent real cost which can be avoided if resource recovery is encouraged.

I would like to illustrate how such a tax incentive provides benefits that far outweigh the cost required for achievement. Let us suppose that in a glass industry the raw material is recycled glass and that the price to the manufacturer of this recycled material is $18 per ton. A 15 percent tax credit will result in $2.70 per ton reduction in tax revenues to the Federal Government. This loss in revenue must be compared with the savings resulting from the use of waste glass rather than the raw materials. These are real savings to the society that are in a direct sense comparable to the tax cost. Such estimates of the society's savings must be of necessity very approximate, but my guess is that in terms of air pollution the saving approximate $1.30 per ton of glass processed and a savings of $8.60 a ton in disposal costs associated with the exploitation of virgin material. The total, direct social savings is then $9.90 for a benefit/cost ratio of about four. This oversimplified calculation neglects, of course, the savings of such nonrenewable resources as energy and such renewable resources as water, which can only be renewed though at additional costs. Similar ratios ranging from five to ten can be calculated for such materials as scrap steel and aluminum. While I hold no brief for the exactness of the numbers I have quoted, they are illustrative of the fact that the benefit/cost associated with a recycling tax credit can be large.

Examining the overall budget impact of the recycling tax credit at whatever level, it is clear that the result in the short term is smaller tax returns but probably initially no larger than $200 million. In the long term budget impact may be neutral or possibly positive as manufacturers switch from virgin materials which carry with them depletion allowance to secondary materials which carry with them a smaller tax credit.

The proposal of tax benefit on the re-use ot materials flowing through the consumer waste stream should have very beneficial economic impacts. First, I will return to an early point in my testimony: the rising costs of municipal waste management. An active, aggressive resource recovery industry should stem the rising costs of municipal waste management. Secondly, the establishment of such an industry can over the long term have positive beneficial effects on employment with a decreasing use of lower skilled employees in the municipal and private disposal sector and an increased use of higher skilled employees in resource recovery. Thirdly, such a policy of positive tax incentives for the re-use of materials can lessen U.S. dependence upon minerals mined abroad. For example, the U.S. currently imports substantial quantities of iron ore and even larger tonnage of bauxite.

I have sketched in a very rough outline a proposal that should have very far-reaching effects. I would be derelict if I did not mention some of the uncertainties associated with such a proposal and which have not adequately been examined. What would be the effect on the virgin materials industry? In view of the present technologies and the vertically integrated structure of many manufacturing industries and the total volumes of materials required, I would suspect that at least for the short term such a tax proposal would have a relatively small effect. A second weakness that has not been studied in sufficient detail is the possibility of windfalls. A third difficulty involves the administration of such a tax proposal. In many ways American industry is already overwhelmed by the paperwork requirements imposed by the Federal Government. The proposed tax incentive would indeed lead to further requirements together with some Federal or State means of insuring that materials labeled as having gone through the consumer stream have indeed done so. I would not in passing, however, that our history shows that our Government has been much more effect in tax collection than in regulation. These drawbacks are real and they need further examination. I do not believe they negate the thesis that there is an urgent requirement to put the resource recovery industry on a competitive basis with those industries that exploit, develop and use our irreplaceable natural resources.

I would like to end by raising an issue that today represents a relatively minor problem but one which can assume major proportions in the future. It is a problem that has not received sufficient attention in my view. Our increasingly complex technology generates consumer products of incredible complexity containing within them materials that are valuable in and of themselves and can under certain circumstances present severe environmental hazards. Many cameras in use today are powered by batteries containing mercury. The microcomputers displayed on page after page of advertising contain components made up of such elements as gallium, arsenic, elemental silicon, cadmium and other potentially toxic materials. In the end these products or components of products enter into the waste stream. They comprise a very small part of that waste stream, and I find it difficult to conceive of a system of incentives or of a technology that would insure their recovery in the sense that we can recover glass or aluminum. If these potentially toxic materials end up in landfills or burnt in incinerators or otherwise disposed of, they enter into the environment and represent a potential hazard to man and to the environment. At present their total mass is sufficiently small and represents no immediate threat to the health of man or to the health of the environment. But as we look ahead I think we should recognize that they could become potential environmental hazards and furthermore they are a valuable resource in material terms.

Compounds and elements which I have talked about would not be regulated under the Toxic Substances Control Act currently in conference. I see two approaches to this problem. The first would involve voluntary agreement among manufacturers using components containing potentially hazardous materials, requiring from the buyer a deposit sufficient in magnitude to assure that the product at the end of its productive use be returned to the manufacturer. Such a return will enable the manufacturer to re-use the materials contained in the components of the product and keep them from entering the environment. The difficulty with this proposal based on voluntary action is the very large number of individual manufacturers in such industries as microcomputers, television, photography, etc. Furthermore, a substantial fraction of these products are manufactured abroad.

An alternative approach is through legislation requiring a deposit equal to about 20 percent of the value of the product as a means of encouraging the customer to return that product for future recycling. Such a measure would, of course, have some administrative difficulties in connection with deposits associated with beverage containers. However, the small number of products and their higher initial cost might mitigate these problems. For these products the question is not of litter or aesthetics but rather a question of human health and of conservation of very rare, natural resources. Because of this, it may be wise to use the regulatory mechanism to insure that these potentially hazardous elements do not enter the waste stream that leads into the environment and up the food chain to man.

Thank you, Mr. Chairman, for the opportunity to present my views with respect to this excellent report. I will be glad to answer questions.

Representative REUSS [presiding]. Thank you, Mr. MacDonald.

Let me start right in with the proposal for a resource recovery tax credit which you make, and maybe it is my constitutional bias against putting more loopholes into the system that is going to cause some of my questions to take on a critical tone.

In the first place, you back away from recommending that anything be done about the oil and minerals depletion allowance because, as you say, in your prepared statement:

> I am certainly not so politically naive as to suggest that the depletion allowances be abolished or decreased in any substantial way, although I do believe many of the reasons that led to the provisions of these allowances no longer exist.

Well, you certainly have demonstrated that not only do the original reasons no longer exist but that the depletion allowances are now counterproductive and bring cheap virgin supplies into being which contribute to the imbalance in our economy. And while I admit those of us who would lay violent hands upon these bonanzas and giveaways have not done too well in the Congress, actually we did secure a small decrease in 1969, and we still retain our bravado about our ability to do something about it.

So I am a little disturbed by the fact that having said that you would not do anything about the depletion allowance because, outrageous though it is, it has been going on for some time, but then you propose a resource recovery tax credit, worse than a deduction, a credit, and you say that you hope that will go away in 10 years after it has done its task.

What makes you think in light of the longevity of the depletion allowance that the resource recovery tax credit is going to be allowed to evaporate by the special interests which would have been built up dependent upon its eternal life?

Mr. MACDONALD. I think you raise clearly what is the fundamental issue. In the best of all possible worlds I would like to see a transition period of about 10 years, in which we phase out the tax depletion allowance, start out with a tax credit on secondary materials, and then phase that out at a rate comparable to the phasing out of the depletion allowance. In the end you would have no Federal intervention in the price mechanism either through a tax credit on resource recovery or through the oil depletion allowance.

But as a start toward that process I do think it is important to give some sort of equity or provide a better base from which the secondary industry can grow. It certainly is not in a competitive position today.

Mr. COMMONER. Congressman Reuss, I do not know whether your ground rules permit interlopers.

Representative REUSS. Yes; they do. Go ahead, interloper.

Mr. COMMONER. I just want to make a scientific remark about this political question, that the laws of physics tell us it is always more costly in energy to recover something than not to dispel it into the environment in the first place. In other words, if we are more sparing in our use of materials the strain on recovering it is reduced, and again this goes back to the economic questions.

Look at steel girders, for example. If you buy them according to the catalog, not according to the building specifications, the girders are simply heavier than are necessary because no one is willing economically to design a girder for each use. It is economically cheaper to overuse materials than to design them for each use because that requires more labor.

Representative REUSS. I want to take up with you later the question you raise, but let me stay with incentives for recycling a bit more, and you certainly support recycling of whatever is recyclable.

Mr. COMMONER. Yes. As long as you produce waste it ought to be recycled as much as possible.

Representative REUSS. And there are a great many wastes which are going to keep on being produced, such as animal and human manures and so there will be a task for recycling.

Your conclusion, Mr. MacDonald, is that without some sort of a subsidy, either directly or by a tax device, you are not going to be able to provide much more recycling because, it seems to me, your conclusions are that it is uneconomic by itself.

Mr. MACDONALD. At the present time, alternatives for the disposal of municipal waste that is fairly local to the urban center, landfill or incineration, cost less than the cost involved in establishing a resource recovery industry and seeing some return from that industry.

In the long term I think the problem is going to solve itself naturally. We are going to run out of land on which to dispose of the materials. Incineration costs are going to be high because of our air pollution control laws. Freight costs will raise disposal costs. Because of these factors a secondary industry will be encouraged. But that is a longer term possibility, something on the order of 10, 15, or 20 years. I think the problem is now, and I think we should try to provide some incentive.

I would argue against a direct subsidy as just not being the way to do it on administrative, bureaucratic grounds, if no other.

Representative REUSS. I want to get to that in just a minute, but, first, step No. 1, leaving aside questions of political feasibility, should be the removal of perverse incentives to squander virgin materials by abolishing the depletion allowance, should it not?

Mr. MACDONALD. Putting aside the political realities, I would certainly think this would be a far more favorable step than establishing another kind of, as you put it, tax loophole. I would not quite describe it that way, but given the fact that we do have depletion allowances, I would argue that a tax credit on secondary materials is preferable than the alternative mechanism of encouraging the establishment of a secondary industry.

Representative REUSS. I want to come to that because I do not know that removal of the depletion allowance is exclusive of taking other steps, too, but, at any rate, step 1, remove the depletion allowance.

Step 2, I think the point that Mr. Commoner makes to try to provide incentives, and we will get into this later, try to provide incentives for less wasteful use of materials, virgin or second hand, with respect to buildings, commodities, everything else. That certainly belongs in there in an early stage in the hierarchy.

Mr. MacDonald. Yes, and we are going to see a decreased use in materials if the price of energy goes up. There will be less incentive, as Mr. Commoner says, to use that very heavy steel girder because the cost of that girder will go up as the cost of energy goes up. You can see it also in the automobile picture, or in whichever sector of the industry you look at. So I think that the so-called energy crisis is going to have an influence on the price of materials and, therefore, on their use. Perhaps it might discourage the wasteful use of material referred to by Mr. Commoner.

Representative Reuss. Yes; although I reserve for later discussion whether rationing by the purse, discouraging waste by the purse, is really going to work in a society which has rendered itself awash with purchasing power by years of excessive money creation. There is a problem there.

Mr. MacDonald. Yes.

Representative Reuss. But let us say that doing something whether by the purse, by allocation, by regulation or other incentives to discourage wasteful use of materials is the No. 2 thing that should be done.

Then we come, No. 3, to your proposal that something ought to be done by way of incentives to encourage recycling, and I certainly would not think that your point is rendered moot by the fact that the earlier two points; namely, get rid of the perverse depletion allowance and, two, do not waste materials. I do not think you should treat them——

Mr. MacDonald. Not at all.

Representative Reuss. Your recycling incentive suggest——

Mr. MacDonald. I would think those three steps would all be very healthy in terms of our energy-environmental picture. I would just say that the one I can see action taken on in the near term is the third step.

Representative Reuss. Then zeroing in on your incentive for recycling point, I am insufficiently persuaded by your insistence that a tax credit is inevitably the way to do it as opposed to a direct subsidy. It seems to me this is the conventional case of which route to go, and we have learned by bitter experience that a tax subsidy is concealed, Congress has no way of getting at it to undo it, it is imbedded in the committee structure of Congress. That is why the smart money goes to Ways and Means and Finance for its bonanzas rather than fool around with the legislative committees, which may be more difficult.

I do not see anything administratively so difficult about determining what recycling you want to subsidize and, to take your example of recycled glass, require a glass manufacturer, in order to get his subsidy, to submit his voucher for the amount of recycled glass he has used, just as a dairy farmer has to show his milk check in order to get his extra dairy payment. I do not see why it is any more difficult to do that on the subsidy route than on the tax credit route. The guy works not for the Bureau of Internal Revenue but for the Department of the Interior or some place.

Mr. MacDonald. If the subsidy takes the form of direct payment to the end user of the secondary material, I would not argue with you because I feel that has many of the same advantages as a tax credit.

Representative Reuss. Well, that is where the tax credit bites.

Mr. MacDonald. That is exactly where the tax credit would apply. But I would argue against subsidy to the municipalities or of a grant program such as those programs developed for sewage treatment plants. This would not be a wise plan to follow at the present time.

Representative Reuss. I agree. But what we are talking about is whether it should be a tax credit program or a direct subsidy program, and I leave you with this thought. You work out in great detail your tax credit program, dotting every "i" and crossing every "t", and I will show you how to do it by a direct subsidy that will work better and be more flexible and retain congressional control over it.

Mr. MacDonald. I certainly agree that in the end if the subsidy is, as you put it, to the end user of the secondary material, the economic effects would tend to be the same. Even if the subsidy should be more flexible, it is my opinion that the end result would be the same.

As to the legislative control, I will leave that up to your judgment. I do recognize the difficulties of trying to get certain kinds of emission charges through the Ways and Means and the Finance Committees.

Representative Reuss. You see, a tax credit is just writing somebody a check, which is perfectly all right. But if you are going to do that why not write somebody a check so that the taxpayers, who pay for the check, may know what is going on.

I now yield to the patient member from Georgia.

Representative Blackburn. I appreciate the gentleman yielding to the very patient gentleman from Georgia.

I must say that I found the statements of each of you most stimulating. I think there is a common thread to some degree between the testimonies of Mr. Boyd and Mr. MacDonald in the sense that you feel that the price mechanism will ultimately work out the best economic use of our resources.

Now, Mr. Commoner, you point out some of the inconsistencies between what we might desire and what is the result of the economics of our present system, but I am puzzled somewhat as to what you suggest as a replacement, or a substitute, for our present economic system.

Mr. Commoner. I am here not as a citizen with one vote but I am here as a scientist, who feels it is his obligation to talk about objective scientific facts, pointing out what political alternatives exist.

The point I made in my testimony is that there seems to be clear evidence that the problems we are facing in environmental pollution, in wasteful use of resources, and in the vulnerability of the economic system to manipulation of fuel resources, all have an economic origin. What that says is that we cannot rely, given that track record, on the economic system, as it is now constituted, to organize effectively the use of our resources.

That raises a very serious political problem. One which requires new ways of organizing the operation of the economic system in this area. Some of these have been mentioned. For example, our economic system calls for resource depletion allowances. I think it is quite clear from the record that these depletion allowances have resulted in socially destructive ways of using our resources, and that a political question arises as to the need for changing this portion of our economic system.

I would very much favor the elimination of all depletion allowances simply on the record that they are bad for the way in which we use our resources. I would favor Congressman Reuss' suggestion for direct subsidies.

There are even more serious problems behind that. The question whether our resources ought to be governed by short-term profitability is a very serious one, and it is time that the people of this country began to face that issue. What alternatives to the present arrangement we discover depends a great deal on what issues are in debate. But I am convinced that the debate ought to be held.

Representative BLACKBURN. Well, the only real substitution for the marketplace as a final determinant for the use of our resources would be some form of Government regulation, and inevitably that becomes a reflection of political influences which may be even less realistic, from an economic standpoint, than the marketplace.

I will grant you that we have abused our environment, and I certainly agree with Mr. MacDonald that we have made it more attractive economically to rip up virgin forests than to recycle paper. I have cosponsored legislation to encourage recycling of motor oil which, I understand, is something that could be recycled very easily but apparently, because of the mechanics of pumping oil out of the ground and refining it the first time, it is cheaper to deliver it to me in a brandnew can straight out of the ground than it is to run it back through a refinery. Now, to what extent is the depletion allowance a factor in that? Do you know, Mr. MacDonald?

Mr. MACDONALD. Yes; it is just that marginal 23 percent that makes the difference.

Representative BLACKBURN. Now when you say, really just 23 percent, in most businesses in our economy, if they clear 1½ or 2 percent they feel like they have had a pretty good year of it in the retail business in particular, in the grocery business. So when we say just 23 percent we have just said one——

Mr. MACDONALD. That is a big——

Representative BLACKBURN. That is a heck of a lot of incentive right there.

Now, I just have a distrust of Government's ability to regulate things. For example, we have heard what I consider to be a very persuasive argument that if we let the user finally pay the total cost of the goods and services that he is utilizing, then he is not going to waste as much because he has got to pay. And, if we go to some form of direct subsidy then the general taxpayer, in a sense, is subsidizing the ultimate user in the things being used.

Now, to me the argument would be more persuasive to do away with the depletion allowances and let the price of goods being sold increase to reflect that increased cost of doing business.

Now, what will be your reaction to that, Mr. Commoner?

Mr. COMMONER. Let me put it this way, Congressman Blackburn. I am looking at the historical record, and the record with respect to the use of resources, for example, is largely that it has been under the control of the marketplace with Government intervention coming in, in order as Mr. MacDonald has pointed out to enhance, the wrong trend we then have had a mixture, of wrong moves both by private and Government sectors, and so the track record would indicate that mistakes have been made on both sides.

However, the fundamental determinant has always been in the marketplace. This has dominated what is going on and I do not quite agree with you that we are certain that Government intervention will involve a great deal of bureaucracy, what you call politics, which connotes something bad from the way you put it.

Representative BLACKBURN. No, please, let me make sure I am not saying anything bad about politics, because I am a politician, and I do not feel there is anything particularly bad about me. But the very things we are talking about today, there is a great deal of talk about the dairy farmers and their interest in the last political campaigns. They receive a direct subsidy, and it has been very greatly speculated that their interest in the campaign may have been influenced by their subsidy. Now politics is part of the business of the real world we live in.

We recently passed a law that the Federal Government will, in effect, subsidize the cost of producing coal by paying what should be unemployment—not unemployment compensation, but black lung.

Mr. MACDONALD. Black lung and also the death benefits.

Representative BLACKBURN. Right, widows' and survivors' benefits to victims of the black lung disease. I voted against it, not because I am against the widows and survivors of black lung victims but because I thought the users of coal should pay that. But it was the political impact of the plight of these miners that put the pressure on Congress that Congress has got to do so.

So every time I see Government intervention I just see confusion. For example, the ICC was set up to help insure a transportation system in the country. Now we find we are about to take over, or heavily subsidize the railroads, because again if you trace back a lot of their problems, you go right back to the ICC regulatory agency.

You see the Food and Drug Administration reacting to some hysteria on cyclamates. If you set the same criteria they apply to banning things that are quite useful to our society; you will find coffee, sugar, tea, and even water would be banned, because anything in excess is going to be destructive.

So, what I would rather see instead of Government intervention is Government retreating from the marketplace.

Now, where environmental concerns are not protected by the marketplace, and I do not think they are, I think this is one of the places where we should have acted. I think it was criminal to allow producers to dump refuse in our streams for many years. The sight of a river burning goes beyond nausea; it is really frightening that we would allow that sort of thing to happen. Certainly Government regulation to prevent that was required, and the cost of removing those pollutants was a part of the cost of producing the goods, and we just did not impose that cost on the producer in the past. We used them, in effect, to transfer the costs to all of society where we all bear the burden of the abuse of our resources.

Mr. COMMONER. Let me suggest that the problem is deeper. If, as I suggested, it is true that the types of productive technologies that have been developed in this country under economic incentive to improve labor productivity, if this is the chief cause of the difficulties that we are stressing here, then we have a very serious fundamental economic problem: The operation of the economic system seems to require not only a high level but also a constant increase of labor productivity.

The President set up a commission a few years ago when it appeared that the rate of increase of labor productivity slacked off. There was a good deal of concern about it.

The point to be noted is that every measure taken to control environmental pollution will reduce labor productivity because it does not generate any new products and it requires labor. There is no way out.

Representative BLACKBURN. I certainly agree with that.

Mr. COMMONER. I would assert then that we are faced with a very serious question. Shall the way in which the use of our resources is governed be determined by numerous independent decisions based on the desire to increase labor productivity and profit?

If so, it will be a miracle if the complex of decisions all favor the proper use of resources and improvement of environmental quality. It would be incredible if decisions made on purely economic grounds turned out to be good with respect to the environment and resources.

All I am asserting is that it is time for us to stop ducking this problem. It is perhaps the most serious political problem that the country has ever faced. The burden of my testimony is that our recent experience with the environmental crisis and our current experience with the energy crisis is important as a signal of the need to examine these basic questions and I am pleading with you to look at those issues.

Representative BLACKBURN. I follow your argument very well but I also recall the testimony of Mr. Boyd in which he said the interdependence of our society is beyond the human imagination—I believe that was something along the line of what Mr. Boyd said.

Mr. BOYD. That is right.

Representative BLACKBURN. So what I am saying is that out of the very multitude of these independent decisions by independent people, each of them seeking to serve his own best interests, that this miracle does derive or has derived so far, in producing the high standard of living here. And I certainly do not see any control of society, having a Government agency with the capability of making all those independent decisions.

Do you have any comment on that, Mr. Boyd?

Mr. BOYD. Yes, I would like to make a comment because I see we are getting out of perspective here. I see things that Mr. Commoner said and Mr. MacDonald said are conflicting. The problems we face are the shortage of materials and the environmental questions, these things are completely interrelated. We studied this for 2 solid years trying to see how we could handle the environmental problems separate from the materials supply question and the use question and we could not do it. That is why we came to this firm conclusion, and we put it out very, very strongly.

Let us take a look first at this recycling business. To put it in perspective, if we recovered all of the steel in the solid waste stream we would increase our supply by about 10 percent. In other words, we are still putting materials into use to improve the quality of life of the people in this country at a much greater rate than they are coming back to us to be reused.

Representative BLACKBURN. Let me make sure I understand that figure.

Mr. BOYD. Do you happen to have a copy of this report in front of you?

Representative BLACKBURN. No.

Mr. BOYD. This is a chart that shows how much material can come back into the materials cycle from the waste stream.

Representative BLACKBURN. In other words, if we take all of the steel that is in our tin cans and automobiles and toys, or whatever else we may have them in, and we recycled it, we would only be utilizing 10 percent of our——

Mr. BOYD. No, no, sir. The recycling industry is and always been an enormous industry in the normal economy; 50 percent of our copper comes from recycled copper; 35 percent of our steel comes from recycled steel, but that comes automatically from the system. The materials in replacement automobiles comes partly from that. I am talking only about the solid waste stream in the cities, the solid wastes which are the environmental hazards. We are discussing here, how to encourage the return of wastes, as resources to the system.

I would like to go back to the Second World War and the Korean war, and I happened to have had something to do with the mechanisms in this Government during those periods. We had incentives to do certain things which provided the solutions to a number of very serious questions. One was a rapid tax amortization provision. Now, all this did was to delay the time at which people paid their taxes. It did not take anything out of the taxpayers' pockets over the long run.

The next thing we gave guaranteed floor price contracts. In the case of copper, for example, the price of copper was 27½ cents per pound when the world market was 34 or 36 cents per pound. These contracts together with accelerated depreciation were sufficient to enable people to undertake major capital investments. It did not cost the Government a dime.

The tax amortization allowance permitted them to secure the early return of their capital, so it gave them an economic chance of doing it. After 5 years there was payment of the full tax on income without depreciation deductions.

Let us go back to the depletion allowance. You must go back to the tax laws to appreciate what depletion is, how do you depreciate a wasting asset, and nobody has found a better solution to it.

Mr. Commoner says we have the resources, we are not going to run out of oil and coal and things like this in the immediate future, but we have got to get it produced. How do you encourage anybody to go out and take a risk of finding oil or minerals without making that allowance which recognized the need to recovering that cost? That was the percentage depletion allowance.

Now, if we take the percentage depletion allowance off the production of oil how does that help the recovery of oil from your crankcase? It does not help us a darn bit because the demand for oil is so great that it is all needed. Now the question is, How do you set up the mechanisms to provide the industrial structure to bring that oil from the service station? Today it is being dumped in the Potomac River through Rock Creek Park and you can see it going down the river. It has to be taken to some refinery. A complicated economic structure is required to gather it.

When you go into recovering the city wastes the biggest cost, as Mr. MacDonald has pointed out, is gathering small amounts of material and bringing them to the plant. You and I who make those wastes must pay for it either in taxes or to the garbageman. If we can find a way to deliver the wastes to a plant and guarantee to take the energy from that plant for use in the city, then industry can make the processing economical. Such a plant will produce a continual flow of energy, you cannot turn it off and on. The waste has to come in steadily or the garbage will pile up.

So all you need to do it to encourage somebody to build that plant by giving him rapid amortization.

With that and the assurance it will be gathered and delivered to his door, and the city will take his energy, he can make money out of the raw material and he will have a profitable operation, it is there to be done.

Representative Blackburn. Along that line, let me ask you this. We received or heard statements from many oil experts which indicate that we do have a great deal of oil reserves in this country in the continental limits, and off the Continental Shelf, that we are not even drilling for right now.

Do you think that the reduction in the oil depletion allowance several years ago has acted, in effect, as a disincentive to production? What about the procurement of prices for oil on the world market? Is that going to act as an incentive to further exploration?

Mr. Boyd. Do not forget, the oil being produced in the rest of the world and being shipped in here is being produced at much lower costs than in this country. so in order to get wells drilled in this country the depletion allowance is essential. The records show that the reduction in the allowance cuts down our exploration. As Mr. Commoner pointed out, there was a distinct reduction in the oil exploration and production. For the first time in our history the amount of reserves has declined because in a given period the rate of discovery has gone down, because we reduced the incentive to do it. But it is merely reducing the risks, the cost of risks is what counts in this thing. If you do not do it through percentage depletion you must have another way to do it.

I completely agree with Mr. Commoner we must cut down our consumption of materials and we must do it by more efficient use of materials and we must get away from waste. The stuff that comes into my house today that I put in the garbage pail, it makes you sick. It just flows in there whether I want it or not. It is just waste. There are lots of things I do that I do not need to do as a matter of common practice. These are wastes we must get rid of.

When we talked about the steel in use for building, we today use far less iron in the construction of a building than we ever did, and every year it gets less because there are people improving the quality of that steel, that is put out in specifications and that is what the architects use.

Now, I have to agree that it is not, sometimes not economical to produce an unlimited variety of steels. You have got to find a way to encourage the research, we must speed up our material science researches.

If we give encouragement to industry to do these things, these questions will solve themselves and the price increases will do more than that.

For instance, if you are drilling oil today you may get something like $8½ a barrel for it if it is new oil, that has been decontrolled. You do not need to do any more than that. We are going to see a lot of oil wells drilled now because of that allowable increase in price because you have to drill deeper, you have to search for more difficult oil fields to discover and it is going to cost you more to get there so that price increase will help. In fact, it already has helped.

Now, in answer to your other question about the availability of resources, I just came back a couple of weeks ago from a meeting at Cal-Tech with some of the top geologists in the country. You will see a letter pretty soon, and not only did we discuss the offshore areas, there is an environmental problem there, nobody denies it, we still have to consider that, but the industry still has not explored half of what is under the land surfaces.

The geologists feel there is as much oil left under the land's surfaces as we have already produced. We produced 100 billion barrels, we have found 150 billion, and they think at least that much more is left, and more than double that would come from the offshore areas. He is quite right, you have the resources.

Representative BLACKBURN. Let me terminate my questions by asking for an observation from each of you on what I think is really a fundamental issue that is being presented today, and that is, given our present economic system, it is realistic to substitute government as the regulatory method for the uses of our resources. And then a question arises in my mind as to how long, or to what degree, can we remain a free people politically and socially, if we are living in a controlled economic environment?

Mr. BOYD. I think you must modify your system. I fully agree with Mr. Commoner. That means doing away with some of the archaic methods we had of controlling operation. You mentioned one of them, the Interstate Commerce Commission over control of freight rates. We studies this very thoroughly. We quite agree there was a differential of freight rates between virgin material and secondary material but how do you fix it? The thing is so archaic there is no way to fix it, there are something like a billion rates and no one knows what they are, and no one uses so many. It is time we found out that the Government regulations are to preserve the market and see if the transportation system can do it efficiently. It is more efficient to move things by rail and water than by truck, et cetera.

Representative BLACKBURN. If we don't do it our railroads are going to go broke, while our trucking industry is burning up five times as much fuel for the same work.

Mr. MACDONALD. Well, I agree with Mr. Boyd, that our difficulties, particularly in the energy field, have resulted from Government regulations. The Government has intervened into the marketplace by pieces. There never was an overall strategy. One can look at the days when supply exceeded demand. Through manipulations foreign oil was to be brought in FOB through Texas so that the prices would be regulated by the Texas Railway Commission thereby keeping them at an artificially high level.

I think the price of energy today is vastly underpriced.

An analysis we have carried out shows that a barrel of oil probably has a marginal value in today's society of about $20 a barrel, much larger than the $8 a barrel that you may get on new oil today. Much of that underpricing again is a result of regulation in which other competitive industries are also underpricing their product.

You mentioned the black lung. If we look in the nuclear area, we see we financed the R. & D. program and intervened by the Price-Anderson Act guaranteeing to cover insurance in case of accidents. I would argue very strongly with Mr. Commoner that if we did allow the price mechanism to work, and work efficiently, we could solve environmental problems and resource problems.

This will only come about, however, if costs are attached to the environmental damages resulting from using the free resources that we have taken for granted, whether they be land, water or air.

And so, if we have a mechanism by which the total costs of using things is carried by the cost of the goods that are produced, I think we can come out of that; and that is why I thought that the best recommendation in the Commission's report, or the best guidance, was essentially that the users should pay. That was policy guidance No. 1 and I would just like to underline that in every possible way.

Mr. Boyd. I fully agree.

Representative Blackburn. Mr. Commoner.

Mr. Commoner. It seems to me that the question that you raise really has to be looked at in terms of two alternative approaches: One, Gordon MacDonald has just explained very fully; namely, that we should move from our present situation, in which the marketplace is not a free one in the ways that he has described, and see to it that the marketplace fully governs the use of resources, and that we pay the full price.

It is interesting that he points out that in order to do that we have to have Government intervention. Apparently if the Government doesn't intervene the marketplace doesn't really work and we see that very abundantly in the oil situation, where a few companies are able to control the price simply because there is no free marketplace in oil.

The question of Government intervention is even on that side.

The other route you can take is the one you brought up; namely, you have to introduce Government regulation of the economic system, which as you pointed out that this would lead to chaos.

My own position is this: The present situation is already chaotic and growing more so every day. What can we say about a country like the United States in 1973 has an abundant supply of oil under the ground; is today closing down its schools because of a lack of oil to heat them; is raising the price of the gasoline needed by inner city dwellers in order to get out to work; and has tripled the price of propane for farmers?

In other words, here is a country where we boast about our affluence, and our modernization. At the same time there are many people in rural Missouri and elsewhere who are going back to heating with cut wood because they cannot afford to pay the price of fuel, which has risen chaotically.

There is something fundamentally wrong here. And your reply is that if we tried to solve this problem by Government intervention we are going to make a mess of it because the Government doesn't know how to do things very well.

Well, my answer to that is that it is time that the Government learned how to do things better.

In my view, it is nowhere written in golden tablets in the Capitol or anywhere else in the world that Government can't be improved. The whole purpose of Government is that it should respond to public need. Government officials are supposed to be public servants and, as the public need becomes clear, it is up to the Government to find ways of doing what is necessary even if it means improving over its past record.

The point I am making is that the experience we have had in the environmental crisis, which is now sharply demonstrated by the manipulated prices that have been imposed upon us by the fuel companies, tells the country that it is time to examine the way in which we use our resources, to examine the governance that the economic system has imposed upon them and, if possible, to improve the way the Government can intervene.

Representative BLACKBURN. Let me make this final observation, when you say: Let's make Government far better than it is, you remind me of Marie Antoinette saying, "Let them eat cake," when the mob was storming the palace.

The Government is a collection of human beings. In spite of their high motivations you still find that private industry, with the competition among human beings, does result in the most efficient delivery of goods and services. No control led economy has come anywhere near matching our performance. In fact, the controlled economies are over here knocking on our doors trying to borrow our technology, today. So, apparently it looks pretty good to them.

Now, so far as the current energy crisis is concerned a great deal of that can be traced right back to the Middle East developments, which really no one anticipated until it was suddenly upon us, and the degree of our dependence on Middle East oil was far greater than anyone had anticipated.

In fact, we were thinking in terms of 5 to 7 percent dependence on Middle East oil, and what we were really considering was only imported, raw crude. We weren't considering the refined crude we had been importing into the Northeast for some years, which itself had its origin in the Middle East crude.

So, I am not as strongly persuaded, Mr. Commoner, although you are a very persuasive person and very likeable as well, I am still not persuaded that Government is the answer to our problems.

Thank you.

Mr. COMMONER. Well, may I test your patience by disagreeing with two of the things you have just said?

I do not agree that the oil situation is a result of the Middle East crisis. We would be in trouble anyway because of a factor that we have all agreed has been in effect; namely, the cutback in exploration.

As far as improving the Government is concerned, it is the voters' responsibility but there is an important role that the Government has to play, which is to open up the issues for public discussion. And unless people in Washington begin to admit that there is a serious question here, the people of this country will not be alerted to the need for working out solutions, and I am simply expressing the faith that once the issues become clear the people of the country will discover how to solve them, even if it means improving the Government.

Representative BLACKBURN. My, you are optimistic. [Laughter.]

Representative REUSS. I would just comment that one can stipulate that the Albanian economy is miserably run and still not have to take great joy in the fact that now in this country we have grinding inflation five times worse than 10 years ago; rising unemployment, shortages of all sorts of things across the board, and an increasing feeling on the part of the people of this country that things weren't working. I agree with Mr. Commoner that we had better do better, if we can.

Let me first clear up a little matter about this oil depletion allowance, and I will address my questions to Mr. Boyd and Mr. Commoner.

I thought I heard Mr. Boyd say just now that the fact, as reported by Mr. Commoner, that oil delivery in this country decreased markedly since 1957 showed that you need the oil depletion allowance.

Well, actually the oil depletion allowance was the same before 1957 and after 1957, right up until 1969, so I wouldn't think that had anything to do with it. I would think a more plausable explanation is the one Mr. Commoner advanced that U.S. petroleum companies found that reduced costs and increased profitability of overseas operations made it more opportune for them to put their drilling resources there rather than at home.

Mr. BOYD. You remember, Congressman Reuss, I said that, I agree with that.

Representative REUSS. Yes, maybe I misunderstood you.

Mr. BOYD. No; I agree with that. The costs of discovery have gone up in this country and is less elsewhere. The flow of capital would go to the place where it cost less to produce the oil. That was one factor.

But the other factor is when we did reduce the depletion allowance in 1968 then there was a further drop in the curve, and if you talk to anybody who is in independent exploration for oil you know he gave up, he wouldn't put any money into it.

Representative REUSS. In fact, it wasn't until 1970.

Mr. BOYD. Yes; it exacerbated the problem, it didn't cause it.

Representative REUSS. At any rate, wouldn't you agree, Mr. Boyd, that with the high prices, much higher prices, for oil in this country, which no matter what is done about it are going to be the order of the day, the incentive to explore in the United States will be greatly enhanced?

Mr. BOYD. It already has.

Representative REUSS. With or without a depletion allowance.

Mr. BOYD. It already has, Congressman Reuss.

Representative REUSS. Let me turn to something of greater sweep.

In your statement, Mr. Boyd, you talked about the shortages that face us, and you say, and I quote:

> We are facing at this moment virtually the same raw material problems we faced in early stages of World War II and the Korean war even though the reasons are different.

And then you say:

> But in times of severe shortage, Government must set the rules. It is not industry's function, for example, to allocate resources in an emergency, * * *.

And we were very grateful for your very concrete recommendations on what the Congress and the Government ought to be doing now by way of emergency allocation of our raw materials.

So far as I know the only main fields of allocation are now petroleum.

Mr. BOYD. And that is only being allocated in a certain area, not in the——

Representative REUSS. In a certain area.

What about the other shortage of materials?

Mr. BOYD. Let me give you a personal example.

Representative REUSS. Please.

Mr. BOYD. I was once president of a copper company and we had a deficiency of copper several years ago when I was there. We couldn't supply all of our customers with copper. The Commerce Department wouldn't let us export copper so we actually distributed our copper on the basis of the previous use of our customers. We could exercise no judgment as to whether that copper should go to food producing or to oil production or whatever it might be. The industry can't do that. The Government must enter into the function of instructing industry where it will move—let me put it the other way around, that Government will guide industry as to which customer they will favor for the good of the Nation itself. An industry man cannot do that. He would be in violation of all kinds of principles and laws, so Government must do that.

Now under the Defense Production Act you have the authority to do that today or the Commerce Department does, but when you do this you have got to bring people in who clearly understand all the ebb and flow of materials, where does it come from, where does it go to, what refinery does it come from, what manufacturer produces this kind of a product, where does it go into the final product that you need, this takes enormous expertise.

In those two emergencies what we did was to call specialists from industry down here for a dollar a year or something like that, put them in the Government operation, supervise them with Government supervisors.

Representative REUSS. You had in World War II the controlled materials plan.

Mr. BOYD. Controlled materials in Korea, in both of those instances they brought industry people down and Government supervised. There never were any scandals as a consequence of that. The British have always done that when they got into an emergency and brought their industry people in because only industry people know these problems. Anybody who has never been through a mess, anybody under 50 who has never been under the rationing system, can have no idea what a mess it is. It takes a lot of expertise. Currently, the conflict-of-interest laws that have been passed by the Congress have got to be reviewed so people can come in and do their duty when they come down here.

Representative REUSS. Well, let's assume that people with the top expertness in the country, and that means largely from the affected industries, some from the universities, but mainly from industries, are available and are brought here and that whatever adjustments need to be made in existing laws to permit that and yet safeguard the public interests are made, what do you think we ought to do right now in terms of allocating all of the scarce materials?

Mr. BOYD. Well, first of all, you have got to know what your economy is. You have to be able to see where you need to put the pressures to improve the problems that are facing you, like improving the supply of oil or whatever it might be.

For instance, the steel that is being manufactured to go somewhere, the steel company has to decide whether it goes to an oil company or goes overseas for drilling oil. He can only decide that on the basis of his business structure. He needs to have somebody from the Commerce Department or someone come and tell him that this particular tool will go to a domestic driller or to a foreign driller. You have the authority to do that in the present Defense Production Act and we have an emergency and we should use it.

Representative REUSS. I am very interested in your testimony on this.

As you say, we have the legal powers. In your judgment there is a need for a well-run, expertly operated controlled materials allocation plan and that should be put into effect right now.

Mr. BOYD. Well, when we talk about controlled materials plan that was a detailed plan to be sure that your materials went into the defense activities. You took a warrant from the War Production Board and you put it down through our office in the Army to the procurement agencies and they would send it over to the manufacturer. That is a detailed plan. We are not in that kind of a condition.

Representative REUSS. No; but tell us what in your judgment we need right now by way of allocation of scarce materials over and beyond the very tiny allocation job that we are now doing.

Assuming that we had in place, and available, the requisite expert personnel equipped with legal authority to do their jobs and with any existing congressional laws now on the books amended so as to take care of any problems that might arise, what would you advocate, what ought we be doing tomorrow if we had——

Mr. BOYD. The first thing you ought to do is make it possible for industry people to come down who had the expertise and come down even in the oil allocation.

Representative REUSS. All right.

As I say, let's assume that a sensible recommendation on how you take care of this is handed to Congress tomorrow, and that Congress rises to the challenge and passes such a law in the next couple of weeks, put that to one side, so that there is no problem of getting adequate personnel, so that you can do that right away.

What commodities would you advocate being put under current allocation and how would you do it?

Mr. BOYD. Well, let me, I will try not to be expert on every commodity because it is a very complicated thing, such things as copper, zinc, and steel.

Representative REUSS. Sure. Still as executive director of the very compendious publication you are knowledgeable and that is why we are asking you the question.

Mr. BOYD. Well, we didn't go quite into that detail. It is one that went through tremendous evolution during the Second World War and Korea. It means just a handful of people who can evaluate the manufacturers problems and can help them to decide, legally decide, where they will send their products, and where they are in short supply.

Now, this is a priority system as of now. As long as you have the kind of shortages we have you can do that with a simple system. That doesn't take any great complex system.

Representative REUSS. But we are not now using such a simple system.

Mr. BOYD. No, we are not using it now, except for defense.

Representative REUSS. And I understand what you mean by a rather simple priority system which works only when you have shortages on the order of 10, 20, 30 percent, let us say.

Mr. BOYD. Well then, you would have to go into a more elaborate system.

Representative REUSS. Well, say 10 percent.

Mr. BOYD. Yes. When we got beyond 7 percent in World War II we found priorities did not work.

Representative REUSS. Yes.

Who would be the recipients of priority assistance and what would be the commodities to which procurement priority certificates would attach? Obviously, this isn't a problem like in World War II and Korea where it is defense industry that is about the only thing you are thinking of. Here you are thinking of the entire economy, it seems to me.

Mr. BOYD. Yes.

Representative REUSS. How would you apply that? What would you do?

Mr. BOYD. You would apply it the same way we did in the Korean war. We didn't have a controlled material plan in the Korean war. We merely had in the agency set up for this purpose, and we used the regular agencies, the authority to tell a manufacturer where to send his products to help him make the allocation.

Representative REUSS. And what, as of January 1, 1974—why don't you assume that Congress does a good job in the next 2 weeks and fixes up these little conflicts of interest points that you are talking about, and you are called back from the farm and placed in charge, what commodities would you attach your priorities system to?

Mr. BOYD. Mr. Congressman, I wouldn't want to say that off the top of my head. May I give you that for the record.

Representative REUSS. Yes, would you.

By all means, I think it would be very helpful when you correct your testimony.

Mr. BOYD. Thank you.

[The following information was subsequently supplied for the record:]

Under the Defense Production Act the word allocation involves a total control of a specific material in which the entire supply is allocated. In our present situation. no such complete control is needed. desirable, nor feasible.

Materials apparently in short supply other than the well recognized energy materials are primarily:

(1) The feed stocks for the petrochemicals industries such as plastics and basic industrial chemicals.

(2) Not iron ore but some forms of steel such as certain oil-well drilling pipe and tools.

(3) Wood products.

(4) Some copper products, aluminum and zinc.

(5) Fertilizers and blasting powder.

In the context of the present situation. there are several solutions. The first and most effective is to permit the market forces to adjust demand to supply *by* *allowing prices to allocate* the resources. Increases of materials supplies have to be stimulated by specific governmental actions such as described earlier: accelerated depreciation and floor price contracts. It is while these forces are recovering from the influence of market distortion resulting from price controls and other disincentives that government priority assistance is necessary.

Representative REUSS. But I gather from what you say you believe that in order to avoid bottleneck shortages and the industrial loss that occurs through a necessitous industry not getting materials it needs that a very widespread, though simple, system of priority allocations should be promptly put in place.

Mr. BOYD. Yes, sir, I believe that, right.

Representative REUSS. It is most helpful.

I have just one more question of Mr. Commoner. You have spoken of the very considerable waste of materials that has gone on in this country for sometime in a wide variety of fields. Short of the total reexamination of our social and economic system which you have urged upon us, and I suppose any social and economic system should always be subject to periodic reexamination, short of that, however, what steps would you like to see taken to cut down on the waste and misuse of materials?

Mr. COMMONER. It seems to me that the oil situation and the energy situation generally ought to be treated as priority and as special problems. It is pretty obvious that any deficiencies are going to lead to a great deal of trouble.

Fossil fuels are limited in supply. When you burn them at high temperatures you inevitably create pollution problems and the rationalization of the energy situation ought to be undertaken regardless of any discussion about some of the more fundamental problems.

It might be very wise to consider social control of the fuel industry, if you like, nationalization. Mr. Blackburn isn't here but looking at the efficiency of nationalized railroads in the world, not in any remarkably different social orders than our own, such as Japan, England and France, they are very efficient operations because they provide the passenger and freight services that are wanted whereas ours do not.

It seems to me that to allow the country to suffer from a fuel shortage because of a slight marginal deficiency in the profitability of finding oil under the land in the United States is a ridiculous situation to get into. I would favor putting the fuel resources in the country under national control.

I understand there has already been a suggestion made that the Government build some refineries. I don't see why the Government shouldn't also drill wells. I believe that sector of the economy is simply too important to leave to the chaos that has been imposed on it by short term profit interests. I think something along those lines ought to be done.

As far as cutting down on waste, there are things that people can learn how to do which have been emphasized a great deal by various speechmaking in Washington of late. But some way has to be found, and I wouldn't minimize its effect on some of the more fundamental problems. For example, it is clear that the automobile buyers of the country understood the relationship between the size of the car and its mileage better than Detroit. Because the Detroit companies seem to have been caught short by the decisions that the buyers have been making to buy smaller cars, and I think we can rely on people to make those moves. I would assume that the kind of educational program that is underway now is very important.

However, I don't think it can be carried out in a socially equitable way without exerting price controls in, for example, fuel sales; otherwise you put a burden on the poor.

The problem of having personal rather than social decision govern these problems is one which has to be looked at very carefully because too often people who are well off can avoid the personal decisions by paying higher prices. Something has to be done about price controls, I believe.

Also of importance is to remind Congress of the importance of regulating environmental pollution and put a stop to the hysterical breakdown in environmental matters which has been under way in the last few months in Washington. It is pretty disgraceful the way in which air pollution standards are being broken down.

The recent move to take radiation control away from EPA and put it in the hands of the AEC because the EPA was about to propose more stringent controls on radiation, is a backward step, and I would hope that Congress could exert some influence over that.

I think at the present time prevention of the breakdown of the excellent legislative controls that were put on environmental emissions is of the highest priority.

Representative REUSS. Thank you very much, Mr. Commoner, Mr. Boyd, and Mr. MacDonald. You all three have been very helpful to us.

We will now stand in recess until 10 o'clock tomorrow morning in this place.

[Whereupon, at 12:10 p.m., the subcommittee recessed, to reconvene at 10 a.m., Thursday, December 20, 1973.]

RESOURCE SCARCITY, ECONOMIC GROWTH, AND THE ENVIRONMENT

THURSDAY, DECEMBER 20, 1973

Congress of the United States,
Subcommittee on Priorities and
Economy in Government of the
Joint Economic Committee,
Washington, D.C.

The subcommittee met, pursuant to recess, at 10 a.m., in room 1202, Dirksen Senate Office Building, Hon. Henry S. Reuss (member of the full committee) presiding.

Present: Representative Reuss.

Also present: Loughlin F. McHugh, senior economist; William A. Cox and Courtenay M. Slater, professional staff members; and Walter B. Laessig, minority counsel.

Opening Statement of Representative Reuss

Representative Reuss. Good morning. The Joint Economic Committee's Subcommittee on Priorities and Economy in Government will be in session for a continuation of its hearings on resource shortages presently faced by the United States and on some current conflicts between economic growth and environmental preservation.

Today, we have asked our distinguished panel of witnesses to take a somewhat longer run look at the consequences of a continuation of our traditional, resource-intensive pattern of economic growth.

Are the shortages we have experienced recently only the beginnings of a scarcity situation which can only grow worse? Or can proper economic policies overcome these shortages?

Must we revise our philosophy that growth is good? Or can the economy be disciplined to grow in ways which are compatible with good conservation practice and environmental preservation?

One aspect of the economic growth controversy which especially concerns me is the question of employment. It has been repeatedly stressed by witnesses before this committee that the real gross national product must grow at least 4 to 4½ percent per year, just to keep unemployment from rising. Thus it would appear that a deliberate policy effort to slow the long-term growth rate would also be a policy to create even higher unemployment than we have traditionally tolerated—and we already tolerate far too much unemployment.

Are we locked into a vicious circle in which we must go on producing and producing, depleting our natural resources to make the most frivolous of items because there is no other way to be sure that people can have jobs? I hope that our panel this morning can suggest some better way to harmonize our various social objectives.

Our first witness is Mr. Jay Forrester of the Massachusetts Institute of Technology. Mr. Forrester is a leading exponent of the view that continued headlong economic growth must indeed have catastrophic consequences for our civilization. We have not previously had his viewpoint presented to this committee, and we welcome him here this morning to explain the framework in which he analyzes these fundamental social questions.

Our second witness is Mr. Ronald Ridker of Resources for the Future. Mr. Ridker is the principal author of a study done by Resources for the Future for the Commission on Population Growth. That study, "Population, Resources, and the Environment," analyzes the subject matter of these hearings in a more traditional economic framework than that used by Mr. Forrester, and it will be very instructive to be able to compare both the methods and the conclusions.

Our final witness is Mr. Robert Solow, professor of economics at the Massachusetts Institute of Technology. Mr. Solow's wit and wisdom have been of great benefit to this committee on a number of past occasions. It is a pleasure to have him here again.

It will be helpful if each of you would limit your initial remarks to about 10 minutes.

Under the rule and without objection, your very comprehensive prepared papers will be received in full into the record.

Mr. Forrester, please proceed.

STATEMENT OF JAY W. FORRESTER, GERMESHAUSEN PROFESSOR, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Mr. FORRESTER. You have a prepared statement that I sent down in advance. I want to refer to the figure in it. You do have a copy?

Representative REUSS. Yes, we do, and present it in any way you would like.

Mr. FORRESTER. You have raised the basic issue of growth, its effect on unemployment, and the difficulty of any transition out of the growth mode for our economy.

The choice we face is one of timing because in the long run the present rates of exponential growth in both production and population cannot permanently be sustained. Therefore, the big issue before us is the way in which we move out of the growth mode and the kind of equilibrium or kind of future into which we make the transition.

Figure 1[1] in the prepared statement focuses on the three major phases in the economic life cycle. There is the growth phase, characterized by rising production and rising population. If there is a rising standard of living during growth, it is created because production grows faster than population.

The continuation of the growth curve shown by the dashed line is simply impossible as a long-term future proposition. The dashed line continues the path of exponential growth. In exponential growth, a quantity doubles in a fixed length of time. We have had dozens of doublings back through history. Doubling has occurred about every

[1] See fig. 1, p. 117.

20 years or 30 years, which means that our demands on the environment and energy double that often. It means that every 20 years we place as much additional load on the environment as we have already placed in all of history up to that time.

Exponential growth is a process that cannot continue. I think we are now in the transition stage shown in the figure. We are approximately halfway up the ultimate growth curve. This is probably true both for the world and the United States.

It is in the transition region that the great economic and social stresses arise. The transition region is at the point of inflection where the upward sweep of the exponential curve gives way to downward curvature and approach toward some sort of future equilibrium or future peaking and decline. Either equilibrium or peak and decline could occur in the future, depending on the nature of the transition. It is in this midregion that the forces occur that become strong enough to push the system out of its old growth mode. Shortage of resources is but one of those forces.

Equally important are the social stresses in the transition period. The filling up of geographical space is accompanied by the filling up of political space and psychological space. In other words, people impinge upon each other more heavily. There is more need for arbitration, there is more need of keeping order, there is more need for government agencies to settle disputes and to control society.

In the transition region, a country begins to divert more and more of its potential productive effort into governmental and other services to cope with stresses that arise from the filling up of psychological and political space. So pressures come in on us, not only from the physical and material side, but also from the political, psychological and social sides.

It is characteristic of the transition stage that all aspects of a society become tightly coupled to one another. We have seen how the environmental pressures have caused an increase in gasoline consumption which has contributed to an oil shortage and has accentuated international stresses. In other words, very quick shifts from the material aspects of existence to the social and political aspects occur in the transition stage. We are now in a different kind of environment, in a very different state in the development of our society, than we have been before.

I think we face two fundamental questions of the present time. One is the question of population versus the standard of living. Any country can sustain some population at a high standard of living. As population goes beyond that optimum point, for any given state of technology and environmental capacity, standard of living will fall. We are reaching the time when the trade off between population and quality of life is the fundamental choice. We have been trying to forestall the choice between population and standard of living by raising the physical limits of the environment by finding more sources of energy and resources.

But we should also lay before your committee the other major issue—the extent to which we have trade offs between the physical side of our existence and the social, political, and psychological side. We are in a dynamic situation of very strong transfers between material and social forces. If we solve the problems in one sector we throw the burden of limiting growth into another sector. To the extent that energy problems, for example, are solved, it encourages continued growth until we come up against other limits. The other limits include the social and psychological stresses that lead to drug addiction, crime, aircraft hijackings, political breakdown and international stress.

These social stresses are very closely coupled to what we are doing in the physical side of existence. So, we should ask: Even assuming that science and technology could solve all of the problems of physical limits, should we want to? If we choose to push back the physical limits, we are saying that we are willing to have the social, political, and psychological limits be the forces that ultimately stop growth.

Personally, I think it is unwise to focus the growth-limiting forces in any single area. The forces should be distributed. This raises important questions about the extent to which we should want to solve the resource and energy limits. Growth must eventually be limited. We can not avoid some set of forces strong enough to limit growth. But we have a choice of how those forces will be composed. We can decide the balance between material and social forces.

As the counterforces arising from growth intensify, we must reexamine our entire constitutional and legal structure. Our social system is heavily laced with influences to promote growth. Such influences were good in a past day but become the source of increasing difficulty in the future. The Congress should begin an extended examination of the nature of growth, the difficulties into which it will lead, how it is driven by the present laws, and how many laws need changing to give a smoother transition out of the growth mode.

I will stop and pick up any points later that you want to raise. Thank you.

[The prepared statement of Mr. Forrester follows:]

Prepared Statement of Jay W. Forrester[1]

World and National Situation

A new foreboding troubles the nation and world. People perceive a more disturbing long-run uncertainty than in past decades. Goals are less united on fundamental issues. The traditional disagreement over means now extends to conflict over ends. The individual is drifting apart from government as the role of government shifts from that of umpire to that of active director and operator. Political leaders no longer possess an image of the future that is consistent with the evident realities; from this lack of shared goals comes a credibility gap and national disunity. The era of political empire has collapsed. The foundations of industrial empire are weakening. The balance of international power is shifting rapidly from resource-using to resource-supplying nations. Even with all such change, little is being done to understand the underlying forces or to plot for the future.

A. Background

For the first time world population, its technology, its institutions and its demands on nature are all impinging on the ultimate capacity of the world environment. Many other civilizations in the history of mankind, by overreaching the capacities of their geography and their technology, have created material and social collapse. But the past rise and fall of civilizations have been on a local scale. Never before has world civilization been so interlocked that it has surged in unison toward impenetrable barriers. In the past, new civilizations rose even as

[1] Copyright, 1973.

others were falling. But for the first time, the rush of civilization toward material barriers, with a reflection of stresses into social and ethical dimensions, is on a "one world" basis.

1. LIFE CYCLE OF GROWTH

Nature of Growth.—Growth is a temporary process. Physical growth of a person ceases with maturity. Growth of an explosion ends with destruction, Past civilizations have grown into overshoot and decline. In every growth situation, growth runs its course, be it in seconds or centuries. From the intensified confrontations between man and nature arise the forces that lie behind the many symptoms of social stress. Figure 1 shows the nature of growth. Population, industrialization, and the use of technology have grown exponentially. Exponential growth is an expansion process in which a quantity doubles after each elapse of a fixed time interval. The interval is called the doubling time. The curve in Figure 1, with its dashed extension, is doubling every twenty years. In the United States the use of energy has been doubling each ten years. For the world, population has been doubling each thirty years. A twenty-year doubling time is typical of modern industrial society. Any growth that repeatedly doubles will, in time, overwhelm its host environment. At some time, growth produces its own termination.

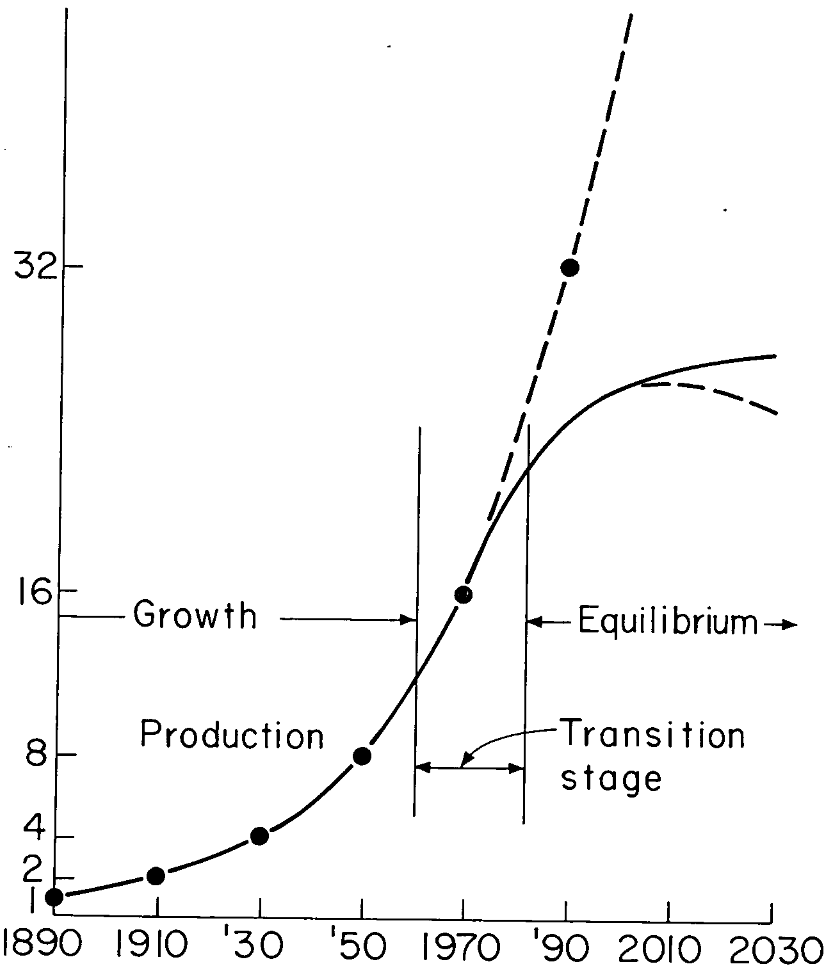


Figure 1

Impact of expontential growth.—The doubling process produces a sudden psychological impact. Population and production can grow for hundreds of years without having a significant effect on the world environment. But then, in two doubling times, growth moves from one quarter of the environmental capacity to the full capability of the world. Only during the last doubling are people inescapably forced to recognize the temporary nature of the growth process. After living with and encouraging exponential growth for hundreds of years, man finds in one lifetime that growth at the former pace cannot continue.

Stages of growth.—Growth follows a life cycle starting with exponential expansion, moving into a transition region, and emerging into a condition of decline, stagnation, or healthy maturity. As Figure 1 shows, the upward thrust of growth must, at some time, level out. The system may move smoothly into an equilibrium, or it may overshoot and fall back. Three quite different stages constitute the life cycle of growth. On the left in the figure is the period of exponential growth. Growth characterizes the entire history of the system until size begins to impinge on its transition stage. In the transition stage, growth for the first time encounters refractory constraints. Sufficient counterforce is generated by the environmental reactions to slow growth toward equilibrium. On the right in the figure is the equilibrium region, which can also take the form of a decline. The three stages must all occur—growth, transition, and equilibrium or collapse.

2. FROM GROWTH TO EQUILIBRIUM

Growth forever impossible.—Although they cannot persist forever, the forces creating growth pervade our society. Not only do people produce people, but also, capital produces capital, learning produces still more learning, bureaucracies produce more bureaucracy, people produce food, and food produces people. A complex net of reactions drives the socio-economic system to increased size. But the doubling process, although it may have repeated for hundreds of years, finally reaches a point where it cannot be sustained. Three doublings, about a hundred years at persent rates, would bring world population to eight times the present numbers. And still another hundred years would multiply again by eight—coming to 64 times present population. Such doubling cannot continue. The only questions open for debate are when will growth slow, and how. In other words, when is the transition stage of Figure 1 and what lies beyond it?

Transition stage.—The transition stage is that time in the life cycle of a society when the forces of growth are being contained and suppressed. The containment forces are simultaneously generated by physical, social, psychological, and political restraints. The transition stage of Figure 1 is a time of special interest. At the transition stage, the many earlier doublings have finally brought the system to a size when the almost irrepressible forces of growth encounter the ultimate restraints of the environment. The great clash is in the transition stage. The transition stage occurs when growth is about halfway up the ladder from zero to the ultimate peak. But the transition stage is only one or two doubling intervals from the time when growth must end. Size and time are not proportional. All of history brings the system only to the halfway point where the transition begins, one more doubling time, occurring in only a few decades, carries the system through the remainder of its growth. The transition stage is created by forces that rise high enough to suppress growth. Social stresses become most severe in the transition stage. Stresses will subside in equilibrium because, by then, the great issues will be resolved and the future will once again be clear.

Now in transition.—I believe the world and the United States are now in the transition stage. Pressures, unrest, doubts, shortages, and alienation are characteristic of transition at the end of the growth mode. The world is experiencing a new set of forces and rapidly shifting pressures and power centers. Such are the conditions of the transition stage. The public loses confidence in political leadership because that leadership is anchored in the traditions of the growth mode. But, as the old tunes are replayed, society marches more deeply into the growing counterforces. In the transition stage, the harder one pushes the limits, the harder they resist. A new kind of statesman is needed. He must have a deep insight into the newly entangling interconnectedness of the socio-economic system. He must be able to restructure public goals and expectations. Leadership must be consistent with the new social realities of the transition stage.

The final, unique doubling.—The last doubling is unique. Only during the last doubling do the processes of growth run headlong into restraint. The transition zone is a special time in the evolution of a society. The world now faces pressures of a new degree and intensity. For the first time in history man encounters restraining forces simultaneously in every dimension of his existence. Everywhere physical space is being exhausted. At the same time shortages of food and resources are appearing. And, along with the material limits, psychological and political "space" are being overloaded to produce social stresses in the form of alienation between the individual and his social institution drug addiction, aircraft hijacking, crime, revolutions, and international confrontations. The pressures entangle all levels of society from the individual to the United Nations. We are in the last doubling. The world and the developed nations have entered that unique transition phase of the life cycle when the very nature of social existence is being restructured.

Future shock.—Alvin Toffler in his book, *Future Shock*, describes the present crosscurrents and pressures, "This is a book about what happens to people when they are overwhelmed by change. It is about the ways in which we adapt—or fail to adapt—to the future . . . (The book deals with) the roaring current of change, a current so powerful today that it overturns institutions, shifts our values and shrivels our roots. Change is the process by which the future invades our lives." But we can say that future shock is simply the frame of mind of a society that enters the transition stage with mental images and mental models that are valid only for the growth mode. We are overwhelmed because we do not understand. We do not understand because the nature of the growth life cycle is not understood. We are only beginning to admit that the transition region exists, to say nothing of coming to grips with its implications.

Forces during transition.—In the transition stage the character of the social system undergoes fundamental change. Growth is produced by "positive feedback" loops. Positive feedback processes dominate the growth mode. But in the transition stage, these positive feedback loops are forced to become "negative feedback" loops. Negative feedback loops are goal-seeking and determine the nature of equilibrium. Such a transition by society is at least as fundamental a change as a person undergoes in moving from the growth of childhood into maturity. The social pressures and political trauma occur not in the equilibrium region of maturity but in the transition stage as new social modes, purposes, and outlook maturity but in the transition stage as new social modes, purposes and outlook are being generated. Tremendous forces are necessary to produce the sweeping changes at transition. Growth continues until the forces are great enough to stop the growth. The forces can be of many kinds. They may be primarily the physical forces of hunger and privation if man blindly pursues old patterns. But, with insight and leadership, the pressures can be self-imposed through changes in goals and values so that nature need not resist so hard and a higher quality of life can be sustained. Many can choose his future, not from impossible utopias, but from realistic alternatives having different systles, qualities, and compromises.

Failures of political leadership.—Like the public, political leaders are caught in the future shock syndrome. Our leaders have been educated from a history that reflects the growth mode. Chamber of Commerce boosterism, military domination, and self-perceptions of world leadership all come from a day when growth and expansion were transcendent, but such history loses its relevance when the fundamental character of the social system changes. Until there are new fundamental perceptions of the dynamic change in society, political leadership will continue to flounder.

Leadership opportunity.—The transition stage marks a great turning point in the flow of events. New modes of thought are needed. New goals must be debated and adopted. Crucial alternatives for the future must be weighed. The long-run and short-run good vie with uncommon contentiousness. People are confused by the crosscurrents. There is a leadership vacuum. Unless better ways are found, the vacuum will be filled by demagogues responding to current pressures with short-term expendiencies and unrealistic promises. A new kind of leadership must be created out of a deeper understanding of the dynamics of society.

3. TRADEOFFS

Changing character of tradeoffs.—The available social tradeoffs are very different in the different stages of the life cycle. During growth the social system presents opportunities to enhance the present at the expense of the future. The tradeoff is in time. But in the transition stage, the social system has become tightly interrelated, problems cannot be deferred, and advantage in one sector is translated quickly into disadvantage in another sector. In the transition stage, tradeoffs are no longer between the present and the future but instead are between conflicting interests in the present. Political skill, economic understanding, and social perceptiveness are especially important if national consensus is to choose wisely among the alternatives.

Temporal tradeoffs during growth.—In the growth mode, the most effective available tradeoff is temporal with present advantage being gained in exchange for a future day of reckoning. That future day of reckoning lurks at the transition stage. The price must be paid when further stress-relieving growth becomes impossible. Five hundred years of geographical exploration and expansion released population pressures at the expense of land shortage by the year 2000. Three hundred years of industrial progress raised the standard of living at the price of energy and resource crises before the year 2000. Decades of modern medicine and public health measures have improved the standard of living in exchange for a world population explosion with its major impact around the year 2000. We now enter the transition stage where the price must be paid for past advantages.

Intersectoral tradeoffs during transition.—In the transition stage the nature of tradeoffs changes. No longer can payment be postponed for enhancing the preent. The transition stage is characterized by a high degree of interconnectedness. Physical space becomes crowded, but so does psychological space and political space. Every action tends to impinge quickly on other facets of the society. Tradeoffs become tradeoffs in space rather than in time. The price for advantage is no longer paid in the future but instead is paid very quickly at some other point in the system. For example, we have already seen the rapidity with which pollution controls on automobiles have coupled to more gasoline consumption, to an oil shortage, and then to international tensions in the Middle East. The environment, technology, resources, and power politics have shown a tight degree of interconnectedness over time spans as short as five years. In other directions, food shortages are raising questions about the ethics of humanitarism when it is realized that aid to starving populations may simply arise their numbers to levels that even aid cannot support. Food, ethics, and population emerge as tightly coupled and rapidly interacting. A new frontier for domestic and international statesmanship is opening to those who can reunify the disarray left by collapse of the guidelines and goals of the earlier growth mode.

Physical vs. social tradeoffs.—In the transition stage almost all facets of society become tightly interconnected and the tightness of coupling depends on the extent to which growth is pressing against the constraints. During growth, multiple goals could be independently pursued. For example, standard of living could be enhanced at the same time that personal freedom was increasing. But in the transition stage, goals as diverse as food and freedom become tightly coupled; if people are free to have children without restraint, the population can grow while the food per person declines. It becomes clear that material goals must be balanced against individual and governmental freedom.

Population vs. quality of life.—May not one of the fundamental freedoms be to strike the balance between population and standard of living? Is there to be equality, or is there to be freedom? In the transition stage a full measure of both simultaneously becomes impossible. Who will make the choice? How is it to be imposed? These questions bring food, resources, freedom, ethics, and politics simultaneously into the mutual tradeoff arena. They cannot be treated separately. Any attempt to address one goal alone will induce countervailing responses in the other dimensions. But no unified political-economic consensus exists to strike a balance between physical well-being and social well-being. By striving for everything, we may achieve far less than was possible. Contending leaders of diverse constituencies and spokesmen for differing objectives pull in all directions without knowing where their combined tugging might lead. The crosscurrents are unfamiliar, and the course in the transition stage has not been charted. Yet, a direction can be set and consensus established if the required effort is made.

B. The Present

World society is now in the transition zone in Figure 1. In many ways growth is encountering pressures that will produce some form of equilibrium. Equilibrium can take many forms. It can be at a high quality of life or low. It can be stable or with traumatic collapses and revivals. The great challenge before mankind is to choose the kind of equilibrium. The alternative is to ignore the choice and let Nature, interacting with man's personality and institutions, do the choosing.

1. THE FUNDAMENTAL PROBLEM

Only one central problem.—Man no longer faces a multiplicity of independent problems. Instead, the diverse symptoms are manifestations of a single set of interacting forces that have coalesced at the transition stage of world evolution. To think of the challenge as several separate problems is to misunderstand the nature of the next several decades. The immediate future is characterized by tight interconnections between the many aspects of society and by rapid transfers of pressures from one sector to another. Because of the transferability, pressures tend to equalize. It is no coincidence that symptoms appear on every hand. That is the nature of the transition stage. While working to suppress the worst pressures, we cause and allow other pressures to increase. The total ensemble of pressures are coupled. They are one set of pressures representing one central problem—the problem of growth encountering restraints in the transition stage of socio-economic development.

Growth as the pressure generator.—The fundamental issue is growth intruding into a fixed space. Practically every aspect of physical and social stress can be traced back to this one central issue. Until the growth issue is faced and dealt with, it will continue to produce symptoms that respond less and less to palliative measures. Population produces population. Technology produces more technology. People have pushed technology to raise the standard of living. The process has worked as long as industrialization could be expended faster than population was increasing. But when agricultural space becomes committed, resources become harder to recover, pollution dissipation capacity becomes loaded, and energy for the accelerating demands begins to falter, technology can no longer be pushed at an ever increasing speed ahead of rising population.

2. THE DERIVATIVE ISSUES

The central process of growth impinging on increasingly resistant limits produces a tight coupling between all aspects of existence. The cross-ties shift stress from high-stress sectors to low-stress sectors of the social-economic-psychological system to equalize the symptoms of trouble. The many symptoms arising from all directions attract attention and become independent political issues. But the tight coupling precludes successful individual treatment. Comments on a few of the most visible public "crises" should serve to illustrate the interconnectedness that makes them individually insoluble. They are all surface symptoms of the underlying pressures from growth expanding into a limited environmental capacity.

Energy shortage.—Shortage arises from population and industrial demand in excess of supply. Shortage transfers internal growth pressures into international stress as we become dependent on other countries. "Solution" through a national energy authority puts government more deeply into operations. Government effort is a holding operation at best, will fail to meet implied promises, and will entangle individual freedom more deeply in government bureaucracy. Hope of enough energy will encourage further growth of demand. Energy shortage is coupled to environmental degradation through strip mining and burning of lower-grade fuels, to balance of payments through imports and rising oil prices, to inflation through balance of payments and the rising cost of producing energy, and to future decline in quality of life through environmental effects and the hazards of long-time storage of atomic waste. To the extent that increased energy is found, demand rises, population rises, and social stress is increased.

Land use.—Control of land use is an issue created by population overcommitting the geography. Land use illustrates the tradeoffs between freedom, environment, government regulation, urbanization, agriculture, and quality of life. The Task Force on Land Use and Urban Growth, chaired by Laurance Rockefeller, recognized the fundamental force in the first chapter title, "Challenging the Ideal of Growth: A New Mood in America"; but backed off in the second chapter title, "But Grow We Will"; the report promotes necessary short-term actions but thereby tends to shift attention away from the ultimate long-term solution. Population growth requires land use control. Control must come from government with increased government-citizen conflict and more man-hours tied up in negotiation and adjudication.

Environmental protection.—Protection is made necessary by growing demands for space, food, and fuel. Environmental concern is a luxury of an affluent society. Environmental arguments will lose in the face of hungry people and cold houses. Human values for the environment erode in the face of more tangible pressures.

Environment is coupled to governmental regulation, individual freedom, unemployment through land shortage for new settlement, industry through pollution, hunger through agricultural demands, and ocean preservation through pollution and demands for food and energy. Environment is fundamental to human life but easily abused today at the expense of tomorrow.

Birth control.—So far birth control has been a debate over allowing individual voluntary choice. But birth rate is primarily determined by individual desires for number of children. In the future, total population will become a matter of national policy. How are we to translate national policy into individual action? How can a nation allocate, regulate, trade, and buy up rights to births to maintain fairness at same time as controlling population for the national welfare? Birth rate is tightly coupled to land use, environmental protection, and quality of life.

Immigration.—Immigration directly impinges on future national policy for total population. Immigration exchanges with birth rate. As each country faces its total population limit, permissible movement betwee countries will be sharply reduced. To the extent that immigration is permitted, it equalizes population-induced stresses; if immigration is permitted everywhere, it drives quality of life everywhere down to lowest accepted anywhere. Right to move is a personal freedom that will be curtailed by increasing pressures from growth. Growth pressures are now generating restrictions on mobility even between cities and states.

Balance of payments.—In the past, with U.S. manufactured output in short supply at high relative price and imported resources in excess supply at low price, favorable balance of transfer of goods raised internal standard of living. In the future, manufactured output will be produced in resource-rich countries with their own consumption; high price of resources and lower relative prices of U.S. output will lower internal U.S. standard of living. Population, demand for imports, and standard of living are coupled. Continued disproportionate consumption of foreign imports will not be possible as population and industry grow in other countries.

Crime.—Crime grows with social complexity and increases with crowding and psychological stress, and is worsened by migration from rural to urban areas. Big government and big business, by seeming impersonal and remote, encourages theft. Unemployment leads to hopelessness and crime. Excess population leaves many without a sense of purpose, who then take refuge in crime. Strong law enforcement can coalesce the sympathies of public and criminal against the government. Growth, mobility, complexity, frustration, unemployment, and crime are related.

Distrust of Government.—With growing social complexity that arises from crowding and interconnectedness, distrust of government increases. Social and economic pressuers draw government out of the role of referee and into active provider of goods and services. But government is limited in the goods and services available and must establish a bureaucracy to allocate goods and services. Each citizen strives to maximize his share of government goods and services, leading to conflict between citizen and government. Government is no longer exclusively the rule-keeper and arbitrator but becomes an active player and competitor.

Mass Transit.—Mass transit is a link in the dynamics of concentrating population. Crowding calls for more transportation that attracts more people. Cities like New York with the biggest transportation networks have the most serious urban problems—not coincidence but cause-and-effect. Mass transit is coupled to land use, population growth, urban density, crime, and central city decay. Unless growth is controlled by other means, mass transit becomes part of the cycle producing progressive decline in quality of urban life. Mass transit is often a temporary expedient that helps until overtaken by consequent socio-economic reactions.

Higher education.—Education has been essential to past economic growth. Probably now we have too much output from higher education for an equilibrium society. Greatest future unemployment threat is in the college-educated population. Unemployed persons with higher education are especially frustrated and a threat to political stability. Quality of higher education is declining as quantity increases. Most critical personnel shortages are in the highly-skilled, apprentice-taught occupations and not in the white-collar ranks.

Government expenditure.—Expenditure rises as social and economic stress causes government to acquire expanded roles. About one-third of U.S. working population are now paid from tax revenues. Administrative superstructure is becoming large enough to reduce capital investment in the economy, increase inflation, capture workers needed in direct production, and reduce national standard of living.

Unemployment.—Population will be increasing faster than jobs, with jobs being limited by space and environment. Production is no longer a simple function of capital and labor but now depends on the capacity of nature. A high capital/labor ratio produces unemployment instead of higher standard of living if production capacity is set by nature. When output is determined by environmental capacity, the capital/labor ratio is no longer determined by economics but by social policy regarding employment.

Inflation.—Present inflation arises partly from rising real costs as demand exceeds environmental capacity, partly from diversion of labor from agriculture and production to tax-supported employment as growth produces political complexity and international tension, partly from monetary and fiscal policy that tries to sustain the rise in consumption as limits to production are encountered, and partly from foreign purchases as internal demand exceeds internal productive capability. Inflation is interconnected to environment, overcommitment of geography, government employment, concentration of power, and unemployment.

C. The Solution Matrix

Growth in a fixed space produces a matrix of interlocked symptoms. Likewise, extracting society from the growth process rests, not on one action, but, on a matrix of interlocked actions. The ramifications will touch every aspect of life and society.

Numerous tradeoffs must be weighed. The transition stage between growth and equilibrium will, at best, be filled with pressures and crosscurrents. Shares of the burden must be balanced in fairness to different sectors and population groups. Present advantage must be weighed against future costs and risks. The more intangible long-run components of quality of life must be protected against short-term material pressures.

This is not the place to attempt a full treatment of the interlocking issues that must be resolved in arriving at a future course for America. Comments on a few of the tightly-coupled aspects of the national future will suggest the scope of the task.

1. NATURE OF MAN

Above all, man is adaptable. He yields to environmental and economic pressures. Cities like Calcutta suggest the low quality of life under which man can survive, and that city illustrates the issue of population versus quality of life. A fundamental question before America is how to keep the "tragedy of the commons" syndrome[2] from overtaking our hopes for man and the country.

2. SUSTAINABLE POPULATION

In the past the United States has been rich enough, and has used a sufficiently disproportionate share of the world's energy and resources, to achieve a rising standard of living even with a rising population. But the transition and equilibrium stages in the economic life cycle will involve a tradeoff between population and quality of life. How is the national choice to be made? If made by default, population can be expected to rise until standard of living is driven down. But how far? Do we accept degradation rather than face the issues?

The United States is now dependent on imports of energy and resources. The present U.S. population may already be higher than is supportable from internal means at the present standard of living. What is to happen in a shifting international balance that, with rising import prices and falling exchange rates, requires withdrawing more and more goods from consumption for export to sustain the import of necessities?

Recent publicity about falling birth rates has led many to believe that the population issue is solved. But Massachusetts already has a population density 1.5 times that of India. And the much heralded zero-population-growth fertility rate, because of the young population, means that constant population will not be achieved until about the year 2020. By that time U.S. population, at present fertility rates, would be some 50% greater than today.

But it appears that social, legal, and economic pressures have substantial effect on birth rates. Many of those pressures are still encouraging a growth of population. Such forces must in time be reversed. How and when to do so is a central question for the country.

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[2] Hardin, Garrett, "The Tragedy of the Commons," *Science*, vol. 162 (Dec. 13, 1968), pp. 1243–1248.

3. EXPECTATIONS

The growth stage left a legacy of rising expectations for standard of living, increasing opportunity, more mobility, and greater equality. But those expectations began to wither in the turmoil of the 1960's triggered by the new realities of the transition stage. Old expectations are faltering, but no new expectations for the future have taken their place. A vacuum in expectations leads to hopelessness and frustration. An empty future can be as dangerous as a disappointed future. A fundamental choice for America is to establish viable long-range expectations that are consistent with present and future realities.

4. INTERNATIONAL RESPONSIBILITY AND ETHICS

In the last several decades the United States has assumed a growing responsibility on the international scene. The self-appointed role has included that of policeman, economic advisor, and ethical consultant. But has not much of the leadership carried the world into the present international complexity, trade that is not sustainable, interdependence that cannot continue, and dreams of human equality that will not materialize?

Much of the promise held out by the U.S. has been based on its own short history during which population was growing to fill empty space and industry was expanding to use up the generous resources with which the country was endowed. The pattern is not consistent with the limitations of a world in social, economic, and population equilibrium.

The pendulum swing toward "one world" and international trade is probably near its limit. Will countries—Japan, Western Europe, and the United States—dependent on foreign resources and markets try to sustain their economic and population growth by force, or will they see the challenge as internal? The internal challenge is to live within one's own capability, while others do likewise, with each country striking its own balance between population and standard of living. If countries try to solve their internal stresses by blaming those stresses on others, devastating war will result. Hope lies in turning attention of all countries inward, each to make its own choices for how to live with the future.

5. EQUALITY

Material equality and a decent standard of living for everyone has become an ethical goal, at least a goal receiving lip service. But is such a goal of equality realistic in a world of limited capacity?

What are the consequences of insisting on equality? If there were to be equality through sharing, and if one or more populations continued to grow, the entire world would be pulled down to the lowest standard that would be accepted by any group. On the other hand, if equality is maintained at a fixed standard of living by limiting world population, who is to do the limiting and at what standard of living? In such a framework of enforced equality, there would be little personal or national freedom. Freedom, ethics, and material well-being confront one another. How are the compromises to be struck?

The same issues and choices exist within a country. Can one state limit its population to maintain its standard of living? Many communities are now moving toward doing so.

Are the pressures for compromise to be brought down to the level of the individual family? Can a family choose between more children and a higher standard of living? The current morality of social justice is moving toward equality of opportunity, education, and even income for each individual. But such an ethical viewpoint does not encourage a constant population. Why not have more children if their well-being is determined by the government independently of their number? Is freedom to choose one's own compromise to be sharply curtailed, or are meaningful pressures and costs to be imposed on each family so that, as they choose their compromises, those compromises still add up to the national interest?

6. ROLE OF GOVERNMENT

In the U.S. the role of government has slowly changed in a profound way. As first established, government was an umpire. Active intervention in economic and social affairs was minimum. Government, embodied in laws and courts, set and enforced the rules. By not being an active participant in the game, government could maintain an impartial role.

But slowly government has acquired a larger and larger active role. Goods are delivered and services performed. Government payrolls (including suppliers to government) are about half that of the remaining civilian economy. Government is now the umpire in a game that government also plays. Impartiality is suspect. The umpire has a self interest to sustain.

7. CONSTITUTIONS AND LAWS

The Federal and state constitutions and the network of laws and court precedents come from the growth stage. Much of the legal structure is incompatible with moving through transition to a favorable equilibrium. Just as the first stage of the country was launched with a lengthy constitutional debate, so must the next major stage be guided by a reformulation of constitutions and laws. To arrive at a new legal framework by orderly processes will require a decade to set the directions and one or two decades to accomplish the changes. If orderly processes for change are not initiated, the processes of disorderly and disruptive change become more likely. The years from 1966 to 1971 gave a taste of such disruption.

8. PRIVATE PROPERTY

Private property rights have been a cornerstone of Anglo-Saxon law. Private property rights have probably been the mainspring behind economic development. Private property imposes a self-discipline and a concern for the future. But crowding leads to steady erosion of property rights with a network of changes in attitude, responsibility, and time horizon. How is the tradeoff to be made between private property, population, and equality?

D. Hazards Along the Way

Proposals for transition to national equilibrium have numerous critics. Most critics acknowledge that growth cannot go on forever. Few of the critics address themselves to the merits of alternative equilibrium futures. The central thread of criticism arises from fear of the social disruptions that are implicit in the transition stage. The fears are justified. But assuming the issues can be ignored is not justified.

If, as most critics of equilibrium acknowledge, growth must slow to a stop, then a transition stage is inherent and the forces to produce it are inescapable. Do we want to foresee and shape those forces, or do we want them to take us by surprise? Even as we choose to look ahead and to prepare, the hazards along the way must be recognized and plans made to minimize them.

1. UNEMPLOYMENT

Probably the greatest hazard is unemployment. A third, or even half, of the present working population owe their jobs to growth or to coping with the unfavorable consequences of growth. A transition economy must make an orderly transformation that changes capital/labor ratios and the nature of work opportunities. If the entire issue of transition to equilibrium is ignored, the "natural" forces and processes will probably lead to massive unemployment, soaring welfare roles, economic disruption, and political instability. With enough time to debate the issues and to change course, a smoother transition should be possible.

2. RETIREMENT PLANS

An equilibrium society has a more uniform age distribution than the youthful distribution associated with growth. In equilibrium, a larger fraction of the population is old and retired. Conversely, the burden of production falls on a smaller fraction of workers. Questions have been raised about the viability of the Social Security system under such circumstances. Private pension plans may encounter difficulty. The nature of and opportunity for saving may change substantially.

3. PERSONAL MOBILITY

We have associated mobility with personal opportunity for advancement. But mobility has usually been toward sectors undergoing economic growth. Without substantial growth, mobility will decline. A tendency can be expected to revert toward the parctices of traditional societies in which position is hereditary and the new generation occupies the role of the old. With any such change go major changes in values and expectations.

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E. Closing Comment

The multiple symptoms of social and economic stress are closely interwoven. They arise from the underlying pressure of growth impinging on geographical, political, and psychological limits. Interconnectedness in the socio-economic system is strong enough to equalize the many pressures. Because of the equalizing, stresses appear in every aspect of existence.

We are in the transition stage between growth and equilibrium where the sum of planned and unplanned pressures will stop the growth process. The more we encourage growth, the greater will become the unplanned pressures. The more we introduce planned growth-slowing pressures, the less will be the unplanned pressures.

Many alternative equilibrium futures exist. One of those futures will be chosen by default if we refuse to examine the choices. There is no reason to believe that the default choice is the best choice. We are at one of the great crossroads in human history. In the next two decades, America will choose its future for the next century.

F. Related Reading

1. Forrester, Jay W., *Urban Dynamics.* Cambridge, Massachusetts: The MIT Press, 1969.

2. Forrester, Jay W., *World Dynamics.* Cambridge, Massachusetts: Wright-Allen Press, 1971.

3. Meadows, Dennis L. *et al.*, *Growth in a Finite World.* Cambridge, Masschusetts: Wright-Allen Press, 1974.

4. Meadows, Donella H., Dennis L. Meadows, Jørgen Randers, and William W. Behrens III, *The Limits to Growth.* New York, Universe Books for Potomac Associates, 1972.

5. Meadows, Dennis L. and Donella H. Meadows (Editors), *Toward Global Equilibrium.* Cambridge, Massachusetts: Wright-Allen Press, 1973.

Representative REUSS. Yes, we will want to explore that at length.

Mr. Ridker, has your prepared statement arrived as yet?

Mr. RIDKER. I am sorry, it has not, it is on its way, it will be here shortly.

Representative REUSS. Well, I think in the light of that I am going to ask Mr. Solow to proceed and we then will call on you. Maybe by that time your prepared statement will be here. If it is, it makes it easier up here.

STATEMENT OF ROBERT M. SOLOW, PROFESSOR OF ECONOMICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Mr. SOLOW. Thank you, Mr. Chairman.

I think I will just read the prepared statement that I prepared, more or less, since I tried to hold that to what I could say in 10 minutes.

Very broad and very longrun questions, like those we are discussing today, are necessarily hard to answer with any precision. As a result, the questions serve as something like a Rorschach test; the answers you get from different people may tell you more about the people themselves than about the world. You have to be careful to make that distinction, though the people who answer your questions may find it hard to do so. They may be like the Rorschach subject who asked the psychologist if he—or she—could keep the ink-blot cards because he—or she—had never seen such sexy pictures before.

There are obvious knee-jerk-optimist and knee-jerk-pessimist responses to the problem of resource scarcity and exhaustion. At one extreme, the natural-born optimist may simply assume that some technological solution will turn up for every problem that nature offers—previously unknown mountains of iron ore, cheap artificial substitutes for scarce minerals, an automobile that runs on sewage and emits attar of roses—and will turn up in plenty of time even if no one is officially charged with thinking about the oncoming problem. Your natural-born-pessimist, on the other hand, will ignore all such possibilities and be obsessed with the simple arithmetic, observing that if you keep ladling soup out of a bowl you eventually hit bottom—without ever wondering seriously if earth is quite like a bowl of soup and the economic process quite like a ladle.

As a matter of fact, if you had to choose one of these naive positions, the optimistic one agrees better with the historic record. There has been continued reduction of extraction costs, permitting the economical use of leaner and leaner ores. The normal pattern is for exhaustible resources to rise in price as time goes on, precisely because they get more valuable as they get scarcer. That has not happened, in general, because investment and technological progress have cheapened extraction, processing, and transportation, and because substitute materials and substitute processes have indeed been found. The forests have disappeared from most of Europe, with no noticeable crimp in building. New metals replace old, plastics and fiber glass replace metals, and the impact of scarcity is postponed. Notice that I don't recommend we adopt the technological optimist's position. But if we are limited to extrapolating something, we're probably better off extrapolating the past than extrapolating a table of the exponential function.

We are not limited to these two extreme positions, so the question arises: What should a sensible person think about resource exhaustion and the limits to economic growth? The first thing a sensible person will notice is that the distant future is very uncertain, and that the fog of uncertainty gets rapidly more dense as you look further and further ahead. In any such situation, what you need is a strategy, not a solution. It is dangerous to make a single guess on the basis of very limited information, or no information at all, and then put all your eggs into that basket. It makes more sense to collect and process information as you get along, and to react piecewise to new bits of information about resources and technology and demand as they come into view.

Whenever you have to make a policy decision based on uncertain information, you run the risk of making a mistake. The deeper insight is that there are two kinds of mistakes you can make, and the more you protect yourself against one of them, the more vulnerable you are to the other. For instance, in the present context it might be that we are "rapidly and inexorably approaching these limits—resource exhaustion and saturation of the environment with pollutants—at the present time" but we make the mistake of acting as if that were not so. That is the mistake the Doomsday people and Professor Forrester are warning you against. But there is another possible mistake—that we are not rapidly and inexorably approaching those limits, but we act as if we were.

The doomsday people claim that the mistake they are warning against has such devastating consequences that it would be silly to think about anything else. They also claim that they are reading the situation right, so that the risk of error is small. The answer to that is simple: their work is not very careful or scientific, and you would have to be trusting indeed to believe them. But their argument is wrong on two counts. For one thing, it is production itself, not growth of production, that uses up resources and pollutes the environment—if we let it.

Growth merely increases the level of production and speeds up the process. So if we are rapidly and inexorably approaching the limits to growth, then we are, somewhat less rapidly but just as inexorably, approaching the limits to production, or even to cumulative production. If all that stuff is right—which there is no good reason to believe—then the consequences are devastating whether we listen to the doomsday people or not; they can't help us.

The second thing wrong with the argument is that the opposite mistake is just as serious. The doomsday prescription means inevitably that most of the world is condemned to grinding poverty because aggregate production can't grow or even level off. Most of the world is unlikely to accept that prescription, and we would be in deep trouble if we tried to advertise it. Think how awful it would be to get into all that trouble, and then find out that the optimists are right after all, and technological progress and the substitution of cheap materials for scarce ones will permit a rising standard of living for a very long time. That is not a trivial mistake.

I concluded that all this talk about limits is ignorance masquerading as knowledge. We know a certain amount about the immediate future for natural resources—maybe 20 or 30 years ahead—through the painstaking work of groups like Resources for the Future, which I hope Ronald Ridker will describe in just a minute. That work does not suggest rapid and inexorable exhaustion of resources and poisoning of the environment, provided we do some relatively straightforward things. No one can see clearly 60 or 100 years ahead. The reasonable thing to do is to collect information and adapt to it in rational ways.

That brings me to the price system, which was the subject of the second set of questions asked in my invitation to these hearings.

The price system is one way of assembling the bits of information known to those with special interest in and special access to the facts. It is also one, fairly decentralized, way in which an economic system can give itself the opportunity to react to information adaptively. I hardly need to describe the way the system can be expected to work: when participants in the market for a natural resource see exhaustion approaching, its price will rise as buyers compete for the small supply and sellers try to do the best they can with what they have left. The rise in price does at least four things, all of them functional under the circumstances. It reduces the demand for the resource by making things that contain a lot of it relatively expensive; it provides an incentive for manufacturers to substitute cheaper materials for scarcer and dearer ones; similarly, it provides an incentive for exploration; and, finally, it guides scientific and engineering effort to those technological areas that are now likely to generate large savings in cost.

These things actually happen. I regard it as one—but only one—of the failings of the various doomsday models that they allow for this process inadequately or not at all. So they are likely to misinterpret the past and misread the future. But I definitely do not want to leave the impression that when you've said that—like Budweiser—you've said it all. I think there are good economic reasons for believing that the unaided price system is unlikely to function perfectly, so there is room for public policy. I have time only to mention some of the reasons why laissez-faire is unlikely to be the best policy in the resource field. I shall not even talk about environmental pollution, where the case has already been made many times.

First, technological, economic, and other research is clearly an important part of the adaptive mechanism. But the private market is likely to generate too little research, especially basic research. That is because knowledge, especially fundamental knowledge, is hard to keep to oneself; and if you can't keep it to yourself, others may be able to profit who have borne none of the costs. Moreover, even if knowledge could be kept secret, and profitable, it is not socially advantageous to let that happen. Knowledge should be shared because it is not used up by being used. In other words, research is a public good in the same way that pollution is a public bad; in both cases the market may malfunction, generating too little research and too much pollution. So corrective action is in order, and that probably means increased Federal finance of research in the natural resource field, as, for instance, the recent energy legislation has provided.

Second, economic theory tells us some reasons why the outcome of competitive market processes is likely to be efficient in the aggregate even though no one involved intends that to happen. That is Adam Smith's "Invisible Hand." But the markets for natural resources are often not competitive in the appropriate sense. There may be very few, very large producers in any country, and in the world. This tendency is exacerbated by the appearance of large international corporations and substantial national monopolies in primary producing industries. I do not know enough to make specific suggestions here, but I want to mention the general principle.

Third, when they speak of competitive market processes in this context economists mean, or should mean, something very complicated; namely, the whole series of future markets for purchase and sale of each resource for delivery now, next year, the year after, and on into the distant future. In many cases, there are no such markets. So there may be no good way for the price system to register information and expectations about the future, and economic activity may be distorted. Part of the remedy may be the encouragement of forward pricing of natural resource products.

Finally, I would carry this train of thought a little further. Even if there were future markets, they cannot function more accurately than the information brought to them. But individuals, even interested and expert individuals, cannot see terribly far, and they may see inaccurately. Moreover, since there are not so many of them, they may get involved in trying to outguess each other and to fake each other out. This might be a good spot for some "indicative planning." The phrase usually stands for something that is not quite planning, and certainly not laissez faire. The notion is to give participants in the market, and independent experts, and Government officials an opportunity to compare expectations and intentions. Out of the process may come some correction of mutually inconsistent expectations, and perhaps a logically coherent set of expectations that can guide people involved in the resource business in making their own decisions. I would only add that since I share Adam Smith's lack of confidence that the public interest gets a fair shake in such conclaves of insiders, I suggest that the proceedings be taped and the tapes handed over to Judge Sirica, and maybe to all of us.

You will notice that I haven't said how long I think economic growth can go on at or near the present rate of 4 percent per year. That is because I don't know. And what is more, I don't feel the urgency of knowing now how long that can happen since it can quite clearly happen essentially as far ahead as one can sensibly look.

I realize that I haven't said anything about population growth and I want simply to say a word. There is very little to be said in favor of continued population growth in the United States or in the world. Recent data suggest that current fertility habits in the United States, at least, are such as eventually to lead to a stationary population. I can only think that that is a good thing. The single most important aspect of population policy in the United States and in the world, for that matter, is to make sure that people's fertility and family decisions are in fact voluntary. The evidence, as I say, is that voluntary decisions in the United States now would lead to a stable population after a fairly long period of time during which the age distribution would level out. That I think is a good thing. And I don't see any argument amongst us on that.

I am not an expert on the social consequences of continued growth or toward a stationary society so I have not much to say to what my friend and neighbor, Jay Forrester, said about this. I would only point out that there are some social problems involved in a stationary population, too, such as a larger proportion of older people, consequently less rapid promotion, and that sort of thing.

Thank you. That is all I need to say now.

Representative REUSS. Thank you, Mr. Solow.

Mr. Ridker, please proceed.

STATEMENT OF DONALD G. RIDKER, DIRECTOR, POPULATION STUDIES, RESOURCES FOR THE FUTURE, INC., WASHINGTON, D.C.

Mr. RIDKER. In appreciation for this opportunity to testify before this subcommittee, I have kept my prepared statement as short as possible by focusing directly on the questions posed by Senator Proxmire in his letter of invitation. However, I am submitting for your consideration an article entitled "To Grow or Not To Grow: That's Not the Relevant Question"[3]—to be published in Science—which speaks to a number of related issues.

The first question asked was are there ultimate limits to economic growth imposed by resource exhaustion or environmental pressures?

First off, I think we have to assume that by economic growth we mean material economic growth, not growth in GNP or some other measure of economic output. Since the latter is a measure of the monetary value people place on what they produce and consume, and since it can change content over time, embodying more services and less material-intensive goods, there is no necessary physical limit on its growth. The relevant question is whether the demand for resources, space, and environmental carrying capacity can continue growing unchecked.

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[3] See article, beginning on p. 134.

If we rule out the possibility of importing materials and energy from outside the earth on an ever-increasing scale, of course material economic growth must ultimately stop. The second law of thermodynamics, the entropy law, makes this certain. Indeed, even a constant rate of economic activity cannot be maintained forever unless that level is within the limits imposed by the amount of solar energy man is able to tap. Scientific and technological advance can postpone and moderate the way this limit is reached but cannot repeal fundamental laws of nature. Ultimately, therefore, we will be forced to choose how we want material economic growth to cease, through the operation of natural forces or in a manner and at a time chosen by man.

The second question posed by the committee was: Are we rapidly approaching these limits at the present time? While no one can say for sure, the few bits and pieces of evidence that are available suggests that such ultimate limits are still sufficiently far away that for all practical purposes they can be ignored in setting policy today.

First, there are studies that attempt to project demand and supply into the future under alternative assumptions about growth in population and the economy and changes in tastes, technology, and institutions. One such study, "Limits to Growth," I want to set aside in this brief statement—although it is discussed in the article referred to above—it is too aggregated, too devoid of adjustment mechanisms, and it incorporates far too many pessimistic assumptions—about technological progress, future reserves of nonrenewable resources, the ability to control and absorb pollution, and the extent of population growth—for its numerical estimates to be taken seriously. This study, along with Professor Forrester's work on world dynamics, has been very important in forcing the world to face up to the fact that there are in fact limits to economic growth; but its estimates of the timing of the ultimate limits could easily be off by several centuries.

A second such study was undertaken by Resources for the Future for the President's Commission on Population Growth and the American Future. While limited in scope, since it concentrated mainly on the United States during the next 50 years, it did review in detail prospects for more than 20 resources and 14 pollutants. Its principal conclusion is that if some costs are paid and some adjustments made, no catastrophe is likely solely as a result of continued population and economic growth during the next half century.

It is true that if we project out in a mechanical fashion, demand for some resources can be observed to grow faster than supply at current prices and pollution levels could grow even more rapidly than demand. But in each case where a problem was identified, solutions to these problems can also be identified without assuming any dramatic technological breakthroughs or revolutionary changes in institutions. Substitutions on the demand or supply side could easily close the gap between demand and supply without serious loss of welfare; and so far as pollution is concerned, feasible changes in policy were found to be adequate not just to keep pollution levels from rising but to reduce them below current levels. This is not to say that the United States will not be faced with severe problems during the next half century, but only that these problems will not occur solely as a consequence of material economic growth.

Nor is it to say that growth will make our resource and environmental problems easier; the longer growth continues the more dependent we become on continued advances in technology and increasingly complex organizational arrangements and the more vulnerable we become to breakdowns in these arrangements, in international trade or to changes in weather patterns. But if we feel the benefits are worth it, we can cope with these problems at least during the next half century or so. Beyond this time period, we cannot say. We do not know what disasters may befall mankind or the extent to which technological innovations like fusion may come along not just to solve these problems but to make a quantum jump in human welfare.

A second way to study this issue of ultimate limits is to inquire into the physical content of the Earth. Several papers presented at a recent United Nations symposium on population, resources, and the environment did so and reached the conclusion that sheer physical magnitudes of resources, space, and environmental carrying capacity are not limiting factors at this stage in human history; other factors, mostly manmade, are imposing more immediate limits on growth that are far more important and serious.

A third way to assess this issue is to inquire into the reasons for the abundance of shortages that appear to have befallen us in the last couple years. While subject to different interpretations, most specialists seem to think that these shortages arise from the worldwide economic boon conditions of the past few years, which has raised demands for meat, timber products, energy and other materials more rapidly than capacity can catch up, plus a series of special disruptions on the supply side, all of which have come at once and none of which are necessarily permanent in the sense of the ultimate limits.

None of this is meant to suggest that we are not faced with serious problems that will in fact limit our economic growth. It merely says that sheer physical availability of minerals, energy, air and water is not the problem. It is unfortunate that the discussion of limits has focused on these ultimate limits, diverting our attention from more proximate and serious challenges to continued prosperity and growth, challenges inherent in conflicts of interest and in the organizational arrangements meant to accommodate these conflicts.

The third question posed has to do with the price system. To what extent can we rely on the price system to discourage the use of scarce resources and to encourage the development of substitutes? To what extent should the price system be supplemented by specific government policies that directly attack shortages, pollution and technological problems?

If prices rise, we can count on consumers and industrial users to economize and find substitutes. Indeed, some of our current problems are present just because prices have been set at inappropriate levels, in some cases too low to discourage wasteful use and in others too high to encourage use of more plentiful alternatives. But we should not conclude from this that the Government should refrain from intervening to affect prices or that the price mechanism does not have to be supplemented by other more direct interventions.

First, if the price rise is very rapid, the shortrun adjustments that occur could result in serious hardships. It takes time for an old car to wear out, for industry to meet the new demand for fuel-saving cars, for commuting habits and places of residence and work to change. One might want to impose rationing or more system of subsidies for special groups for an interim period that could last for a couple years in order to ensure that the hardship is spread equitably.

Second, the Government should intervene in any case where the price is unlikely to be set appropriately through the actions of the private economy. Unfortunately, in the world today, this case is very common. The private economy is hardly one that can be characterized by many small sellers and buyers none of whom can by themselves affect the price. Nor is it one where there is sufficient information in the hands of sellers and buyers to permit them to make rational choices about the future. Common property resources like air and the waste absorption capacity of the environment are not even priced, in effect meaning that users treat them as having a zero price. And myopia and the absence of long term futures markets lead us to ignore the costs we are imposing on future generations. In all such cases it would be appropriate for the Government to intervene to set the price at a more appropriate level than it would be set by the private market economy. Of course, it is often extremely difficult to determine what the appropriate price should be, and public authorities are subject to influence by special interests. But we should not fool ourselves into believing that because of these problems the private economy can always do better. In many cases, the choice comes down to who is going to rig the price, a special group of producers or sellers who have no responsibility to the general public or a representative body that is at least supposed to have such responsibility.

But finally, even if all prices were set correctly by the Government or by competitive markets there would remain a number of things for the Government to do by more direct means. While many technological innovations can be induced by changes in prices—for example, by making it profitable to develop a recyling technology—it is difficult to imagine that the appropriate level and direction of basic scientific research and extremely expensive technological innovations such as are needed in the energy field could be accomplished this way. Few firms have the money to invest and many of those that do are locked into existing technologies which could become obsolete as a consequence of new developments. Moreover, the blatantly unequal distribution of income, wealth, and power both within and between countries, cannot be overcome by setting prices that are appropriate so far as scarcity is concerned. Here again, more direct means must be used if resources are to be allocated properly.

In the end there is no alternative but to apply a mixed strategy, one that includes taxes and effluent charges to supplement the operation of the private economy, more direct regulations and controls to supplement the price mechanism and institutional and organizational changes to alter market power and structure. There are no certainties in this area; nor are there any panaceas.

Thank you.

Representative REUSS. Thank you, Mr. Ridker.

[The article referred to in Mr. Ridker's statement follows:]

[Article from Science, vol. 182, No. 4119, Dec. 28, 1973]

To Grow or Not To Grow : That's Not the Relevant Question

(By Ronald G. Ridker*)

It is fashionable these days to assert that there are two points of view on the question, "Must we limit economic growth?" (*1*). On the one side is the pro-growth, or business-as-usual, school, which centers around the implicit belief—stated more in actions than in words—that, as a social goal, material economic growth should take precedence over equity in the distribution of income, wealth, and privilege and over concerns about the social and environmental costs of growth. At the other extreme is the no-growth, or scrap-the-system, school, which at times comes close to assuming that these problems will all disappear if only growth disappears.

I believe that both viewpoints are wrong—indeed, that they border on the irresponsible. There can be no doubt that the fruits of economic growth will make the resolution of the social and environmental problems we face much easier to solve. That fact makes it irresponsible to argue for zero economic growth in a world still dominated by poverty. It is equally irresponsible, however, to use this fact as a rationale for the continual postponement of efforts to resolve basic social problems, both domestic and international. The relevant question is not whether to grow or not to grow, but how to channel and redirect economic output, and whatever increases in it come along, in ways that will make it better serve humanity's needs. If this is done, it is quite likely that growth will in fact be restrained. That is as it should be. But such reductions will be far less than the reductions that would be needed to solve the same problems through attacks on growth per se.

What about those persons who remind us that the earth is finite, that if growth continues we will eventually run out of resources and environmental carrying capacity? Should we not stop growth in the consumption of materials and energy before that day comes? Are not these problems so serious that any attempt to correct them, short of stopping all material economic growth, can only be considered a palliative?

If we rule out the possibility if importing materials and energy from outside the earth on an ever-increasing scale, this argument must ultimately be correct. The second law of thermodynamics, the entropy law, makes this certain. Indeed, this same law makes it certain that even a constant rate of economic activity cannot be maintained forever, unless that level of activity is sufficiently low to permit mankind to live within the limits imposed by the flow of solar energy he is able to tap (*2*). Technological breakthroughs may make it appear to be possible to continue growth forever. But this illusion arises from man's myopia. No amount of scientific knowledge can repeal the laws of nature; they can only postpone their consequences. No matter how closely we approach it, there is not such thing as a perpetual motion machine (*3*).

But knowledge that growth must eventually cease is of no practical significance by itself. The relevant question is *when?* It makes an enormous difference for policy today whether the "we" who must limit growth is mankind alive today or some far-off, future generation. Will the law of entropy catch up with us in 100, 1000, or 100,000 years?

One recent study, *The Limits to Growth* (*4*), claims that the relevant limit is more like 100 than 1,000 or more years. Indeed, it purports to demonstrate that the only way to avoid cataclysmic increases in worldwide death rates within the next 100 years is to stop all population and material economic growth throughout the world during the next two decades or so. But on at least three counts I find this demonstration to be completely unconvincing.

First, the model used in *Limits* contains few of the important adjustment mechanisms that have helped the world avoid similar catastrophies to date. There is no price mechanism to signal pending shortages, to make it profitable

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to invest more in exploration and research, or to induce consumers to reduce their consumption and shift to substitutes. There is no government to monitor the situation and to supplement the price mechanism where it does not provide adequate signals. Nor does anyone learn from the experience of others and change his behavior accordingly. As the World Bank Task Force that reviewed *Limits* says:

"Can we really believe that most of the population of Detroit could succumb to persistent pollutants without the rest of humanity making any adjustments in its producer-consumer behavior? Humanity faces these problems one by one, every year in every era, and keeps making its quiet adjustments. It does not keep accumulating them indefinitely till they make catastrophe inevitable. One does not have to believe in the invisible hand to subscribe to such a view of society. One has merely to believe in human sanity and its instinct for self-preservation (5, p. 15)."

Closely related are the problems arising because of the extreme degree of aggregation incorporated in the model. There is only one composite industrial output, one nonrenewable resource, one "pollutant," and one geographic unit—the world as a whole. Not only does such a formulation greatly reduce the confidence one can have in the postulated relationships between the aggregates, it seriously compounds the problems arising from inadequate adjustment mechanisms. Consumers cannot substitute one output for another; producers cannot substitute one resource for another; society cannot alter the composiion of output—for example, deciding to spend less on military and more on research, development, and exploraton. Since the model does not allow for these possibilities, there is really no alternative to reductions in population and economic growth.

Third, the study incorporates highly pessimistic assumptions about technological progress, future reserves of nonrenewable resources, the ability to control and absorb pollution, and the extent of population growth that is likely in the next two centuries. In addition to leaving out the possibilities of technological breakthroughs such as fusion and solar energy—the omission of which may make sense in a 50-year projection, but not beyond that—the use of shale oil, tar sands, and geothermal sources of energy were ignored. The authors allow for the possibility that reserves of their aggregate resources could increase five times over the next 100 years, a seemingly generous allowance until one recalls that estimates of iron ore reserves increased about five times just between 1954 and 1965, and estimates for copper reserves by 3.5 times since 1935, according to the U.S. Bureau of Mines. Moreover, promising underwater sources of minerals are ignored: in reviewing the possibility of such sources, the World Bank finds that within the next 20 years it should be possible to recover on a commercial basis 100 million tons of nodular materials from the seabed each year and that such recovery could be increased and sustained "indefinitely" at the level of 400 million tons. The smaller of these figures "would add to the annual production of copper, nickel, manganese, and cobalt to the extent of roughly one-fourth, 2 times, 6 times, and 12 times, respectively, compared to the current free-world production levels" (*5*, pp. 7–8). One need not concur entirely with this judgment in order to assert that this possibiliy should not be ignored.

As far as pollution is concerned, there is no scientific evidence for the functional relationships assumed in the model: for the amount of pollution that can be safely absorbed by the earth's environments, for the effect of pollution on birth and death rates, or for the degree to which treatment and changes in processes can reduce emissions of pollutants per unit of output. And as far as population growth is concerned, the historical relationships between birth and death rates and the level of development cannot blithely be projected into the future. Public health and family planning programs, the availability of modern contraceptives and the spread of knowledge about them, plus changing attitudes toward marriage and sex are all operating to weaken the historic linkages. Indeed, recent census data (not available at the time *Limits* was written) suggest that a slowdown in population growth may have already started in more than half of the 70 or so countries for which data are available.

Contrary to what *Limits* says (*6*), all these factors can make a significant difference in our estimate of when and how growth must stop. First, a correction of the overly pessimistic assumptions could result in a postponement, by several centuries, of the date at which growth must stop, even without introducing additional adjustment mechanisms (*7*). Second, as that limit is approached, all kinds of adjustment mechanisms will come into play to slow down and elongate the decline. Indeed, the whole idea of talking about a specific "date" is wrong. The adjustments are continuous and occur without benefit of any social knowledge that some limit is being approached. Assuming we avoid nuclear war, the world will surely end "not with a bang, but with a whimper."

There is one other study that sheds at least some light on this question of limits. This is the study undertaken by Resources for the Future for the Commission on Population Growth and the American Future (*8*). Concentrating mainly on the United States and only on the next 50 years, it reviews the prospects for more than 20 resources and 14 pollutants and can be interpreted as saying that, if some costs are paid and some adjustments made, no catastrophe is likely to result from continued growth during the next half-century. Indeed, at least as far as the United States is concerned, the results are fairly sanguine. We appear to have the resources and the know-how both to continue growing and to cope with the problems of that growth, if we are willing to adjust our lifestyles a bit. This is not to say that there will be no serious shortages during the next 50 years, but that these shortages are unlikely to arise solely as a consequence of population and economic growth.

These conclusions can be usefully illustrated with reference to energy and pollution, two areas of concern in which many believe we already have serious problems. The so-called energy crisis confronting the United States during the next 10 to 20 years is certainly not a result of a worldwide shortage of energy, nor even the result of an overall domestic shortage of energy sources, given our immense reserves of coal and nuclear materials. Rather, it is better described as a crisis arising from inappropriate policies, compounded by what has been described as "the transitional problems of absorbing environmentalism into the set of shared public values" (*9*). Domestic gas prices have been too low to encourage significant exploration. Oil prices have probably also been too low, but in addition there has been inadequate federal leasing and a failure to couple tax privileges with incentives for additional drilling. Research and development efforts in all areas other than nuclear energy—in particular, coal gasification, shale oil, and solar energy—have been totally inadequate. These factors, coupled with environmental restrictions on the use of high sulfur coal and restraints on the construction of nuclear power plants, have put an excessive burden on oil, leading to rapid increases in imports. The rising demand for imports, in turn, forces us to view with concern the recent successes that the Organization of Petroleum Exporting Countries has had in demanding higher prices.

But given the policy options available to us, these problems need not be long-lasting. During the next 30 years they can be met by moderately reduced demand, brought about by increased prices (*10*), increased use of coal, the development of adequate nuclear power capacity, and expanded imports of oil. Beyond this period, if not before, coal gasification, shale oil, the breeder reactor, and geothermal sources are likely to become available, reducing our dependence on imports. Undoubtedly, social and institutional changes (such as mass transit and apartment complexes permitting significant savings in energy consumption) or fusion, or solar energy, or some combination of these will also come along, or can certainly be made to come along if needed (*11*). Thus, while problems abound, so do solutions short of stopping economic growth—if we are willing to push for them.

The case of pollution is especially interesting because it can be used to illustrate graphically the degree of flexibility present in the socioeconomic system. Figure 1 presents a summary (*12*). The bars labeled A indicate the amounts of various pollutants that were generated in 1970 and those that would be generated in the year 2000 under different assumptions about population and economic growth rates, but assuming no significant changes in technology (*13*). The bar labeled B in 1970 indicates the amount of the pollutant actually emitted, the difference between A and B reflecting the extent to which control and treatment were exercised in that year. For the year 2000, these bars indicate what is likely to occur as a result of probable changes in technology, without any change in pollution controls and treatment. In contrast, the bars labeled C indicate what would result if the standards being recommended by the Environmental Protection Agency for implementation in 1976 were applied in the year 2000.

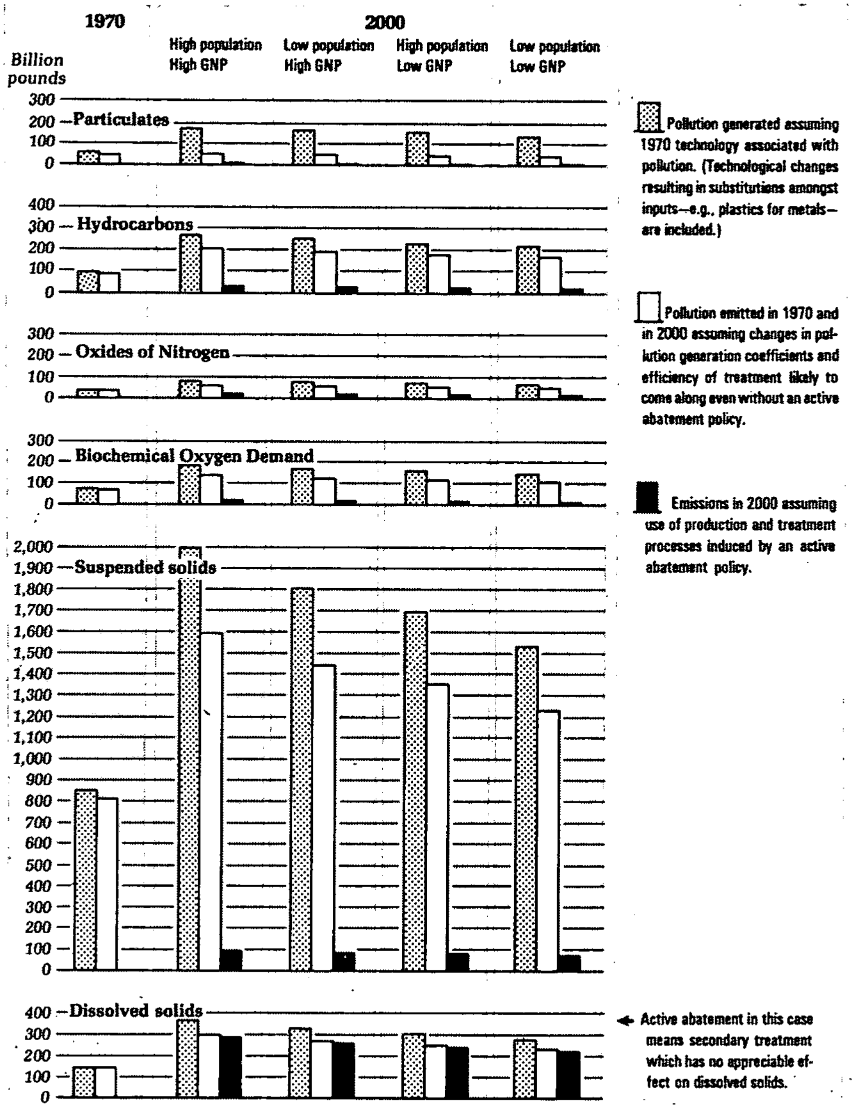

Fig. 1. Pollution generated and emitted under alternative assumptions (12).

The annualized cost of pollution treatment and control in 1970 was $8.5 billion (in 1967 dollars), approximately 1 percent of the gross national product (GNP) in that year. To achieve reductions of the kind envisioned, I estimate that this figure would have to grow to between $33.6 billion and $47.5 billion (for the low population and high population growth cases, high economic growth in both cases) by the year 2000. As large as these figures are, they still amount to less than 2 percent of GNP in that year. To put it differently, we would have to give up less than one-tenth of 1 percent in annual growth of GNP to make room for these expenditures: that is, instead of growing at 4 percent per year, GNP exclusive of these expenditures would grow at something over 3.9 percent per year. Within this time frame, therefore, direct attacks on pollution clearly dominate over restrictions on population and economic growth as means of reducing emissions.

Indeed, for most of the problems associated with economic growth, direct attacks are probably better than indirect ones. To assert otherwise is a bit like junking the family car because the tires have worn out or reducing a boy's food consumption because the sweets are giving him acne. Why use a meat ax when a scapel will do better?

There are two important exceptions to this general principle. First, in the interest of humanity and world peace, it makes sense for the richer countries of the world to tax themselves and transfer the proceeds to the poorer countries. But this is not the same thing as saying that worldwide economic growth should be restricted. Obviously, if worldwide economic growth did stop, the chances of bringing about such a transfer would be far lower than they are today. Second, some of the costs of growth—particularly those outside the resource and environmental fields—may not be amenable to a direct attack. How can the regulations needed to control the negative slipcovers of growth, the hecticness of modern life, and the superficiality of personal relationships that growth seems to generate, be controlled without reducing growth itself? It seems to me that the advocates of no-growth would have a better case if they were to focus their attack on these consequences of growth rather than on the resource and environmental consequences, which, in very large measure, can be managed by other means.

Of course, direct attacks on the resource and environmental consequences of growth will themselves reduce the growth rate, thereby helping to reduce the more general and pervasive costs of growth. If these latter costs are not then reduced sufficiently for our taste, then let us agree to restrict our economic growth by a larger amount. Over time, as we learn more about the earth's reserves and what is technologically possible, and as our tastes and preferences change, the situation will require reassessment. By proceeding in this step-by-step fashion, we will do ourselves and future generations less harm than by applying generalized, meat-ax approaches.

The study by Resources for the Future is quite limited, however. What about problems lying beyond the next 50 years; and what about the environmental threats the study was not able to quantify and analyze in detail? These are areas where ignorance dominates. Should we not, in effect, stop the ship, or at least slow it down, until we know more about what lies ahead in the fog?

It is true that we do not know what kinds of disasters we may be letting ourselves in for by permitting economic growth to continue. But it should be remembered that we are also ignorant of possible technological and institutional breakthroughs that may eventually come along, breakthroughs that might not only save future generations from disaster but make them substantially better off than the current generation. In light of this total ignorance about both positive and negative developments that may occur, what is the prudent course? It is not obvious that the prudent course is to save resources for future generations, at least not obvious to any but the most affluent on this earth.

The analogy of stopping the ship until one knows what lies ahead in the fog is an interesting one, conjuring up a picture of passengers sitting comfortably in their staterooms waiting for the fog to lift. It is a rich man's image. The poorer two-thirds of the world's population cannot wait, particularly when it is not clear that future generations will be worse off than people today. If the poor are to wait, the prudent course would be to share the stateroom—that is, the available resources—with them.

These conclusions follow only if we do take advantage of the opportunities available to attack directly the problems associated with growth. If political and institutional constraints make it impossible to apply direct measures forcefully, we are likely, as the figure for pollution indicates, to be faced with an accumulation of very serious problems; in that situation, reductions in economic as well as population growth begin to make more sense. Those who advocate reductions in growth may believe that we will not apply such direct measures with sufficient force. I believe they can be proved wrong. But to do so will require stepping outside the intellectual constraints of the debate over growth and no-growth. As I indicated at the outset, proponents of growth tend to argue that solutions to the world's social and environmental problems should be postponed because economic growth will make them easier to solve, while the proponents of no-growth sometimes appear to argue the reverse, that no-growth will solve our problems or somehow make them easier to solve. Both schools, it seems to me, are cop-outs. What we must do is get on with the solution to the problems that obviously and directly face us. And the sooner the better.

REFERENCES AND NOTES

(*1*) I wish to set aside at the outset the question of population growth, which almost everyone agrees must sooner or later be limited. I also set aside the question of whether growth in GNP must also be limited. The GNP is simply a measure of the monetary value that individuals place on final goods and services produced and sold in the market. It is not a physical measure like tons or ergs, but an artifact that changes character and content as people change their notions of what is valuable and what they want to produce and consume. If one allows for the fact that the composition of GNP is not fixed, that services and goods with reduced material content may replace material-intensive commodities, there is no reason that GNP must someday cease to grow. The relevant question is whether the demand for, and use of, resources, space, and environmental carrying capacity can continue to grow unchecked. It is this material content of economic growth on which I focus.

(*2*) The qualification is important, for the amount of solar energy received by Earth is enormous compared to terrestrial stocks of energy. Indeed, the entire terrestrial stock of energy is estimated to be equal to only 4 days of sunlight. In principle, solar energy would permit man to live for another 5 billion years (the remaining estimated active life of the sun) at a reasonably high standard of living, provided population growth ceased during the next century or so. But as a practical matter, with the technologies and ways of life imaginable throughout the world in the foreseeable future, this indefinitely sustainable standard of living is probably significantly below the level at which most of humanity exists today. A fascinating discussion of these issues can be found in N. Georgescu-Roegen, *The Entropy Law and the Economic Process* (Harvard Univ. Press, Cambridge, Mass., 1971). The estimates in this footnote came from the references in an article by him in *Ecologist* 2, 13 (July 1972).

(*3*) Another often-mentioned reason growth must eventually stop is environmental deterioration. In the last analysis, however, everything boils down to the availability of energy in useful forms, for with energy man can treat, move, or protect himself from pollution and environmental deterioration. Even space can be increased with sufficient energy—by building upward and outward. A limitation on the use of energy could be the buildup of waste heat, but this depends on the source of energy and the efficiency with which it is utilized. To the extent that reliance is placed on geothermal heat and energy from the sun, a serious buildup of heat is not so certain.

(*4*) D. H. Meadows, D. L. Meadows, J. Randers, W. W. Behrens III, *The Limits to Growth* (Universe, New York, 1972).

(*5*) International Bank for Reconstruction and Development, "Report on *The Limits to Growth*," a study of a special task force of the World Bank, mimeographed, Washington, D.C., September 1972.

(*6*) For example: "Our attempts to use even the most optimistic estimates of the benefits of technology in the model did not prevent the ultimate decline of population and industry, and in fact *did not in any case postpone the collapse beyond the year 2100* [italics added]" (4, p. 145). The same point is made about the efficacy of voluntary birth control and more optimistic assumptions about reserves of resources and ability to control pollution.

(*7*) This is easily demonstrated by running the model with different, but equally plausible, assumptions. For example, see R. Boyd [*Scicne* 177, 516 (1972)], who demonstrates this on the Forester model.

(*8*) U.S. Commission on Population Growth and the American Future, *Population, Resources, and the Environment*, R. G. Ridker, Ed. (Government Printing Office, Washington, D.C. 1972), vol. 3.

(*9*) J. R. Schlesinger, "Energy, the environment, and society," speech before the Atomic Energy Commission Conference Board, New York, 19 April 1972.

(*10*) K. Watt's statistical analysis indicates that the price of gasoline is a more important determinant of per capita consumption in cities than is use of mass transit, density, or size. While the implied price elasticity of demand is surprisingly high and may not reflect what would occur in practice, this finding is very promising and warrants careful consideration [K. Watt, lecture presented at the AAAS annual meeting, 28 December 1972].

(*11*) On the possibilities of restraining demand, particularly in the short run, see J. Darmstadter, "Energy options: limiting demand," remarks prepared for the Upper Midwest Council Conference on the outlook for energy, Minneapolis, Minnesota, December 1972 (mimeographed copies available from Resources for the Future, Washington, D.C.)

(*12*) Prepared from table 8 (*8*, p. 48).
(*13*) The high population growth rate assumes a three-child family, the low a two-child family. The high economic growth rate assumes a decline in weekly working hours from an equivalent of 40 hours at present to 37 hours in 2000, whereas the low would bring the figure down to 29 hours.

Representative REUSS. Mr. Forrester, I would like to explore a bit more with you your position that we should not even try to overcome the physical barriers to growth, such as resource exhaustion, because the social and psychological consequences of too much growth would be even worse than letting growth be halted by technological limits.

I don't know whether that is a fair statement of your thesis. It is intended to be fair. Feel free to correct it. But at any rate, it would be helpful if you could give us some examples of what you have in mind.

You said something about resources which have definite physical limitations. Is it your point that, there being only one Grand Canyon and one Niagara Falls, it wouldn't be a good thing to knock ourselves out trying to find higher standards of living and better means of transportation so that every vacationer or honeymooner, as the case may be, may try to visit one of those places, because there being only one of them and the line forming to the right, it would just get too crowded, so you had better not have a line of infuriated honeymooners who haven't been able to see any Niagara Falls or what? I need some help.

Mr. FORRESTER. I agree with the thread that ran through your comments. I don't think the country is likely to take the extreme position of doing nothing about more energy. I wouldn't recommend no action in the areas of energy, resources, and pollution control.

But I think it is very important to present the case on the other side—the case against trying to create the impression that we can solve our social problems by pushing back the material limits. The tradeoff between social and physical limits will be a difficult case to bring to people's attention. Physical limits, if allowed to operate, can help slow growth before growth intensifies social stresses beyond the tolerable level. We need to make the case as strongly as we can for the advantages of using physical limits to share the burden of slowing growth. Otherwise, a balanced view of how solving the present growth-limiting stresses will intensify future growth-limiting stresses will be overlooked in the mad dash to solve the looming material limits. My main point is that to the extent we either do solve material limits or merely create the impression that we can, we tend to take the emphasis off the fundamental growth process that is generating social stresses. As long as the growth process goes on, the mechanisms for intensifying the stresses goes on, and we walk deeper and deeper into the trap of letting population rise above the level that can be sustained at a desirable quality of life.

We should seriously think about distributing the pressures and intentionally leaving some of them in the material area. More important than anything else, we should focus on the fundamental tradeoff between population and the environmental capacity of the country.

We are living well beyond our means now in terms of imported energy and imported resources. I believe the movement toward one world, the movement toward depending on international trade, will swing back. We are almost at the end of this pendulum swing because other countries are going to see it in their best interests to use resources for their own production, with their own labor, for their own consumption.

The United States is not in a good position to continue in its present way of life from within its own borders. But the country will come under greater and greater pressure to live within its internal capacity.

The social pressures and limits are very closely coupled to the physical and material limits. Mr. Ridker put this very well when he said we had no choice really but a mixed strategy. He mentioned Government intervention in prices, which is another way of saying that growth and the overloading of the physical environment is forcing us to take more and more drastic action from the political side with more and more reduction of freedom. We are at the point where we face choices between growth and freedom. As growth continues, it becomes necessary to restrict freedom and we move into a more and more tightly constraining psychological and political framework. Reduced freedom is one of the prices we pay as we avoid facing the underlying issue of expanding population.

The most fundamental long-term legislative challenge involved here is to look through the entire constitutional and legal structure of the country to see the extent to which it is loaded with positive incentives to increase population. Any such governmental pressures to encourage growth should be reversed.

As Mr. Solow said, we have seen a decline in birth rate but we are still facing another 70-percent increase in population at the same time that we can expect a reduction in the available outside resources and energy that we can import. So we have difficult times ahead. We would want to stay with voluntary population limits rather than governmentally imposed limits. But now we have a situation in which there is voluntary restraint in the face of various positive governmental forces to increase population. I am suggesting that we ought to remove the legal, tax, and social-program forces for increase of population, and reverse them to negative forces. Coupled with the other social processes that are going on, such changes in laws would bring population more quickly to a lower level than it would otherwise reach. If we don't do this, I think we will move toward the situation that Britain is finding itself in. England is past its period of excessive growth and is falling back toward a sustainable level. It is a good place to look at the social pressures that come from past overextension beyond one's environmental capacity.

Industrial societies have overstepped their place in the world. I believe we will see that Japan, Western Europe, and the United States will come under increasing pressures that will make it very difficult for them to accumulate the capital to sustain the kind of high-capital-intensity expansion that has characterized the past.

So we have a set of pressures that are tightly coupled and come in on us from every angle. We cannot solve the present problems by simply addressing ourselves to pressures in one sector.

Representative REUSS. Pressures in one sector, what, resource scarcity?

Mr. FORRESTER. Yes, the current efforts to solve energy and resource problems are not going to solve the long-term social problems.

Representative REUSS. I am going to pass this thesis on to your two colleagues on the panel in a minute, but I want to ask one more question about it.

Do you distinguish between two kinds of scarce resources? One, resources which while scarce, if one put one's mind on it could perhaps be made available and hence growth kept going somehow or other, and, two, resources which really are scarce; that is, great natural vistas in the United States, Grand Canyon, Niagara Falls; land anywhere, as in Europe, where things are getting pretty full; and materials which we have to swipe from the rest of the world. Somehow or other, I gather you are suggesting the terms of trade are going to go worse for us and there are special limits on those imported materials.

Are those the irreducibles that cause you to say maybe we shouldn't be so desperate to keep growth going because what shall it profit us to have growth if it simply makes everyone desperate because they then line up and can't get the amenities that they think they want?

Mr. FORRESTER. I made no specific mention of vistas or Niagara Falls or——

Representative REUSS. I know that.

Mr. FORRESTER [continuing]. The Grand Canyon. But in the spirit of your comment, I did say that political and psychological space are extremely important.

I was thinking more of the stresses in our urban environment from high population density. Particularly, I was thinking of the way in which we have shifted about a third of our population into tax-supported employment, very largely as a result of an effort to cope with various kinds of frictions that occur in a society that is becoming crowded.

A massive part of our working population is devoted to arbitration of the pressures from a crowded society. We have not only the employment in government, but also a very large counterpart in the private sector. We have regulators and those resisting regulation. We have pulled almost two-thirds of our working population out of agriculture and direct production. A major part of the present inflation probably comes from the material shortages that result from a reallocation of people out of direct production and into administrative activities that have been triggered by this filling up of psychological space. We have a very large social phenomena on our hands that ties back to pollution and shortages of space, water, and energy.

The stresses impinging on society have generated such phrases as "future shock," from the book by Toffler. The set of stresses such a term embodies are a consequence of the growth process and will intensify until we come to terms with the underlying issue of where growth is leading.

Representative REUSS. Just one final question before I get the comment of the other two members of the panel.

Where does all of this leave us on unemployment? I have suggested it increases unemployment and you must have some way of addressing yourself to that.

Mr. FORRESTER. I think the people who are concerned about unemployment arising from a move into equilibrium are completely correct in their facts and we all should be alarmed. I think, though, that the issue cannot be avoided. The longer we go down this road of pushing, growth, the more difficult the inescapable transition becomes. It is not an issue that can for very long be laid aside and buried under the carpet. It is, however, an issue of tremendous gravity. If you look around the country and ask yourself what percentage of the working population is involved in producing growth or coping with the difficulties induced by growth, you will find that is an alarmingly high number, perhaps 30 percent. In this category of activity needed only for growth is a large part of the education establishment, a substantial part of the financial institutions, and perhaps 20 to 30 percent of the white-collar group in corporations.

Unemployment can be a very substantial problem. But the issue cannot be long avoided by pushing more growth. Although the future may be difficult, many choices and alternatives do lie ahead.

It may turn out that the energy shortage and the unemployment problem will somewhat compensate. Labor may be used in a more intensive way. The move toward high capital-intensive production may be ending and the move back toward a more labor-intensive production should be considered. I am told that our supposedly efficient agricultural sector in fact uses five or six times as much energy in petroleum as it produces in food. So we have an agricultural sector that is very inefficient as a converter of petroleum into food. This is by comparison to agriculture in other parts of the world which converts manpower into food in a highly efficient way.

Major changes lie ahead. Many questions need answering. We should not depend on past trends. We should not assume that the way things have been going in the past are indicators of how they will go in the future. The whole of mix of manpower, capital, energy, and space is changing. A new way of life lies ahead and we should be doing more than we are toward exploring and arguing the issues as we are doing here this morning.

So far the discussions about growth have been relatively superficial. We can hope that over the next decade they become more penetrating and that more people address themselves in depth to the issues you are raising this morning.

Representative REUSS. All right, I now want to turn to the other two panelists to express their agreement, disagreement, or otherwise comment on Mr. Forrester's thesis.

Mr. Ridker.

Mr. RIDKER. Well, I think it would be useful to start with something Bob Solow mentioned. He said that the future is uncertain, that we do not know what it has in store. This needs emphasis. We do not know what disasters we may be letting ourselves in for by permitting growth to continue; but we also do not know what technological breakthroughs may come along not just to offset those disasters but perhaps to usher in a new era of abundance. And he also said that we need——

Representative REUSS. Could you pull that mike in a little closer?

Mr. RIDKER [continuing]. A strategy rather than a special solution. Let me try to carry that just one step further, if I may.

I have at times tried to ask myself what is the prudent course to pursue when faced with this enormous ignorance and uncertainty about the future.

At first glance one could say the prudent course would be to slow down growth. An analogy could be used for this purpose, a ship going through a dense fog, not knowing what lies ahead. Would it not be better to stop the forward movement of that ship until we can determine what lies ahead; that is, until such time as scientists can say something more about the ecological disasters that some people claim lie ahead in the future if we continue in the way we have.

This picture of the situation is a very specialized one which in effect assumes that we are rich and can comfortably sit in the stateroom with a glass of beer waiting for the news to come in. Now, that may be true for certain groups in the United States and other affluent countries, but it is not true for the bulk of mankind who are more likely to feel a greater sense of urgency to proceed with the voyage toward this other shore despite the problems that may occur in the fog, because they lack drinking water and food, because for them the stateroom is not that comfortable.

In this sort of situation, what is the proper approach? I think there are only two things that we can do. One is to try to monitor the future, as best we can, and change and adapt our strategy as we get some more evidence on the way; and the other is to concentrate on rather direct attacks on whatever problems face us rather than worrying about what amounts to indirect attacks on those problems by trying to slow down the growth process.

It is true that we can reduce pressures on resources and on the environment by slowing down growth, but we can be far more effective in doing so by directly attacking the fundamental shortage or the pollution. It is true also that we can maintain an adequate level of employment by raising, by keeping growth up to a certain level, and that we might be able to do something about social stresses by either raising or lowering the growth rate until we get to that appropriate level, but again I think it would be wiser if we were to concentrate on fundamental reasons for these problems; that is, to directly attack the employment problem and the social stresses that we have in our system. To do otherwise, as I said in the article supplied for the record is a bit like asserting we should junk the family car because the tires have worn out or we should reduce the boy's food consumption because the sweets that he is eating are giving him acne. A direct approach, a direct attack on our problems is almost superior to one that attempts to alter the rate of growth.

Now, in the process of attacking such problems directly, growth will slow down somewhat, but probably by far less than would be necessary using an across-the-board approach. And to the extent that it does slow down in this fashion, that is as it should be. This is what I meant in the article by saying that the issue of growth or no growth is a side issue, that it is not the relevant problem.

Representative REUSS. So you do emphatically agree that growth for itself should not be a goal?

Mr. RIDKER. Yes.

Representative REUSS. Mr. Solow.

Mr. SOLOW. Well, sir; I feel a bit like the sailor in the Turkish harem: I hardly know where to begin.

I really cannot see the point of blaming everything up to and including the common cold on the fact that the real GNP tends to go up at about 4 percent a year.

In answer to your first question Jay Forrester got from the Grand Canyon to Great Britain, which is quite a long haul, and a very revealing one.

I think the British would be astounded to know that the problems that they have right now are problems that come from excessively rapid growth. I think most of them find their problems coming from something quite different. The British have gone from a standard of living well in excess of continental Europe to a situation where income per head in Britain is certainly less than that in Sweden and Switzerland and propably less than that in France and Western Germany and Britain, to cut it short, is just a beautiful example of the possibility of having social problems without economic growth.

I want to say a little bit about the Grand Canyon too.

In talking about natural resources it was worth distinguishing three classes, I suppose. First, are things like Niagara Falls and the Grand Canyon scenery items; second, exhaustible natural resources that one uses as inputs to production and ultimate consumption; and third, renewable natural resources like the fish in the ocean, forest, things of that sort.

In the case of the scenery or the unspoiled countryside, if such places are worth having, the fundamental problem surely is one of population and population density only. It has very little to do with what else happens in the economy. Very large population and very dense population can certainly crowd the land and make it unscenic and unattractive and even make things like the Grand Canyon unviewable and unenjoyable.

So one needs clear public action to preserve scenery and even sometimes to ration public land use, as in the case of campgrounds, for instance, which may otherwise get too crowded. But that is almost entirely a population matter and has very little to do with the rate at which one mines coal, drills for oil, extracts copper and aluminum from the Earth.

It is worth pointing out that even renewable resources can be overused and exhausted. The whale population of the world, I gather, is in danger of extinction from excessive whaling activity.

This is another case of the failure of the common property notion to provide proper economy of natural resources. But you are quite right to worry about the fixed items of scenery. They are very special. But I think the dangers to them is mainly a function of population growth.

I want to say a little bit about the international question, if I could. We do import natural resources, we also import tea, coffee, bananas, and innumerable other things. We also export a certain number of commodities, including resource commodities. What is of concern there or ought to be of concern to a person of conscience in this country is not whether we are taking Venezuelan oil and sending them "only" manufactured products in return; the question we ought to be concerned with is whether we are taking Venezuelan oil on inequitable terms, and that is quite a separate issue.

Leaving aside short-run political questions or even long-run political questions for that matter, which have no immediate causal connection with and the rate of increase in real GNP, a benevolent despot, if there were such a thing, in the Middle East ought to be asking himself how he can best use this resource for the benefit of his subjects, or compatriots. It is not clear that the best thing to do is to sit on the oil. In fact what is the best thing to do depends entirely on what is happening to the price of oil relative to the price of other things. Sitting on oil for the Sheikh or whoever, is an investment, just as surely as buying some other kinds or earning assets is an investment, and when sitting on the oil earns an adequate rate of return then the benevolent despot will sit on it in fact. If it doesn't the benevolent despot will do better to sell it and buy something that will earn a satisfactory rate of return for the people.

Now, we have been waiting for a long time for the terms of trade in the world to move in favor of primary producers. A large part of the world population would be a lot happier today if that prediction had come true 20 or 30 or 40 years ago when it was being made. It may yet happen. If it does happen, we ought not to complain. It will be for the benefit of parts of the world, not merely the oil parts of the world, that are very poor, and it would do us little harm if they got a better return for their primary products, including agricultural commodities. But it is not so certain that it will happen.

I am talking too long but I do want to respond to the question about unemployment that Congressman Reuss raised specifically.

There are at least two things to be said about it, that I can think of right now. One is that anything that happens suddenly to the economy is a problem. And if the pictures in "The Limits to Growth" were to come true and in the mere space of a couple of years the American economy or world economy were to hit some kind of ceiling and bounce off hard, then there would be a serious unemployment problem as there would be a serious unemployment problem if the country had to adjust to any very sudden change in its economic circumstances and in the direction of production in a short interval of time.

I discount that simply because I don't believe in those pictures in "The Limits to Growth." I see no reason at all to have any confidence at all in the likelihood of that scenario. Given a long, slow process, the unemployment problem is not fundamentally the serious one, sir. The slow process of adapting to physical or other limits to economic growth will presumably show itself as a reduction in the rate of increase of human productivity or even as a fall in the level of productivity. That would automatically lead to larger inputs of labor per unit of output than when productivity is high and rising in a world that is not feeling any serious physical constraints.

From this point of view, the economy needs an increase in real output sufficient to account for the population growth and the productivity increase, if there is not to be increasing unemployment, voluntary or involuntary. So presumably if at some time in the future the story begins to be true, we will feel it by seeing that productivity stops rising because we are running up against fundamental scarcities of something, presumably natural resources. The problem will present itself to us, I think, not so much as an unemployment problem, but as a problem of our standard of living. If we have grown used to a rising standard of living, we will find that it is not rising as fast as it used to, and we may find that uncomfortable. It may even level off.

One last thing. There is only one reason to continue economic growth in the United States or any place else and that is because we want the output, because we think that the things that get produced are worth having for ourselves and for the population of the world, and because we do not see any imminent or even incipient danger in continuing the growth. It has fundamentally nothing to do with employment or anything else. If we don't want the output we ought not have the growth.

I think Ronald Ridker is exactly right: Most of the world, including a very large fraction of our own population, would be amazed to think that there are people talking about saturation with goods and services.

Representative REUSS. You have just said that the reason for growth is because we want the goods that are produced by growth.

Do you accept the present method of determining how much goods people want?

Do you reject Mr. Galbraith's suggestion that a great deal of that is determined by people being motivated by advertising, to want annual model changes, frequent change in clothing styles, disposal items, paperplates, soft drinks in cans, plastic wrappings, other things, in some cases dictated by the Government, such as an SST almost, and so on.

Are you content to accept the current determinates of what people want as an index of what growth there should be? If you are, you are hooked, it seems to me.

Mr. SOLOW. Well, no, I don't think I am hooked.

Let me say two things there. First, there is undoubtedly a good deal of truth to the proposition that our tastes, everyone's tastes are in part in the hands of Madison Avenue, the advertising community, producers in fact, who try to convince us that we want whatever they would like to sell to us.

There clearly is an element of that and perhaps a large element.

There is a terribly important question about how big that element is. This is a situation in which it is not merely enough to say, yes, advertising has some effects, period.

A good deal of advertising is self-cancelling, so to speak. Individual sellers of beer advertise mostly because other sellers of beer are advertising. I think if all advertising of beer were to stop at once the total consumption of beer would not change very much.

Nevertheless, there is a clear residual effect of advertising and salesmanship and, like most educated middleclass people, I deplore it. But I am conscious of the fact that is sometimes merely a subtle way of saying how refined my tastes are and how crude other people's tastes are and I like to avoid that when I can.

As I look around, though, I honestly cannot say that for very large parts of the population, whose median family income is of the order of magnitude of $11,000 to $12,000 a year, I have to look for explanations as to why they want goods and services. Which particular goods and services they want may, of course, be influenced by producers.

One might look for some policies to limit misleading and wasteful advertising. But to suggest, merely because there is a lot of advertising, that the country is, in term of its true preferences, saturated with goods and services, that seems to me to be impossible to believe.

Representative REUSS. Well, a good debate has certainly been arranged and I don't know who laid down the left to right seating but it seems to me that Mr. Forrester is saying that growth can be harmful and steps should be taken to slow it down because if that isn't done it will produce social and psychological collisions. Mr. Ridker says that, no, he won't take steps to slow growth down but you don't really need growth, and he won't take steps to keep it going.

Mr. RIDKER. I would directly attack the problems we face and let growth go where it will.

Representative REUSS. Then I think Mr. Solow says let people's demands, however titillated by government advertising and other exogenous forces, determine how much goods will be produced and thus growth must continue. That at least is a nice set of positions for this committee to mull over and you have all been intensely helpful in presenting your point of view and we will have to think.

Let me ask Mr. Ridker a more immediate question.

In your testimony earlier, when you were addressing yourself to immediate steps that ought to be taken, in the short term, you mentioned rationing, presumably of petroleum supplies and any other scarce commodities, and then you used the phrase "and subsidies for special groups." You didn't elaborate on that but were you thinking of some sort of subsidies to the poor via a national income program, a negative income tax, which I am glad to read the President is thinking of reviving?

Would that be the sort of thing which you are thinking about? The poor after all do take it on the chin when the prices of food, of fuel, and interest rates go up.

Mr. RIDKER. Yes, I was. There are different was to ration equitably. The price system is one way of rationing, it forces people to purchase only what they can afford within their budgets and it will work equitably so long as the distribution of income is equitable. But if some people have more marbles than others, and we think that that is not the appropriate distribution of marbles, then they are going to be able to play the game to a larger extent than other people. But there is several ways of taking care of that.

One is through rationing where you give everyone an equal amount, perhaps with some exceptions for those who need their car in their job or for people who live in Los Angeles and can't use mass transit, and so on. But what I had in mind, and I admit it was spelled out far too lightly in the statement, was that if the rationing system being considered is one which would permit the transfer and sale of ration stamps, there is an administratively simple way to accomplish the same thing. That is to permit the price of petroleum to rise to whatever level it might go in order to close the gap between the demand and supply and then provide an across the board subsidy or tax credit through the income tax or social security route to everyone. It is possible to demonstrate that under certain circumstances that could have the same effect as a rationing system where you sell the rationing stamps and it would be cheaper to administer.

Representative REUSS. You would restrict that, though, to petroleum, you wouldn't recompense the working poor for the drastic increase in food prices and clothing prices and housing costs and medical costs, which I believe strike with a special vigor on the lower income groups?

Mr. RIDKER. No; I guess I would not restrict it only to the petroleum. The reason I had petroleum in mind was that to a large extent here is a case where the price has risen and is likely to rise very rapidly. It is the rapidity of the price rise that causes the bulk of the hardship given our unequal distribution of income. But on the broader issue I think we have to ask whether we accept the unequal distribution of income. That is a more fundamental question—and certainly the price rises make the problems associated with distribution worse.

If we do not accept the current distribution, some kind of a general tax credit or negative income tax, that the President seems to be favoring now, would be appropriate.

Representative REUSS. Mr. Solow.

Mr. SOLOW. May I comment on that?

On the very last question that you asked, sir, and that Mr. Ridker was discussing, I think one ought always to be looking carefully at the standard of living that our system of income transfers is permitting the very poorest people to attain. Whenever that standard of living suffers, gets below what seems like to tolerable minimum, one ought to step in and do something about it. Thus, for instance, Congress has quite correctly indexed the benefits under the social security system. One needs to reinspect such minimum-standard-of-living guarantees as ar e now written into the law when food prices rise sharply, as they have. Otherwise those standards of living are going to suffer particularly badly because, as you point out, very poor people spend a very large fraction of their income on food. I would go further and say that we should continually be revising those standards. That is almost independent of the immediate oil situation.

I would like to clarify something Mr. Ridker said. I think he may have uttered a misprint, if you can do such a thing.

I presume that he is comparing a rationing scheme not to letting the price increase just by itself, with some sort of rebate, but letting the price rise through an excise tax on gasoline.

Mr. RIDKER. Yes, sir.

Mr. SOLOW. If Congress were to levy an excise tax sufficient to restrict the demand to what is available, then Congress would be faced with the problem of what to do with the substantial revenues that would come in from such a scheme. This is not the time to legislate a general tax increase for fiscal policy purposes so the revenues would have to be rebated in whole or in part, and Mr. Ridker is entirely right that such a tax is mathematically equivalent to a coupon rationing system where the ration coupons are themselves transferrable. I should certainly think if the Congress were ever to go that route, that is, large excise tax on oil products, gasoline in particular, and rebate of the proceeds to the public, then this would be a time to look very carefully at the distributional implications, between rich and poor, of the particular policy enacted.

If this morning's Boston Globe, which is all the newspaper I have seen so far today, is right, then we have started down one of the worst methods of handling the situation. The administration seems to be proposing a simple price increase in oil products and gasoline plus what is misleadingly called an excess profits tax on oil producers, but is actually a very small graduated excise. I don't know whether to call this a silly or dangerous scheme.

It seems to me to be wrong to allow gasoline to be rationed solely by a simple price increase, because (a) the windfall profits will be tremendous, (b) the shortrun elasticity of supply of oil products is not very large, and (c) if we want to stimulate exploration we could do something aimed directly at exploration, and not just splash the oil companies with profits.

Representative REUSS. I agree with you except I think you are too charitable to Secretary Shultz and Mr. Nixon and the other perpetrators of this, or maybe it is the Boston Globe which didn't tell you all but as I understand——

Mr. SOLOW. If the Boston Globe knew all, it would tell all.

Representative REUSS. As I understand it, it isn't even an excess profits tax which is proposed really, though they use that nomenclature, it is an excise tax on the price increase on top of the price increase, so it seems to me everything you have said goes double.

On the excruciating problem which you indicated Congress may be faced with; namely, how to dispose of the billions of dollars which may turn up in the Treasury through one or another scheme, good or bad, under debate, I can speak only for myself. I shall face that challenge fearlessly when it comes, and I think most of my colleagues, will, too.

I have just about concluded, unless somebody has anything to add. I want to express our gratitude to each one of you for presenting a very fully reasoned point of view. Your statements are going to be of great help to us and I hope when you come back in a year or two you will find that some of it has sunk in.

Thank you all very much.

We will now stand in recess until tomórow morning at 10 o'clock in this place.

[Whereupon, at 11:35 a.m., the subcommittee recessed, to reconvene at 10 a.m., Friday, December 21, 1973.]

RESOURCE SCARCITY, ECONOMIC GROWTH, AND THE ENVIRONMENT

FRIDAY, DECEMBER 21, 1973

CONGRESS OF THE UNITED STATES,
SUBCOMMITTEE ON PRIORITIES AND
ECONOMY IN GOVERNMENT OF THE
JOINT ECONOMIC COMMITTEE,
Washington, D.C.

The subcommittee met, pursuant to recess, at 10 a.m., in room 1202, Dirksen Senate Office Building, Hon. William Proxmire (chairman of the subcommittee) presiding.

Present: Senator Proxmire.

Also present: Loughlin F. McHugh, senior economist; William A. Cox and Courtenay M. Slater, professional staff members; and Walter B. Laessig, minority counsel.

OPENING STATEMENT OF CHAIRMAN PROXMIRE

Chairman PROXMIRE. The subcommittee will come to order. This morning's session concludes for the present the subcommittee's hearings on "Resource Scarcity, Economic Growth, and the Environment." The issues raised yesterday and the day before have been so numerous, so thought-provoking, and so important that they have suggested many lines of inquiry which this committee should pursue in the future. In both the short and long run the effects of resource scarcity on our economic health and on the quality of our environment raise critical policy questions.

One of the questions which disturbs me most is the way in which we seem to let these shortages creep up on us. The Paley Commission examined the resource and materials outlook back in the early 1950's, concluding that serious shortages were in the offing. That is the early 1950's some 20 years ago.

A new National Commission on Materials Policy has just this year reexamined these questions of resource supply. Mr. James Boyd, who served as Executive Director of the Materials Commission, testified on Wednesday that he felt we currently faced shortages of sufficient severity that Federal allocation policies were needed for a number of materials, not just for petroleum. Yet, I am aware of little study or action on this question going on within the Government. Indeed, it is true that this is perhaps the last day of the session, and members are obviously very busy elsewhere and we have a number of very important bills about to be acted upon on the floor of the Senate and the House, and some important conferences are going on but, nevertheless, the fact that there is such little concentration on this long term problem is best evidenced by the fact that there are so few here this morning.

Our hearings generally have not been very widely reported or attended because there is an enormous amount of attention on the energy crisis. The people can see that in the price at the gas pump today and tomorrow and they can also see that in the unemployment and many other effects on their life right now but it is just very sad we cannot look forward with a little more wisdom to the impact of what is just around the corner.

Resource scarcity raises new threats for the environment. As part of the effort to cope with the current fuel shortage, environmental standards are being relaxed on several fronts. Certainly, we would like to get the reactions of our witness this morning to these recent developments.

We are privileged to have as our witness this morning, Mr. Russell Peterson a native, as I understand it, of Wisconsin, I am very proud and happy to say, a distinguished environmentalist, a former Governor of the State of Delaware, and now serving as Chairman of the President's Council on Environmental Quality. Mr. Peterson, I believe this is your first appearance before this committee. It is a great pleasure to welcome you, so please go right ahead with your statement.

STATEMENT OF HON. RUSSELL W. PETERSON, CHAIRMAN, COUNCIL ON ENVIRONMENTAL QUALITY

Mr. PETERSON. Thank you, Mr. Chairman.

First of all, I appreciate being included here today in this important committee hearing. I have prepared a very brief statement, some thoughts relative to the subject I was asked to discuss, the subject of resource scarcity, and the impact of economic growth on environmental quality. I do not intend to read that document.

Chairman PROXMIRE. Well, the entire prepared statement will be printed in full, as you prepared it, in the record at the end of your oral statement.

Mr. PETERSON. I thought it might be helpful to take off from your introductory comments because what I would like to discuss with you is much more important to the problem of energy and quality of life than those problems being discussed all around the city about the near-term aspects of the problem. I am talking about the tremendous importance of recognizing the peaking out of the production of our scarce natural resources, and the recognition of that peaking out well ahead of time so we can do something about it.

The current problem with energy is, of course, exacerbated by the action of the Arab nations but the underlying problem is one of much greater import to us over the long run of history, and it is vital that leaders every place, the public and private sector, spend more time focusing on such things.

In the prepared statement I submitted, I talked about the 74 materials which are considered to be essential to a modern industrial society. I pointed out how we had for a long time been moving forward in our country without any great concern about their availability because we had been blessed with tremendous resources in our country and we were able readily to get others from foreign lands. But in recent years it has become more and more clear that the day of reckoning is coming when we will have to face up to getting along with smaller amounts of these materials per capita and to finding substitute materials. The writeup points out that today, in the case of 22 of those 74 materials that are important to our industrial society, over half our needs are obtained from imports. As the world population increases and the affluence of the world increases, others will be competing for these scarce resources. It will make our problem increasingly more difficult as the decades go by.

But I would like to take the specific example of petroleum to illustrate the point that I was making a few minutes ago, and that is that the nonrenewable resources will peak in production at some date. In the case of our U.S. supply of petroleum from the 48 contiguous States our production peaked out in 1970. Some people do not believe this, but I believe that it is a fact, well-documented. We ought to face up to it. What happened in recent years is continuing major growth in the use of petroleum, doubling our use in 15 years. To say it a little differently between 1955 and 1970 we doubled the rate of production of petroleum in this country, petroleum from our contiguous 48 States. And during those 15 years we used more petroleum than we had used in all of the previous history of our country.

The significant point here, however, is that from 1970 on there would be a continuing decline in the productivity of petroleum in the 48 States, falling off about half in the next 15 years.

Furthermore, natural gas will peak out about——

Chairman PROXMIRE. When you say the productivity of petroleum, you mean the production of petroleum?

Mr. PETERSON. The production of the 48 contiguous States, I am leaving out Alaska.

Chairman PROXMIRE. Yes.

Mr. PETERSON. The production of petroleum in those States will fall off from 1970 and within 15 years it will be about half of what it was at the peak year.

Chairman PROXMIRE. Does that not depend on exploration and the success of exploration?

Mr. PETERSON. No, it depends——

Chairman PROXMIRE. On the shelf and so forth?

Mr. PETERSON. No, it depends upon the actual amount of oil which is available in the land and in the technological ability to get it out. A lot of people say that the rate of exploration and so on will correct this problem. In my opinion, that is not true. Even with an all-out effort to explore, to dig, to pump, the production of petroleum in this country, in the 48 States, will continue to decline, and decline rapidly.

Chairman PROXMIRE. You may be completely right but I just wanted to—and I apologize for interrupting you before you finish your statement—to see if you could reconcile that statement with the statement of another expert witness.

You testified that in the late 1950's we had a leveling off of our production of petroleum, and that it corresponded almost one for one with the leveling off of our exploration, and that it was because our system of encouraging exploration is not effective. Oil exploration seems enormously attractive because of the tax advantages we know about but it just is not doing the job, and the argument was that if exploration incentives are made more effective we will get more exploration and if you have more exploration you will get more proven reserves. There is no way of knowing; we may have very little unproven, unexplored reserves. We may have a great deal that we do not know about, that has not been explored, especially on the Continental Shelf and so forth.

Mr. PETERSON. We have explored for oil very thoroughly throughout our land. As you know, we poll the people of the country to see how they think about problems by sampling a few thousand people and we learn to have confidence in that polling. We have sampled our land very, very thoroughly, drilling thousands of holes.

Chairman PROXMIRE. Including offshore?

Mr. PETERSON. Including offshore, in the gulf and off the west coast. We have done a very minimum amount of exploring off the Atlantic coast, most of it off the Canadian coast, where they find primarily dry holes. The basic facts here are well-explained by the person who I think is a good expert to listen to, Mr. King Hubbard of the U.S. Geological Survey. He has shown, for example, that the amount of oil discovered per foot drilled has been falling off rapidly. You would expect that as we ran out of attractive sources of oil that we would, as we looked for more, drilled more and more, uncover less per foot. The several mathematical considerations he has brought to bear on this subject all check, demonstrating that the peak year occurred in 1970.

And he also says, and I believe it, that by about 1975, we will peak out in the production of natural gas in these 48 States, and the world will peak out in the production of petroleum about 1995. To illustrate the main argument I want to present, the main message I would like to bring, let me take a hypothetical case.

A nation has been producing electricity by burning petroleum to heat the water to make the steam to run their electric generators. Their use of petroleum for this purpose has been doubling every 15 years. This year they peak out in the production of petroleum and thus in the production of electricity from this source at 1 million units of electricity, 1 million units of energy. This same country has had a lot of foresight. They have gone to work to develop a new source of electrical energy based on the use of nuclear energy to power electric plants. They finish their research and pilot and demonstration plants and are now in production and have built up to the promising level of 10,000 units per year. That is 1 percent of their total energy. That is about the percentage of the total energy produced in this country today that comes from nuclear plants. Let us say, they work a miracle by doubling their production of electrical power from nuclear energy powerplants every 5 years. So they go to 20,000 units in the next 5 years and to 40,000 10 years from now and 80,000 15 years from now. But during that same 15 years production of power from oil-fired electrical plants will have fallen off from the 1-million-unit peak to one-half million units.

Chairman PROXMIRE. Have you looked at this overall not only from the standpoint of nuclear energy but also from the standpoint of coal, shale, geothermal, solar and so forth?

Mr. PETERSON. Yes, sir.

Chairman PROXMIRE. These are all long term but coal less so than the others, and the impression that we have gotten to some extent is that with intense technological effort that we can greatly expand the energy resources but we still would not be able to meet our geometric increase in consumption that has to be tempered, modified and changed but we probably will have a great deal more in energy resources in 25 or 30 years from now than we have now. It will be different but it will be more.

Mr. PETERSON. Well, I think that we can have a reasonable growth in the total amount of energy in this country, but I think it is very impracticable, if not impossible, to continue the rate of growth which we have been carrying out here in the last few years. I believe——

Chairman PROXMIRE. At any rate, it will be very, very expensive.

Mr. PETERSON. It will be very expensive as far as petroleum and natural gas are concerned, which have been the main source of our energy. Over 70 percent of our total energy today is coming from petroleum and natural gas. That is why it is so critical for people to focus in on the downturn in their production.

As I said at the start, people have not paid attention over the years to predictions of resource scarcity problems arising. Today the most critical thing for us to face up to, more critical than the immediate energy problems, is the peaking out of production of those two critical materials. Now, let us talk about coal for a minute. There is a natural resource of which we have great abundance, which even if we used it in a very major way its production would not peak out for well over a century. I think we need to move rapidly to increase the production of coal in this country and do it in a way compatible with environmental quality.

I think we need a marked increase in effort in the use of solar energy. The technology on hand does not indicate that we will be able to get a very high percentage of our total energy needs from solar energy, but the desirability of so doing is high. The sustained production of such energy for billions of years is guaranteed. I believe we should put a major effort into using energy from the Sun, a nuclear fusion plant which is properly sited. Other sources of energy are fission nuclear plants which will provide an increasingly higher percentage of our total energy. They should be moved forward but with increasing concern about protecting the environment.

I believe that the use of shale and geothermal——

Chairman PROXMIRE. Let me stick to coal just for a minute, and let me follow upon that. If we are going to protect the environment and use more coal, how do we do it? Do we have an adequate supply of low sulfur coal, for example, particularly if we cut back on strip mining?

Mr. PETERSON. We do not have an adequate supply of low sulfur coal readily available. I think we should move to develop new techniques for deep mining so we can get at more low sulfur coal. I think we should also carefully select places where we can use low sulfur coal via the strip mining technique, carefully selecting the location so that we can guarantee reclaiming that area, not do the strip mining unless we can guarantee to reclaim the area.

But one of the main pushes in the use of coal should be, in my opinion, toward gasification of coal at mine sites.

Chairman PROXMIRE. Liquefaction, too.

Mr. PETERSON. Liquefaction, too. I put gasification as a higher priority because I think it permits one to obtain a clean fuel which then can be readily transported through pipes to the consuming sectors.

Chairman PROXMIRE. Are those processes, liquefaction, gasification, technologically and economically feasible for the near term?

Mr. PETERSON. I think they are technologically and economically feasible. The magnitude of production from those sources in the near term is not very high, but we ought to——

Chairman PROXMIRE. What is the near term, 5 years?

Mr. PETERSON. By 1985, I would anticipate that we would be obtaining a substantial amount of energy from coal via the gasification process.

Chairman PROXMIRE. By 1985?

Mr. PETERSON. 1985.

Chairman PROXMIRE. How substantial, in terms of our needs? If 75 percent of our present needs are the result of gas and oil, primarily oil, how much of that gap can be taken up by coal, say, in the next 10 years?

Mr. PETERSON. I have developed my guesstimate of what that would be, I do not have it in my head, Senator, but I would be pleased to give you that idea.

Chairman PROXMIRE. Would it be a half, a quarter, give us a rough idea?

Mr. PETERSON. No, I would say if through the gasification of coal we could get up to 3 or 4 percent of our needs by 1985, that would be a tremendous accomplishment.

Chairman PROXMIRE. And that is our most promising source in that limited period of time, right?

Mr. PETERSON. Well, the more promising source is to use the coal directly and to require stack gas cleaning, for example, to keep from polluting the air with the sulfur oxide.

Chairman PROXMIRE. If we do that, how much will that help?

Mr. PETERSON. I think that will help in a major way.

Chairman PROXMIRE. 20 percent, 25 percent?

Mr. PETERSON. We can and should double the use of coal between now and 1985. I believe that will be necessary in order to provide for the declining production of petroleum and natural gas.

Chairman PROXMIRE. Think how that dramatizes your fundamental point. You say we should double our use of coal between now and 1985, that is 12 years, and in that period we would normally double our energy consumption, so that all that would do would be to stay exactly where we are with respect to the use of coal. That means we do not have more coal to substitute for the use of oil than we do now. It would double the use of coal to take care of our needs but if we just double the production of coal we are standing still on the treadmill.

Mr. PETERSON. That is right. We need to push the fission nuclear energy program now in the works and the major increase in the use of coal in order for us to provide for a very modest growth in energy use. I say that because of the tremendous downturn I anticipate in the production of petroleum and natural gas.

Chairman PROXMIRE. How about shale?

Mr. PETERSON. I do not want to predict any marked use of shale. I think the demonstration projects that are now being planned are very much in order to give us a better understanding of what is the potential for using shale. There are so many problems associated with it that I do not think we should count on shale as a major source.

Chairman PROXMIRE. We have been told we have a perfectly enormous potential here, that it is equivalent to a greater supply than all the oil the Arabs have under their control. Furthermore, we have been told that it is economically feasible at the equivalent of $6 a barrel, which means it is very close to the price that we are moving to already. It is all, of course, within our continental limits. Why are you so pessimistic?

Mr. PETERSON. Because I believe the environmental factors, the energy requirements to retort the shale, to get the oil out of it, the reactivity of the residue resulting from the retorting of the shale all create problems which at this date we do not know how to cope with.

Chairman PROXMIRE. Well now, we have this great need, we have the resource, we have a softness, unfortunately, with respect to environmental consequences; you have indicated yourself that you would not object to strip mining providing strip mining were done in a way to restore the land. Why do you feel it is not possible to be able to exploit the shale resources with the condition that that land be restored?

Mr. PETERSON. Well, I did not say it was not possible. I said I did not know how that could be done today and that is why I thought the demonstration project which is being planned was in order to help us learn how we might use shale. But I think it would be wrong at this stage in our planning to count on that as a major source of energy.

Chairman PROXMIRE. You would not count on it but you think it is a real possibility?

Mr. PETERSON. What?

Chairman PROXMIRE. You would not count on it?

Mr. PETERSON. I would not count on it.

Chairman PROXMIRE. But you think it is a possibility?

Mr. PETERSON. I think it is an area where we should carry out research and development, to consider whether or not it could become a major source of energy. But I think it would be a mistake in our planning if we counted on it at this juncture.

Chairman PROXMIRE. All right. Go right ahead, sir.

Mr. PETERSON. If one looks to the world as a whole, and again accepts this peaking out of production of petroleum, according to the analyses I have seen and believe, petroleum will peak out worldwide about 1995. I believe that date will be of tremendous importance to the world because of the great reliance that other nations, like Japan and Western Europe, place on the use of petroleum.

The downturn in production of petroleum will probably be steeper than the rise in use of petroleum between now and 1995, because I would believe it would be almost a certainty that those countries that had the remaining resuorces of oil would become increasingly desirous of preserving what they have in the ground. Thus the amount available to the rest of the world during those critical years would be reduced more rapidly than today's projected production curve would indicate. Thus world leaders, in my opinion, should today be focusing in on the peaking out of the supply of petroleum in the world and planning how we are going to cope with it.

Nations like Japan and the nations of Western Europe, as you well know, are not blessed like we are in this country with such things as coal and with the possibility of using shale. I want to say again loudly and clearly all of us in leadership positions in the public and private sector worldwide should pay serious attention to this peaking out of the production of our limited resources.

Thank you.

[The prepared statement of Mr. Peterson follows:]

PREPARED STATEMENT OF HON. RUSSELL W. PETERSON

Mr. Chairman, it gives me great pleasure to have been invited here to offer some views on the subject of resource scarcity and economic growth.

In recent months, I have given several speeches in which I made the point that the well-being of a nation should be measured by the quality of life of its citizens, of which one component is growth in economic well-being. To me, quality of life is a measure of one's success in the pursuit of happiness—success in the progressive satisfaction of a continuum of needs.

Some of man's needs are for goods and services which depend upon the availability of non-renewable resources. Many other important needs, such as health and education, are not heavily resource-dependent. I believe that the American way of life has become overly dependent upon the continued availability of raw materials in ever-increasing quantities.

The world industrial society currently relies on the use of 74 non-energy minerals. No one country has an adequate supply of all of these. The United States is fortunate to be a country rich in natural resources.

From the very beginning of the Nation, most of our resource needs were supplied domestically. But, rapid expansion of our economy has occurred over the past three decades to the point that we are no longer resource independent. The United States now imports over one-half of its current demand for 22 of the 74 nonenergy minerals.

We can no longer view our own resource requirements independently from the demands of other nations. The resources of the world are finite and foreign demand for these limited resources is increasing rapidly.

To date no non-substitutable, non-renewable resource has been completely exhausted. In fact, if there are no disruptions in the foreign supply of materials, we anticipate no resource availability problems in the near future.

The longer term picture cannot be so favorable. Some high-grade ore deposits have been depleted. In response, we have relied upon technological advances to economically mine lower grade ores. These new technologies unfortunately have tended to be both more energy intensive and otherwise environmentally destructive than the processes they replaced. Without these technological changes, however, present estimates of population growth and per capita consumption indicate that by the year 2000, we may exhaust the present world reserves, at today's prices, of copper, gold, platinum, lead, mercury, silver, tin, tungsten, uranium, and zinc. While technological advances are likely to occur, at the very least internalized energy and environmental costs will force prices for these materials up.

Economists often argue that we will never exhaust our resources because the market mechanism will run the price up encouraging substitution and conservation. If the price mechanism is allowed to function, they say, these resources will never be completely exhausted. They will, however, become much more expensive. We often overlook the fact that resources which are too expensive to use are, in effect, exhausted. One way or another, this means that per capita consumption of many scarce resources in the future may decline significantly.

With this resource picture, what should be done?

The Council on Environmental Quality recently had a task group study the adequacy of current methods of determining resource availability. Four factors were considered important: supply, demand, price, and level of technology. The effort showed that the data available were inadequate. Better efforts will have to be made to obtain and coordinate information on the availability of critical resources.

Analyses should be made, commodity by commodity, to forecast if and when critical shortages might develop and to examine whether we are dangerously dependent upon foreign sources of supply. Appropriate actions can then be designed, such as the development of substitute materials, to attempt to alleviate the most pressing problems.

To cope with the problem in the long run will require a reduction in per capita demand for virgin materials.

Of primary importance is the number of consumers. The limited resource base strained by massive U.S. consumption is being strained even further as the world population rapidly expands. To give the world a per capita consumption equivalent to that of the United States would increase consumption of world resources by a factor of 2.5 to 10. To give 7 billion people (the most optimistic estimate of a stable world population) this per capita consumption would mean increased production of from 4 to 16 times current levels.

Per capita consumption also must be restrained. In every industrialized society, resources are extracted in relatively high concentrations, refined, mixed with other materials in manufacturing, used as products, and finally discarded. Well-being, however, is not related so much to the amount of resources per year consumed by each individual as it is to the resources that are available for his use at a given time. By designing products for durability, ease of maintenance, and resource recovery, the world's stock of resources can be made to serve many more people for many more years.

The time has come to encourage the reuse and recycling of materials instead of relying so heavily upon virgin resources. The technology exists to recycle but now a climate must be generated to encourage the practice.

The time has also come to stop subsidizing mineral development with cut rate energy, environmental damage, and the lives and health of workers. We must see that mineral development is carried out without despoiling the environment or endangering health, and that it pays its full costs. This will allow the market mechanism to function.

It will be increasingly difficult to continue to provide the United States with its material needs in the face of a growing world population and standard of living. Even at a reasonable world population level, great diligence and skill will be required to conserve and recycle our mineral resources, to discover additional reserves, to invent and develop alternative materials, and to alter some of our life styles. This is our task.

Chairman PROXMIRE. In your prepared statement you note the data availability on resources are inadequate, data availability. This is something which has bothered some of us a great deal. The President of the United States does not seem to have data he can count on. He made a speech a month or so ago on the energy crisis in which he gave us specific figures on the shortage in which he estimated about a 17-percent shortage of petroleum, and that was contradicted by figures that came out from the petroleum industry.

A week or so ago the Bureau of Labor Statistics came out with a wholesale price index which exploded because petroleum prices increased. How do they know? Well, they said that is their estimate. Where did it come from? They told me it came from Platt's Oilgram. No independently gathered Government statistics, they rely on the industry. So we are at the mercy of the industry to give us the information.

As my colleague, Senator Nelson, said yesterday, we are sitting in the dark with the lights out because we are in the dark on the figures.

Did the Materials Commission develop, try to develop, its own data or was it unable to do so?

Mr. PETERSON. I am not adequately acquainted with what the Materials Commission did, how they arrived at their data. I do know that they have concluded and CEQ has concluded that there are inadequate data available to cope with the availability of resources and the projection of the availability of resources in the world. Obviously, without the data we are flying blind. We need to give the collection of the appropriate data high priority. In my 2 weeks on this job, I have not dug into that but I think it is important that I become well-versed on what data are available, how we can improve the data, and so on. Obviously it is a vital need to have the facts on which we base our judgment and our planning.

Chairman PROXMIRE. Governor, have you had a chance to evaluate the Materials Commission recommendations?

Mr. PETERSON. Not adequately, no.

Chairman PROXMIRE. What are some of our specific data needs? What authority does the Government need to force industry, the oil industry, in particular, to supply the needed data?

Mr. PETERSON. I do not know the answer to that, Senator, but I think that the Government needs to get the data. When you are talking about information obtained from drilling or from mining operations, for sampling information which is in the private sector, I think we ought to have a mechanism for making that information available to the planners in Government. How to do that and properly recognize the proprietary interests of the companies in our free enterprise system I am not sure. But somehow we need to have access to that information.

Chairman PROXMIRE. Let me give you an example of one of the problems. In the natural gas area we would like very much to know what the reserves are. It is a very important policy question, one that relates, for instance, to whether or not we deregulate natural gas. There has been an enormous pressure on the Congress to do so, it missed by only one or two votes in the votes we had in the Senate in the last couple of days. It is likely to be deregulated and if it is deregulated on the basis of the size of those reserves, they will have a profit on the reserves of some $150 billion. That is the increase in their reserves if the deregulation should result in prices going from 25 to 75 cents a thousand cubic feet, that is what it amounts to arithmetically. In addition to the windfall increase in the value of their reserves they would have annual profits increasing by about $11 or $12 billion a year.

Now, I have talked to a former Commissioner of the Federal Power Commission who tells me that he thinks that one of the things we should do is to develop our own TVA in this area to do two things. Not only to provide a competitive yardstick but also so we would know more about what was going on in the industry, know how their costs were running. This way we would have data that we do not have now, and we would be in a far better position to evaluate and judge the information they give us.

This seems to me to be a very far-reaching and profound step and I doubt if the Government will take it, not only under this administration but under any, because it would be a very serious change, kind of a seminationalization of an industry that probably will not be nationalized. But it indicates, because this is a very responsible man and a very able man and a thoughtful man, how far we go just to get data, just to get the figures, the statistics which we have to have in order to have proper tax policy, regulatory policy, inflation policy. We just do not have that information now.

Mr. PETERSON. Well, I think it is very important for us to get the data. The well-being of all of us is so closely tied to doing the right planning in this area. The major thrust of my testimony here today is to call attention to the impending rapid decline in the supply of petroleum and gas. To make such a forecast calls for having data available. If we have the right data to help us understand impending problems, we are in a much better position to make decisions which will alleviate the problems which otherwise would plague us when those shortages arrive. This is such a tremendously important thing to all of our country that it is vital we get access to the data necessary to cope with it and that means getting priority, I think, over some other considerations.

Now as for the particular mechanism for doing that, I am not prepared to say. I want to give that some thought and maybe at some later date I will have a more definite opinion.

Chairman PROXMIRE. Sometime ago the Hart Subcommittee on Monopoly was told by the industry the size of their reserves. The subcommittee felt the figures were not consistent, and they challenged them, and they subpoenaed the records of the companies and found they had been understated so greatly that they actually, in adjusting what the figures on the reserves were, they found they had to increase them for this one company 1,000 percent. So you have that much of a difference between what the industry stated when they felt unchallenged and what the figures actually showed when the Government was able to get the records. So maybe we have to go into some kind of a massive subpoena operation, almost as massive as the Watergate tapes.

In your prepared statement you say the time has also come to stop subsidizing the mineral development. That is a very interesting statement. First, let me ask you, can we develop a specific list of those substances?

Mr. PETERSON. Well, we provide the large user of electricity with lower rates than the smaller user. That is one example. Mineral development is being subsidized by cut rate energy. The whole community pays for the environmental damage caused as a result of digging and pumping and scooping various raw materials, of burning the fossil fuels and polluting the air, et cetera. In effect, the community is subsidizing such operations. The people causing the environmental damage ought to be paying it themselves instead of calling upon us to pay for it through taxes or through reduced health. That brings me to the next item. We are subsidizing some economic development with the lives and health of the workers. I believe that coal mines, for example, developed techniques are intolerable for human beings to operate under, conditions which are very unhealthy.

Thus it is vital for us in the future to develop the techniques of deep mining which do not subject the workers to the health and safety hazards they have been subjected to in the past. That will mean greater costs to the mining operation. As the total market price for energy goes up, it provides the opportunities for the producers of energy to pay the full cost of producing the energy and still realize a reasonable profit on those actions. To bring the costs back to the producer of the energy will be healthy for our whole system.

Chairman PROXMIRE. I agree with everything you have just said, and I want to get into that in a minute but before I do you have omitted, and maybe deliberately omitted, one of the most conspicuous kinds of subsidizations of mineral development, which has been alluded to by other witnesses, we provide oil depletion allowances, tax credit for foreign oil royalties, ICC freight rate preferences for virgin materials, and so forth.

So what we do is subsidize the expoitation and the rapid use of our limited resources. What the general taxpayer does by permitting this tax privilege is to put a premium on using up these resources, but what that means in a sense is the general taxpayer is subsidizing the people who consume the fuel, and we artificially hold down the price and artificially increase the consumption by following that policy, isn't that right?

Mr. PETERSON. That is right, but I think it is the wrong way to operate.

Chairman PROXMIRE. The difficulty here, of course, is what you have to do is, and I think this is the time to act and the time is moving away from us very rapidly because I think the policies on the part of the administration of permitting prices to rise rapidly without requiring the companies to forego their tax privileges, for example, if we have the kind of price increase that would seem in the offing, that we have already had for that matter in gasoline and we are having in these many other areas of fuel prices, it would seem to me that it would be a perfectly proper time to repeal some or all of these incentives for over investment and rapid use.

And we could do that without discouraging production, without discouraging exploration provided it coincided with the overall increase in price, isn't that right?

Mr. PETERSON. It would seem to me wrong to hurry up and use a resource of which we are running out.

Chairman PROXMIRE. That is just what the depletion allowance does.

Mr. PETERSON. Right.

In the case of coal, for example, where the other situation exists, where we have a resource available in large quantities and need to develop it more rapidly, their encouragements to move in that direction might well make sense.

The slogan of the oil companies, which they used for a long time, as you remember, was, "A nation that runs on oil cannot afford to run short." I think maybe a more appropriate slogan would be, "A nation that runs on oil is bound to run short." That was the message I was trying to get over earlier.

I was reading an item about Saudi Arabia considering going along with the request to markedly increase its production of oil, raising it up to something like 20 million barrels a day. If they did that they would completely deplete their huge reserves in something like 20 years. I wonder if that is healthy for the world as a whole, to increase the rate of usage and thus build up to this critical peaking out year at an earlier date.

Chairman PROXMIRE. I think the Arab nations are beginning to realize that. That is one of the reasons why they are acting as they are, and they are learning something in the process. They find they can get as large a gross income and a far larger net while greatly reducing their production and the best investment they can make isn't in gold or deposits in this country or in bonds or even in stocks. The best investment they can make is their own oil in the ground. Why deplete it?

Mr. PETERSON. I believe we should pay much more attention to reducing the demand curve for energy in our country. We do a lot of talking about supply, getting more and more energy to take care of an extrapolation of a very high rate of growth of the use of energy today. I think that many aspects of the quality of life in our world could be furthered by reducing the demand curve for energy. The efforts underway now to conserve energy, and the way that people are responding, are very encouraging. Hopefully we can retain that ethic.

Chairman PROXMIRE. Hopefully we can, and I think that people are decent and patriotic and socially concerned, I think much more so than we give them credit for, but probably in the long run there is only one way to do it and that is a cruel, unpopular difficult way; that is, to increase the price.

Mr. PETERSON. That is right.

Chairman PROXMIRE. If people have to pay more for their gasoline or their oil or their fuel they just won't buy as much and they will have to find a way of economizing in that. They will be more careful about their use of it, they won't waste it as frequently. They won't take as many trips that aren't necessary.

Mr. PETERSON. Yes.

Chairman PROXMIRE. If you can think of other ways to conserve fuel in the long run I think that would be fine.

I think the President's speech is very useful in the short run. People always respond to this kind of thing but it begins to diminish as time goes on and Presidents make one appeal after the other, unless the consumer can see directly the cost, he is unlikely to economize.

Mr. PETERSON. I think the environmental ethic has been very helpful in getting many people to look at some of the problems differently.

Chairman PROXMIRE. That is right.

Mr. PETERSON. The movement toward the small automobile was well underway before this current crisis. The current crisis has accelerated that move. I know that many people in the United States today consider having a small car a status symbol, while some years ago it was the other way around as you know. People were out in the front yard polishing up their big cars.

Chairman PROXMIRE. I hope we can get that idea across to administrators who have big limousines.

Mr. PETERSON. As I understand, they are moving very rapidly to smaller cars.

Chairman PROXMIRE. Mr. Peterson, there is a rollcall, I have to run over and vote and I will be back in a couple of minutes. The subcommittee will stand in recess for about 7 or 8 minutes.

[A short recess was taken.]

Chairman PROXMIRE. Mr. Peterson, when we had the recess briefly to go to the floor we were discussing how we reduce demand for energy and especially how you reduce waste of energy resources. In your prepared statement you emphasize the importance of encouraging recycling. I would like to get your reaction to a bill I introduced this year to encourage recycling, and to prevent the wasteful consumption of resources. I had a bill of this kind in the hopper for sometime and it is based on the experience by Germany in the Ruhr River. As you know they have a tax on the effluent that industry pours into the water to carry off waste from industrial plants and it has been an enormously successful matter there. The Ruhr River is the most intensely used by industry, I suppose, of any river in the world, all kinds of polluters, coal, chemical, paper, everything is on the river, and yet it is a river in which you can sail and swim and even drink the water, and it is because they have had this tax which provides a clear understandable objective economic disincentive to pollute. The tax is reduced as they reduce their pollution. As they recycle it and take the pollutants out the tax goes down. If they don't reduce pollution the tax goes up. It has been a great success. It has been tried in a number of places in this country and wherever it has been tried it has done well. Somehow we can't persuade the Congress or administration to really go all out for this as a national policy and I wish they could. But the bill I would want to have your reaction to, this would impose, it is another bill that would impose a penny-a-pound on all containers and materials entering the solid waste stream, with the money to be collected by the Federal Government. It is estimated that this would raise about $3 billion a year, which would be used to augment and construct municipal solid waste disposal facilities. In addition, the bill provides that a credit against the charge would be permitted to the extent a given product consists of recycled material, or if the product is designated returnable by the manufacturer.

Would you comment on that kind of a proposal?

Mr. PETERSON. Yes, I think the costs of producing a product and marketing it and the costs to the community as a result of pollution and littering of the countryside caused by the product should be borne by the person producing and marketing the product. I personally would be sympathetic with a variety of techniques for bringing this about, including consideration of taxing the pollutants which enter our air and our water.

One thing which I am considering, in trying to think out how we can implement the above, would be to require the manufacturers to be responsible for recovering and reclaiming and disposing of their products once they had finished their useful life. The complexity of doing this varies, of course, with the particular product. But let's take an automobile, for example, which is a simpler product to deal with in this case than some others.

If a manufacturer had the responsibility for recovering his automobile once it finished its useful life, you can bet that that company's engineers and research people would be designing automobiles to facilitate their recovery, to get more out of it.

Chairman PROXMIRE. Also smaller automobiles. Supposing you had a penny-a-pound tax, this would mean that there would be a clear incentive for reducing the weight of automobiles, appliances, and so forth, and it would also provide, as I point out, a fund for taking care of this material paid for by the people who should pay for it, that is the users of the material itself, the users of the automobile in this case or of the paper if you are polluting streams by producing paper, they would be the ultimate beneficiary of using the water as a free good or using—disposing of the waste so they should pay for it in our economic system.

Mr. PETERSON. I agree with that, and I think we need to be concerned with the costs that future generations pay, too. If we use up a natural resource so that it becomes unavailable for them, they are paying a penalty as a result of what we are doing today.

Let's compare a 5,000-pound car with a 2,000-pound car. We have had great discussion about the impact of the lighter car on the use of gasoline which is perfectly straightforward. But very few people have talked about the result of using 3,000 pounds fewer materials. That means, of course, much less energy for producing those 3,000 pounds of materials. It means less pressure on depleting our supply of such raw materials, and finally it removes the 3,000 pounds of waste from the dump at the other end.

Chairman PROXMIRE. If you provide a specific credit for recycling the material then you get a reinforcement, don't you, of utilizing the materials and the resources as fully as possible, and eliminating waste or at least greatly reducing it?

Mr. PETERSON. Yes, we should give incentives to recycling.

Chairman PROXMIRE. What I had in mind is that you levy a penny-a-pound charge and then you give a credit to the extent that the product consists of recycled materials so that you have a double effect to encourage the use of recycled materials and recycling.

Mr. PETERSON. It sounds like a reasonable idea. I would like to think of that more, the implications are great.

Chairman PROXMIRE. We will send you the material. We would be happy to have you comment on it.

Last year I introduced a sulfur emissions charge bill, that the charge be pegged at 20 cents per pound for sulfur emitted.

Could you support that kind of a proposal?

Mr. PETERSON. I can support a number of proposals that would reduce the introduction of sulfur oxides to the atmosphere, and I think a more rapid way to cope with that problem would be to require the installation of the technology now available for cleaning the stack gases, and require that that be done by a given near term date. There has been a lot of resistance to that. There was a claim that the technology was not available, but it is available now.

Chairman PROXMIRE. But that is the problem. I think if you get something that is simple, objective, and requires as little administrative followup as an effluent tax, which has worked as well as we all know it has, or a 20 cents per pound of sulfur emitted which you can measure and determine as technological fact, and nobody can dispute it, and it is not a matter of going to court and delaying it in court, just impose the tax, and they either pay the tax or cut pollution.

Mr. PETERSON. No doubt about it, it would act as an incentive to get the stack gas cleaners.

Chairman PROXMIRE. That is right. The stack operators would have it in mind and that is what I have in mind.

Several years ago, the Club of Rome published a study entitled "Limits to Growth." The study suggested that we are rapidly running out of scarce materials and resources—oil, minerals, fertilizer, foodstuffs, et cetera—and that it is only a matter of years before we reach a critical shortage of these resources. The report seems to suggest that conservation methods can only delay our reaching the critical point—but that it is inevitable, we can't avoid it, given our present attitudes toward growth, that we will eventually reach the critical point and rather soon. The report implies we can only avert this disaster through strict means of population control. What is your reaction to this thesis?

Mr. PETERSON. I think the book "Limits to Growth" is of great value. It has shocked people all over the world into recognizing some of these forces at work, and made people recognize that they cannot continue to operate in the same way we have in the past. We have developed a way of life of perceiving of things and doing things and now someone comes along and says, "Wait a minute, you can't continue to do it that way because we are heading for a tragedy if you do. That shocks people and they come out fighting. There has been tremendous criticism of the book "Limits to Growth."

But, as the months have gone by, that criticism has gradually subsided and more and more people have recognized the tremendous message that that book has provided. I don't mean by my comments that I necessarily subscribe to every word in that book, but I think there were three things that that book said all of us ought to listen to very carefully. One was the impact of exponential growth. I was talking about that earlier in connection with growth in the use of resources.

Second, the need to be thinking about problems over the long range and worldwide. And, third, is to recognize that decisions made today can have a major impact in years to come. Their recommendation that we analyze our problems in a systematic way, look at the whole system, over a long range period is vital to us all.

That book ended up, by the way, with a chapter, an optimistic chapter, about how if we do make some major changes in the way we operate we can continue to have a growing quality of life.

I have been talking around the country about the fact that growth in quality of life is unlimited. Growth in some other areas is definitely limited.

You asked another question at the end and I have forgotten what it was now.

Chairman PROXMIRE. On the population control as a way of meeting a disaster.

Mr. PETERSON. Yes, sir.

I think population growth is the single most critical problem we have in the world. All of the rest of the problems are worsened as a result of increasing population. I do not know of anything from a quality of a life standpoint that is improved by further growth of population, and believe that leaders throughout the world should be doing whatever they can do to reach zero population growth in the world.

The developed nations, such as ours, and I mean by this Western Europe, Russia, Japan, Canada and so forth, about 1.1 billion of us have all markedly reduced their birthrates. Several have reached zero population growth. It is conceivable that all of them will reach zero population growth in several decades.

Let us assume that all of us in the developed nations level off at 1.2 billion, which is a possibility. The rest of the world, 2.8 billion people, is growing at a rate of 2½ percent per year. In most of those countries there is no real indication of any reduction in that growth.

If you extrapalate that growth rate into the further, let us extrapolate it for a century to exaggerate the situation, you reach 35 billion people in the world, of which 1.2 billion are in today's so-called developed nations. The developing nations would then have 97 percent of all the people in the world.

To say it another way, throughout all the centuries of history we have built up to 3.9 billion people in the world. In the next century, if the present rate of growth in the developing nations continued, we would add eight times that number of people.

Now, there are forces at work that can keep that from coming about, inability to provide food for that number of people, for example. We need to do whatever we can to reduce the rate of the population in the world. As I understand the problem, no nation, unless China today is an exception, no nation has ever reduced its birthrate significantly until it had realized a substantial improvement in economic well-being. If you accept that, then it says we have to get the economic well-being of the developing nations raised substantially to reduce population.

Chairman PROXMIRE. Think of the contradictions of that course. You said that the one force that you mentioned that would limit this exponential growth that would limit this exponential growth that would be so disastrous and catastrophic is the limit of food supply, and then you say that our experience only indicates one way we succeeded in limiting it is to improve people's——

Mr. PETERSON. Economic lives.

Chairman PROXMIRE [continuing]. Standard of living. Well, the heart of a standard of living is an assured food supply, and you have to get that first. Then, as you build that and become more efficient in agriculture instead of your people having to spend all of the time scratching a bare living out of the soil you have enough efficiency so that more of them can be working in other things, building homes, building roads, building back forests, beginning the long climb up. As they do that, of course, their population grows. Our population grew enormously while we were doing that, while we moved in this country from an agricultural society to an industrial society. So it is very—it looks as if there is going to be an extraordinarily difficult century ahead of us if we are going to find a way of limiting the impact on the environment to prevent a catastrophe, and at the same time, satisfy these underdeveloped countries. It is easy enough for us, although even in this country there are many people who are not at all well off. In other countries the overwhelming majority suffer from that and only with a great deal of growth and intensified use of resources do they have any chance of progressing ahead. You talk about the population, and I think you are absolutely right, I talked about it too, but as I understand it, we use about 50 times as much resources per capita as the people who live in India do.

So it is a very, very tough problem for us to know where to begin to solve it. In the past we have solved population growth in the most disastrous way of all by wars and, I suppose, that is one way we could solve it now but that is something that none of us would want. That could end the civilization entirely.

Mr. PETERSON. I think that the absolute minimum, short of some catastrophe, population we can level off at is about 7 billion. It really takes an optimist to feel we could do that in the world. At 7 billion, I think it is practical to produce food to have a reasonable diet for everybody. If the population leveled off at 7 billion then we need to increase productivity of food by 85 percent from what it is today, in order to give that 7 billion the same average diet the people today have, which is far from adequate in many lands. To give everyone——

Chairman PROXMIRE. When would you reach 7 billion?

Mr. PETERSON. What?

Chairman PROXMIRE. When would you reach 7 billion?

Mr. PETERSON. Reach 7 billion in the year 2050 as I look at this. This is a matter of judgment.

Chairman PROXMIRE. Well, an increase of productivity of 85 percent is no trick at all in that time. We have increased productivity in this country in food far more rapidly than that in the last quarter of a century.

Mr. PETERSON. A lot of our productivity over the ages has come from putting more land into production, and today we have 4 million acres in the world in cultivation and many people believe the probability of increasing that significantly is not very high.

Chairman PROXMIRE. Just think of the fantastic increase in productivity in this country when you consider this, that today we have only 6 percent of our people producing food, 6 percent on the farm. The Soviet Union, which also has advanced very greatly compared to the situation 50 years ago throughout the world, the Soviet Union has 40 percent of their people on the farm and yet we produce 20 percent more food than they do. That is an enormous advantage in productivity.

Mr. PETERSON. In order to provide the people of the world if we had a 7 billion population, with the type of diet we have in this country would call for a 300 percent increase in productivity in the world, and I think that we could do that. I think that it is within the realm of possibility to make that happen.

But, in order to do that calls for almost a miracle in limiting population.

Now, in Taiwan and Formosa, we have had a recent demonstration of the principle that by raising economic well-being you can reduce the birth rate. As a result of Japan and the United States bringing in many commercial operations, industrial operations, bringing in the technology, the management know-how and capital, there has been a fantastic economic growth, something like 12 percent a year. During that same interval the birth rate has gone way down. To apply that same approach in countries like India, Pakistan, South America, Africa, is difficult indeed. Nevertheless, we need to see what we can do. I believe if we approach this thing properly the people in the developing countries would work with the developed countries cooperatively but it is going to take a lot of education, a lot of salesmanship. International regulations, I think, could help to bring this about. But population growth just has to get more attention. The way of life in this country will be markedly influenced as a result of the population explosion in the developing countries.

Chairman PROXMIRE. Mr. Peterson, thank you very much. You have been most helpful and we do appreciate your coming this morning. I think your testimony has been good; you have made a fine record which I appreciate.

The subcommittee will stand adjourned.

Mr. PETERSON. Thank you, Mr. Chairman.

[Whereupon, at 11:20 a.m, the subcommittee adjourned, subject to the call of the Chair.]

APPENDIX

STATEMENT OF E. F. ANDREWS, VICE PRESIDENT FOR MATERIALS AND SERVICES, ALLEGHENY LUDLUM INDUSTRIES, INC.

We Need Economic Stockpiling

The national stockpile is potentially one of the most valuable economic assets available to this country. A long-term plan for developing—rather than liquidating—our inventory of critical materials should be adopted without delay.

While it is true that the current defense-oriented hoarding of materials makes little sense in an era of nuclear weaponry, we need the economic leverage of raw material reserves more than ever. Our increasing reliance on overseas sources for basic commodities makes it almost mandatory that we set up some sort of domestic supply hedge.

In short, we should take advantage of our essentially meaningless defense hoard and convert it into a useful economic stabilizer—one with clout, one that would make foreign sellers think twice before capitalizing on our "have not" situation.

One thing for sure, there's ample precedent for this kind of approach. Indeed, look at all the GSA purchases and sales over the past 10–15 years and you find that virtually every single transaction was either economically or politically motivated. We haven't sold or bought for purely military reasons since the late '40s.

Other countries seem to be thinking along similar lines. Thus over the past year or so Japan, France, and West Germany have all started to develop economic stockpiles. True, these overseas moves have been limited, but they do seem to indicate a very real need for protection in a world where an increasing portion of a country's available raw material supply is located outside national boundaries.

The big pluses of any economic stockpile approach:

An insurance policy for American businessmen—buffering them against the wide range of foreign variables currently beyond their control.

Some modest dampening of cyclical price swings in the traditionally volatile raw material area.

Little or no cost to Uncle Sam—for stockpile selling would occur during peak markets, with subsequent replenishment during normal or even weak market periods.

Less speculation of futures markets—with stockpile tonnages serving to dampen gamblers' enthusiasm.

Somewhat lower inventories and on heavily imported items such as tin or chrome

I would, however, limit this economic stockpile to "have not" or negative materials, and would be opposed to including items where we are self-sufficient. There's no reason to stockpile items such as molybdenum where we produce more than we use. As such, I would sell all GSA held molybdenum and other "surplus" items as soon as conditions permit.

What about the possibility of prices of moly and other such items subsequently getting out of hand? We have enough domestic clout (via price curbs, wage controls, production incentives, etc.) to correct any such situation.

To take the stockpile route in such cases would be more expensive and probably a lot more inefficient. Why do things the hard way?

On the other hand, the stockpiling needn't be limited to nonferrous metals. Chemicals, minerals, hides, textiles, and other crucial materials could also be included. And if we didn't have insoluble storage problems the concept could be expanded to include even fuels.

As pointed out earlier, there is ample precedent for economically motivated stockpile transactions. The nickel disposals of the early '60s were made primarily to alleviate a shortage. Dito, the early '60 sales of molybdenum and vanadium. And both aluminum and copper have been sold to "cool" these two critical markets.

TWO-WAY LEVERAGE

Nor need all the economic leverage be exerted on the "sell" side. Thus in 1970, Uncle Sam purchased considerable quantities of titanium to keep open U.S. metal facilities.

How would you go about changing from a defense to economic stockpile? It needn't be all that difficult since we already have an existing reserve. A simple Act of Congress could do the trick—with perhaps the current defense-oriented Office of Emergency Preparedness (OEP) replaced by another OEP (Office of Economic Preparedness.)

The new OEP would then review current stockpile objectives from an economic vantage point—adding on or subtracting from existing miiltary stockpiles to meet new objectives.

What would the new economic criteria be based on? I would factor in such business-oriented variables as (1) U.S. consumption, (2) U.S. production, (3) the geographical location of foreign suppliers, (4) the number of alternate sources available, and (5) the economic and noneconomic leverage we might have on supplying countries.

Thus while we might be equally dependent on overseas sources for both nickel and tungsten, the nickle goal might be considerably lower than that for tungsten—because nickel comes mainly from friendly near-by Canada while tungsten comes from less-reliable, more distant China.

GUIDELINES

The economic objectives would of course have to be constantly reviewed—because of changing needs both here and abroad. But certain basic guidelines in stockpile purchases and disposals suggest themselves:

(1) Never dispose for export. The point to keep in mind: The stockpile is to protect us internally in situations where we lack self sufficiency. In short, don't give away what we don't have.

(2) Never dispose from the stockpile at a rate higher than the difference between consumption and production. If for example we consume 15-million lb. of tungsten but produce only 8-million lb.—we would never sell more than 7-million lb. Reason: Anything larger would be feeding a surplus into the domestic market.

(3) Never sell anything from the stockpile when the shortfall between production and consumption is available from normal sources at acceptable prices and conditions. In other words, buy abroad when the price seems fair.

(4) If and when material is disposed, it would be replaced at future dates when normal conditions again prevail. In other words, whenever feasible, let's try to keep the stockpile at around stated objectives.

If nothing else, an economic stockpile could eliminate a repeat of what happened in tungsten over the last decade. China, with 70 percent of the world's known supply, first drove prices down—and then when marginal operators in other areas of the world dropped out, the Reds zoomed the price way up.

Indeed, it was only the U.S. stockpile that saved domestic users from taking a bath. Note, for example, U.S. prices have moved in a relatively $10/stu range over the past decade—in sharp contrast to the $35–$85/stu range reported on the LME.

In any case, it was only when it became apparent that Uncle Sam was ready, willing and able to act that the Chinese began to change their tactics.

THE OBJECTIONS

True, there are some who would object to an economic stockpile on the grounds that it would tie up a lot of government money for the express purpose of aiding business. Some State Department officials also might object since it could conceivably antagonize producing nations.

And still others feel that it could be used as a club against either management or labor. But I believe that fashioning a TVA-type of quasi-government set-up or a body similar to the Federal Reserve Board, these latter misuses could be avoided.

In summary, increasing reliance on overseas sources is something we're going to have to live with—and if we don't do anything to help ourselves, nobody else will.

STATEMENT OF HAROLD J. BARNETT,* PROFESSOR OF ECONOMICS, WASHINGTON UNIVERSITY, ST. LOUIS, MO.

Energy, Resources, and Growth

A. RESOURCES, ENVIRONMENT, AND GROWTH

We inquire into the compatibility among economic growth, availability of natural resources, and quality of environment. By growth we mean possible increase in population and increase in output and consumption, both total and per capita. The questions are whether scarcity of natural resources and limits of environment increasingly impede growth, and whether economic growth uncomfortably presses upon the natural resource base and environment. What are the problems for society from such pressure, and what are their solution?

There are two forms in which natural resource problems may emerge. One is that we shall face diminishing returns or increasing costs as growing population numbers and consumption press upon the limited resource base. That is, economic welfare percapita will decline as additional numbers of people seek to wrest improved living from the limited resources. We might visualize this increasing cost problem as a *quantitative* reduction in welfare—that is, fewer goods and services for each member of the growing population [*1*, Ch. III].

We focus on real costs of resource products as the measure of economic scarcity and availability of resources, rather than on volumes of specific ore reserves or number of acres. Real costs measure the difficulty in getting resource products, in terms of labor and other inputs which must be diverted to such production. If real costs per unit of resource product increase, then we are less well-off, because we must work harder to have the same amount of goods. Or else we must reduce consumption of these or other goods. If real costs per unit of resource product decline, then, for any given volume of effort, the bounty on our tables and in our homes can be greater. Meaningfully we can say that resources have been economically more plentiful. In summary, the significance of a threat of resource scarcity is the prospect of higher real costs and fewer goods for our consumption and investment.

The second problem is that quality of our physical environment will deteriorate as it becomes polluted from increasing numbers of people and increased economic activity and wastes. Roughly, we can characterize the pollution problem as a qualitative reduction in welfare [*1*, Ch. XII]. The pollution problem contrasts with my case of diminishing returns or increasing costs just mentioned, which causes quantitative reduction in welfare. The distinction between quantitative and qualitative, however, should only be taken as suggestive. In fact, the question of whether we face increasing costs is *the* basic question. For example, inadequate quantities of goods could reduce quality of life by leaving us hungry; and large output could give us tools to improve environmental quality.

1. Resource availability and costs

I shall first report from a major study on the question of costs [*1*]. We examined economic growth from approximately the Civil War to the late 1950's in the United States, a period of almost a hundred years. The U.S. had very great population growth during this period, both from natural increase and immigration. We tested the historical record for the possible appearance of increasing costs in those economic sectors which depend strongly upon natural resources. That is, we examined into the cost of incremental products from the extractive sectors—agriculture, minerals, forestry—in an effort to learn whether in fact scarcity of natural resources had caused diminishing marginal returns to labor and capital during this period of great U.S. population growth. If so, then the unit cost of extractive products would be increasing. It would take more labor and capital to get each pound or ton or other unit of agricultural, mineral, and

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*I am grateful for suggestions and criticisms of my colleagues, Profs. A. Jones, D. Heathfield, P. Sturm, and M. Weidenbaum. None of them is responsible for the errors which remain. The paper relates only to the United States.

forestry products. We could not measure cost in dollars and cents since overall inflation or deflation would move these up or down irrespective of real costs. And so we measured costs of the extractive products in terms of days of labor and other input. We did this for agriculture, minerals, and forestry, and for individual products within each of these sectors.

In agriculture the cost per unit of products in terms of real units of labor and capital, after making appropriate allowance for purchased materials, declined. By 1957 it had fallen by more than 50% from the average real cost in 1870–1900. (In index terms, if we set real cost of a unit of agricultural product at 100 in 1929 then the level in 1870–1900 was 132, the level in 1919 was 114, and the level in 1957 was 61.) This decline is evidence *not* of economic resource scarcity and diminishing returns relative to growth, but of increasing returns. It says that we get our additional units of agricultural commodities at declining cost per unit—that we became richer, not poorer, in goods available. Figures 1 and 2 show the time series of labor cost per unit for various agricultural products. Declining cost is pervasive over the whole agricultural sector, contrary to the increasing scarcity hypothesis.

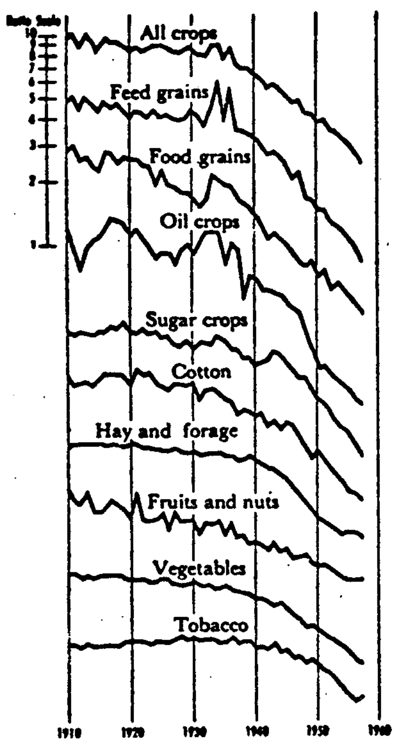


Figure 1 U.S. agriculture: labor cost per unit of output in all crops and nine major commodities, 1910–57

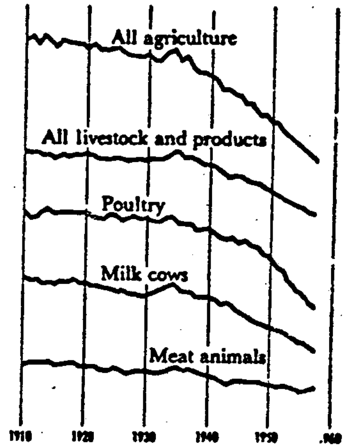


Figure **2** **U.S. agriculture: labor cost per unit of total output and of output of livestock and products, 1910–57**

Then we asked the same question for minerals. What has happened to the cost of mineral commodities as the nation has grown and mineral use has increased forty-fold? We find that here also diminishing returns did not appear. By 1957 the cost per unit of mineral products had declined by three quarters from the turn of the century. (The index numbers (1929=100) were 210 in 1870–1900, 164 in 1919, and 47 in 1957.) This evidence is strongly contrary to the concept of increasing economic scarcity of resources relative to growth.

Figures 3 through 5 present the data on labor cost per unit in all minerals, metals, and non-metallic minerals. Declining unit cost is pervasive, and is very rapid for some products.

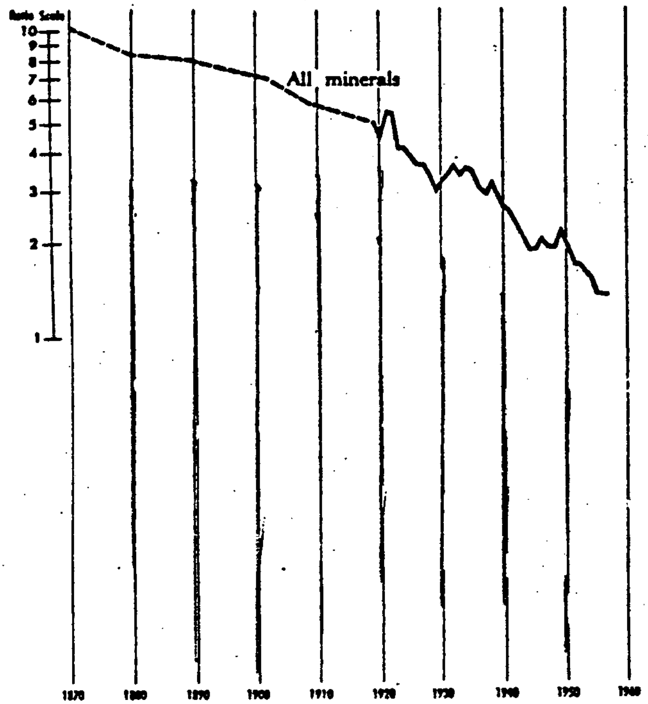


Figure 3 U.S. minerals: labor cost per unit of output, 1870–1957

Note: Solid lines connect points in annual series; dashed lines connect points over a year apart.

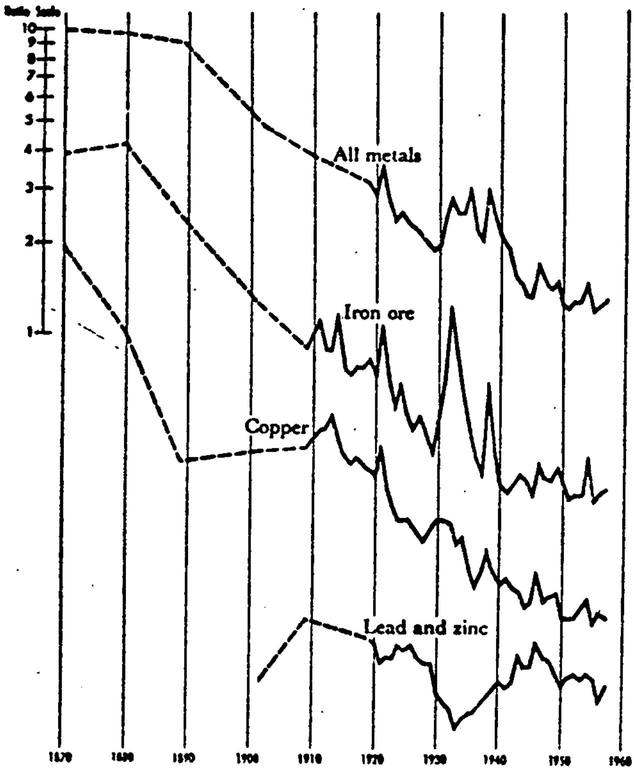


Figure 4 U.S. metals: labor cost per unit of output, 1870–1957

Note: Solid lines connect points in annual series; dashed lines connect points over a year apart.

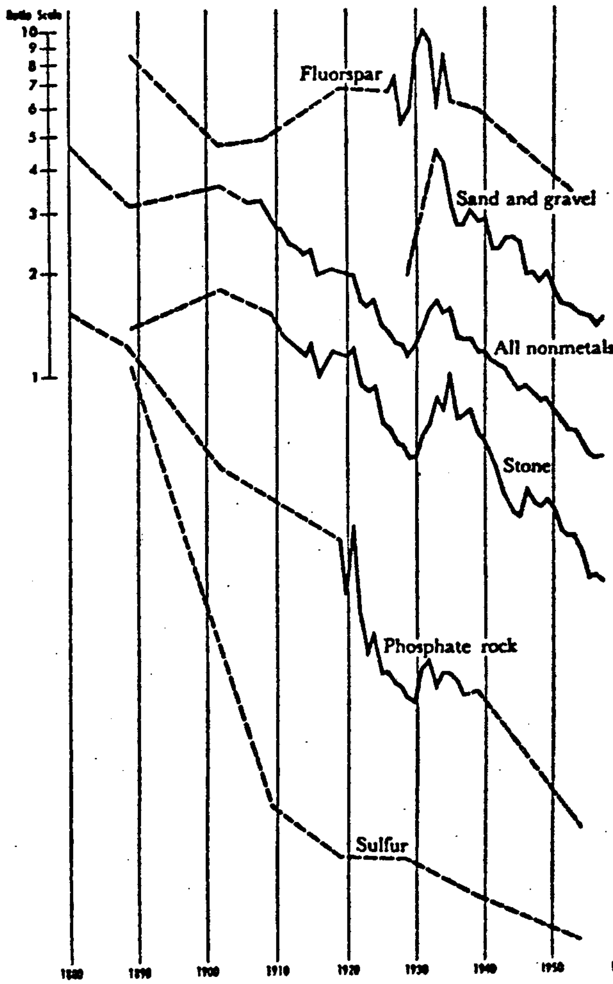


Figure 5 U.S. nonmetals: labor cost per unit of output, 1880–1957

Note: Solid lines connect points in annual series; dashed lines connect points over a year apart.

In forestry we *do* find an appearance of diminishing returns. As the economy grew, the cost of forest products, measured in days of labor and units of capital goods, with appropriate allowance for purchased materials, increased by approximately one-half from the late 1800's to 1957. The index numbers of forestry products cost were 59 in 1870–1900, 106 in 1919, and 90 in 1957.

If we appropriately combine all of these extractive products just described—agriculture, minerals, forestry—we can arrive at a measure of cost of extractive products as a whole. We made such a combination giving each of the sectors, and each of the products within sectors, their weighting of economic importance. The real cost per unit of extractive goods overall declines by more than one-half—i.e., the industry shows strong increasing returns, *not* diminishing returns. The index of the unit cost of extractive products (1929–100) falls from 134 in 1870–1900, to 122 in 1919, to 60 in 1957.

We then divided the period of almost 100 years from the Civil War to 1957 into two parts. We characterize the sub-period from approximately the Civil War to the first World War as one in which the physical U.S. was still expanding, even moving its frontier. It was not pressing strongly upon its resource base. We then hypothesize that the period from 1919 to 1957 was a case in which the nation's resource base was more fixed, in which there would seem to be less physical accommodation to growth. The results are surprising.

The favorable record of declining unit cost of extractive products *improves in the second sub-period* as compared with the first sub-period. In agriculture and minerals, the two major resource sectors, unit costs declined only moderately from 1870–1900 to 1919, but precipitously from 1919 to 1957. By way of illustration, in minerals costs declined by approximately 25% in the first sub-period and by about 70% in the second sub-period. Note the slopes of the curves in Figures 3, 4, and 5. Similarly, in agriculture the decline was less than 20% in the first sub-period, but almost 50% in the second sub-period. See the slopes of the curves in Figures 1 and 2. Forestry tells the same story of a more favorable record in the second sub-period, than in the first. In the first sub-period the unit cost index of forest products rises from about 60 to about 106, but in the second sub-period the unit cost index declined slightly, from 106 to 90.

These then are the results of a careful quantitative test of the "increasing scarcity hypothesis," that economic welfare is threatened by diminishing returns as population and output grow. In the U.S. this has not been true historically; and increasing returns, contrary to the hypothesis, in fact have accelerated since World War I. Still further the hypothesis falls most strongly in the case of minerals, where it could have been reinforced by depletion.

Why has the diminishing returns hypothesis been wrong in the U.S. during the period of my study and, from a preliminary review of the evidence, to the present? Essentially the reason is that the progress of civilization persistently improves the availability of resources in economic terms. *As measured by real cost, resource availability improves exponentially, at a rate of several percent a year.* This more than offsets exponential growth in population and percapita consumption. Unit costs of agricultural goods have declined as rapidly as unit costs in the overall economy, and unit costs of minerals have declined even faster. See Figures 6, 7, and 8.

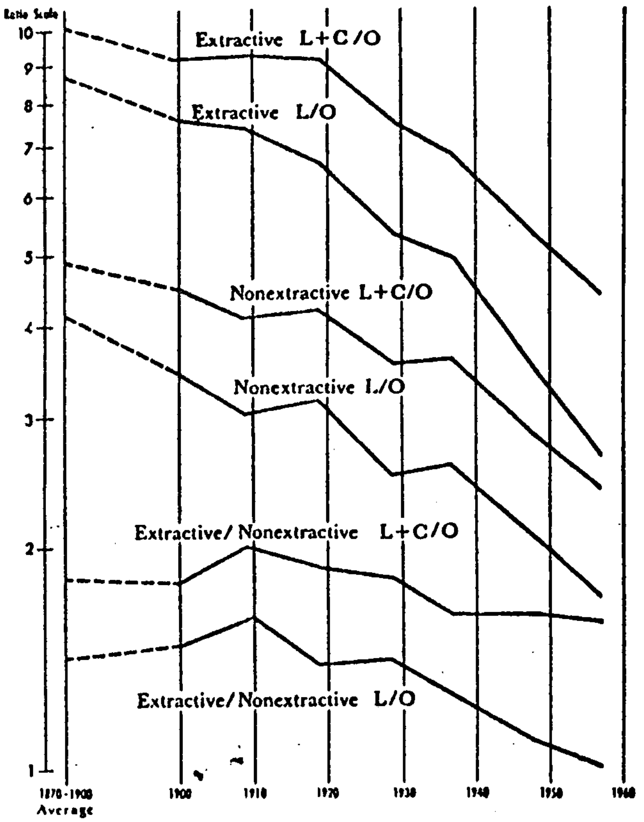


Figure 6 Trends in the cost per unit of extractive output relative to nonextractive output in the United States, 1870–1957

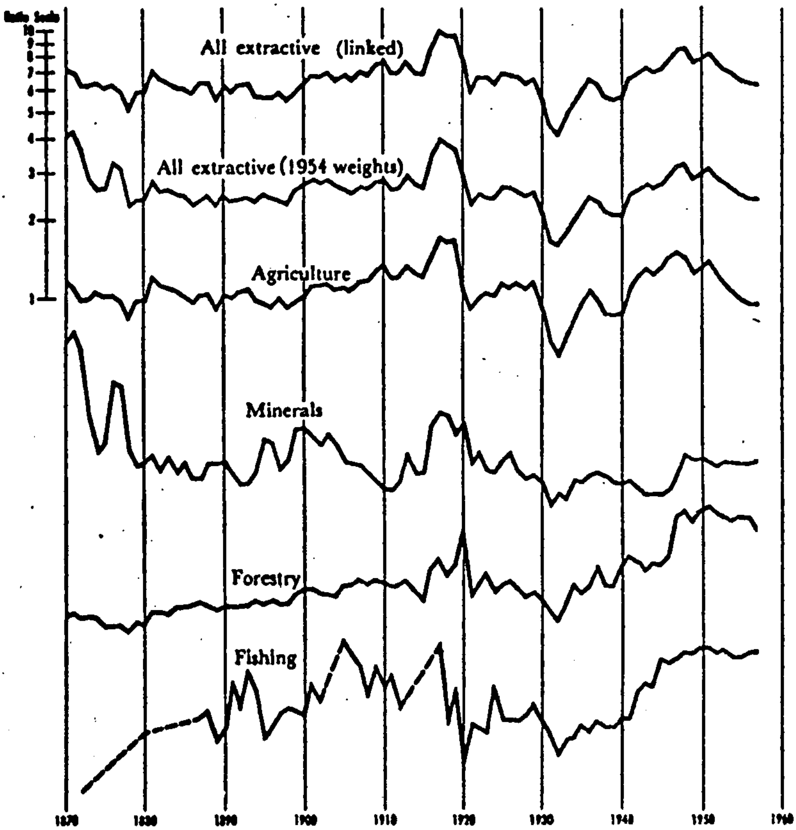


Figure 7. Trends in unit prices of extractive products relative to non-extractive products in the United States, 1870–1957

Note: Solid lines connect points in annual series; dashed lines connect points over a year apart.

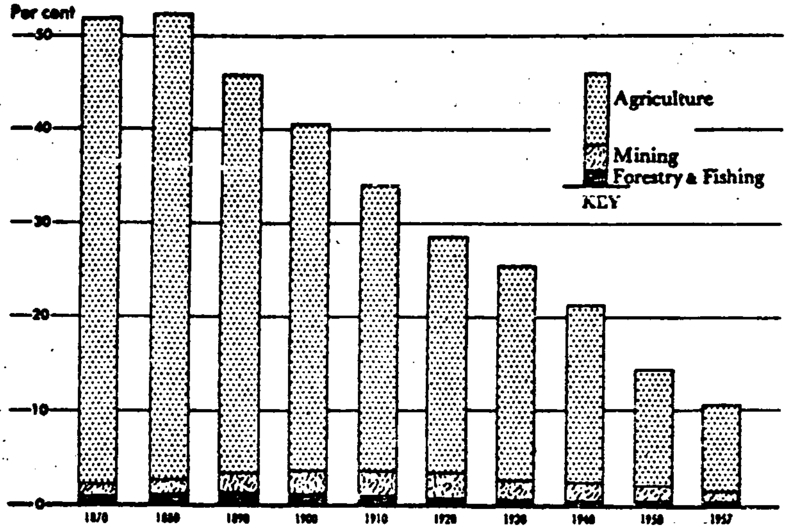


Figure **8 U.S. extractive workers as a percentage of all workers, 1870–1957**

So much for the historical record, and failure of the hypothesis that economic growth and sufficiency of natural resources are incompatible. Now I want to consider the future—the outlook for U.S. growth, resources, environmental quality and costs during the next 30 to 50 years.

Since World War II there have been three very major studies in these areas: the 5 volume Report of the President's Materials Policy Commission (Paley Commission), which projected resource availability and costs to 1975 [*16*]; the massive Resources for the Future study of 10 years ago, which projected resource availability and costs to year 2000 [*10*]; the 1972 research report of the President's Commission on Population Growth and the American Future (Rockefeller Commission), which projected resource availability and costs, pollution, and costs of pollution abatement to the years 2000 and 2020 [*14*]. And we also have the important Third Annual Report (1972) of the President's Council on Environmental Quality, which projected costs of environmental improvement to 1980 [*15*].

The major findings of these rather large studies relevant to our topic are these:

(1) There are strong propensities toward economic growth in our economy. The tendency is for growth in output and income per capita of 2 to 2½ percent a year.

(2) The tendencies concerning population growth are more ambiguous. Projections range from 2.1 to 3.1 children per woman. The first figure, 2.1 children, is equivalent to zero population growth; 3.1 is equivalent to population growth at 1½ percent per year.

(3) Extractive products—agricultural, mineral, and recycled materials—will be available in sufficient quantities to sustain such economic growth, without significant increases in real costs. That is, resource availabilities in economic terms are expected to keep pace with increases in demands. There will be substitutions away from commodities with unfavorable cost trends toward more favorable commodities. Overall resource availabilities will accomodate increased demands without slowing growth.

(4) Active policies of pollution abatement will be successful and expensive; but they can be accomodated without significantly slowing rates of economic growth.

2. Environmental quality

I now elaborate on the question of pollution abatement and environmental quality, drawing upon the recent research by the Rockefeller Commission and the Council on Environmental Quality [*14*, *15*]. In 1970, annualized costs of pollution abatement, both public and private, were about $10 billions. At this level of outlay the public believed it had unsatisfactory levels of stream, air and land pollution. Moreover, if the policies and technology of the 1960's continued to the year 2000, air pollution emissions would *triple and* stream pollution emissions more than *double* as the economy grew. Two or three times as much emissions into the air and water which envelop us as in 1970 would be quite unacceptable to most of us.

Prompted by this outlook proposals have been made or accepted for more active abatement policies. These are officially put forward in the 1973 water and 1975–76 air emission standards recommended by the Environmental Protection Agency (EPA). They are all technologically very feasible without any dramatic technical breakthroughs. But of course they entail costs, rather substantial costs.

In annual terms such policies would raise abatement costs from the $10 billions in 1970 to about $30 billions in 1980. Costs would then rise to $35 or $45 billions per annum in the year 2000, depending on the rate of population growth. Put another way, pollution abatement costs would rise from 1 percent of the nation's output (as in 1970) to 2 or 2½ percent. Large though these figures on pollution abatement costs are in absolute terms, they are small relative to our economic growth. We would have to give up only a tenth of a percentage point in annual growth of national output to pay for this active abatement policy [*14*, p. 26].

What would we get for this large absolute but small relative payment? As compared with pollution generated and emitted in 1970, we would get:

86% reduction of particulates put into the air; 65% reduction of hydrocarbons; 40% reduction of oxides of nitrogen; 75% reduction in biological oxygen demand in streams; 80% reduction in suspended solids; but 110% increase in dissolved solids.

As noted, these figures on environmental improvement in year 2000 result from applying standards which have been adopted or are being recommended by EPA in public policy for introduction by 1975–76. The probable situation is more favorable than I have described. Some technical breakthroughs in pollution control are likely to occur (as they have in the past), some cost reductions will occur, and improved policies can be adopted as necessary.

In summary, improvements in environmental quality of air, streams, and land are quite compatible with economic growth. Indeed, once we accept that we do not face diminishing returns we see that growth in per capita income and improvement in technology provide the social interest and the economic and technical means to seek improvement in the environment.

3. Comments on Forrester-Meadows (F–M) thesis.

A diametrically opposed thesis has recently been presented by a group of computer specialists, led by J. Forrester and D. Meadows and seponsored by the Club of Rome [*9*, *11*]. In this view, Mankind now faces Doomsday. We are fast running out of agricultural and mineral resources, rapidly poisoning ourselves to death by pollution, and crowding ourselves to suffocation. Moreover the crisis of near extinction is virtually unavoidable. These adverse developments reinforce each other, and some, such as excessive birthrate, exert baneful effects over very long periods. Mankind is very near to the point of no-return, if indeed we have not passed it. How do I reconcile my own views and data, persented above, with those of Forrester-Meadows? [See *6* for major book reviews.]

F–M do not present detailed support for their conclusion. In essence, they present, rather, a classical, mathematical idea of grandeur, ultimate truth, and absolute power. It is that no world of physically finite resources can contain physical resource pressures if these expand exponentially through infinite time. When viewed in the cosmic perspective of the beginning of creation to the end of Man's time, there is little ground for quarreling with this view. The Forrester-Meadows error is to assert that this ultimate truth is relevant and specifically descriptive for present and near-term societies. They give no evidence, nor even indication that they are aware of relevant knowledge, analysis, reading or data.

F–M further trap themselves in a minor notion of limited validity, which is also inapplicable to contemporary human society. This is the concept that an exponentially growing social variable approaches a ceiling at full speed, without brakes. It smashes at the ceiling limit and then catastrophically declines. This is not a general truth. It is at variance with evidence of social resilience and adaptation. For example, in economics, when supplies of a commodity become short, we shift to others; in engineering, when a technology becomes obnoxious, we choose another; in politics, when a ruler's power becomes oppressive, we neutralize him or remove him peacefully or by force. "Collapse models" do not characterize modern societies.

A third F–M error is in the definition of the mineral and agricultural resource limits which are relevant for economic analysis. F–M fail to see that economic resources must be measured in economic terms, not in acres or tons. They assert, for example, that mineral resource availability is limited to the stock which was known in 1900, and is likely to last 250 years. This is not economically sensible. Real costs of incremental supplies and of substitutes and alternatives determine resource availability, not acres of Iowa farmland, or tons of Arkansas bauxite, or pounds of egret feathers or whale blubber, or board feet of Virginia cherry wood [*1*, Ch. VIII; 6]. Had F–M seen that the economic limits relate to costs and substitutes, they would have found that resource availability has been improving, rather than the reverse, and that economic welfare has been advancing. See Figures above. In the year 2150 there will be more economic resources available than in 1973, as in 1973 there were more than in the year 1900. Knowledge, technology, capital and need create resources [*1*, Ch. XI; 10]. Using F–M methodology, a study performed in 1700 would probably have shown that Mankind would have exhausted resources by 1900!

A fourth error is the absence of economic thought and evidence from their economic analysis of pollution. They think that pollution control will persistently require sharply increasing costs, absorbing ever increasing fractions of the national product. They think that these costs may be beyond our capacity to bear, with the result that length of life will decline. The fact, as shown earlier, is that only small fractions of the annual *increase* in output will be required to maintain environmental quality. We can have both cleaner aid and water *and* enlarged economic welfare. [*1, 14, 15*].

Finally, in summary, F–M fail to see the full significance of technological advance, in association with affluence, enlarged capital and knowledge, improved labor, and substitutions among inputs and products. They see only that technology spawns more products, more capital, more waste discharge and crowding. They have not noticed that technology and affluence also provide desire and means to limit births; to maintain or improve environment; to create and supply substitutes for scarce agricultural and mineral resources; and for avoidance of other resource limits as these become visible. Moreover, our improved technology and productivity have been growing exponentially, and the rate gives no signs of retardation.

B. ENERGY AND GROWTH

We turn now to questions of energy and growth: Does energy have any special significance in the connections between natural resources and growth? How do energy demands relate to growth? What has been the historical trend in real costs of energy? What is prospective availability of energy for economic growth; is it likely that U.S. economic development will be impeded by energy scarcity? Does our analysis yield insights into some of the energy questions which have become prominent during the past few years?

1. Special significance of energy

Many people, perhaps most, feel that "energy" plays a very special role in society. The very concept of "energy" is a broadranging one. It is pervasive in basic drives for food, activity, sex, and rest; fundamental in physics and engineering; major in technological change, industrial development, and substitution of inanimate energy for the strength of men and beasts; and a keystone in our comfort and convenience—at home, in our vehicles, in our recreation, and in our meeting and working places. In each of these various respects "energy" is important. And the importance is magnified by semantics. We use the same words for varied phenomena, and the sense of importance in each "spills over" to all the other meanings of energy.

Beyond these generalizations energy has a special significance in our concerns over natural resources and economic growth.

Consider minerals production. We normally prefer to extract out metals, materials, and chemicals from high grade ores—i.e., from ores with large percentages of the desired elements. We prefer ores of 5 to 15 percent copper, 60 percent iron, and bauxite over leaner ores. Also we prefer ores which are easily accessible—on or near the surface, close to consuming centers, on dry land, etc. But the fact is that low grade, distant, and less accessible ores and sources can be economically utilized if technology, capital stock and energy availability permit. In this sense, energy availability is a key to whether we avert minerals scarcities. Energy has played an important role in averting natural resource scarcity, as we have substituted taconites and porphyrys for higher grade iron and copper ores. In the same sense, energy is key to going to much lower yield materials, indeed down to the plenitude of metals in sea water solutions and ordinary rocks of the earth's crusts [7].

Now consider food and fiber production, and possible scarcity of agricultural land. Food and fiber plenitude can be assured provided there is adequate availability of minerals and chemicals, energy capital resources, and a vital technological environment. And so, to avoid food and fiber scarcity, energy availability plays a key role as it did for minerals and chemicals. Already in our present society, energy and chemicals have made possible enormous increases in land productivity of food supplies. If the U.S. had to rely on work animals for its farm "horsepower," their feed might require 15 to 30 times as many acres of cropland as are cultivated today. If synthetic fibers from energy and minerals were replaced by cotton, the additional land required would exceed acreage now planted to cotton.

Beyond energy's role in processing leaner ores, providing chemicals and nutrients for agriculture, and in substituting for agricultural land, energy is indispensable in yet another aspect of economic growth. In economic growth, capital goods are substituted for labor in production processes. Capital goods require energy input, heat or power, to operate. The substitution of capital goods for labor implies a substitution of inanimate energy for men and beasts. Here also we have a sense of a special significance of energy availability.

And in still another sense we tend to think that energy plays a unique role in economic growth: in meeting the direct demands of the consumption sector. We think of automobiles and air travel, temperature control in buildings, TV and other household appliances.

These are some of the reasons that concerns for availability and real costs of energy grip us strongly. It is generally appreciated that our market system, technological know-how, and ability to provide capital goods work strongly to avert natural resource discontinuities during economic growth. An important question is whether energy availability can support and accomodate the processes of change and growth.

2. Energy demands to 1965

The foregoing generalizations suggest increased intensity of energy use during economic growth. This is because of recourse to lesser grade or access of minerals and land, need to heat and drive enlarged producer facilities, substitution of energy for men and animals, and energy for household and vehicle consumption. These suggest that economic growth tends to require more than proportionate growth in energy use [7].

This was general belief and my own initial hypothesis in the late 1940's when I first investigated U.S. energy use relative to national product (real Gross National Product or GNP). However, my 1950 research monograph revealed surprising results, and uncovered a relationship which apparently had not been ascertained before. *Over a quite long period, beginning at least about the time of World War I. U.S. energy use grew less rapidly that real national output.* I projected this would continue during the next generation [2].

The ratio of Energy/National Product (GNP) is shown in the solid line of Figure 9, reproduced from the original monograph [2, Chart D]. The decline in energy use per unit of national output was quite persistent over more than 3 decades, at a bit less than 1 percent per year; but there are also irregularities, such as a subnormal level in World War II and a rise in 1947 [2, p. 6].

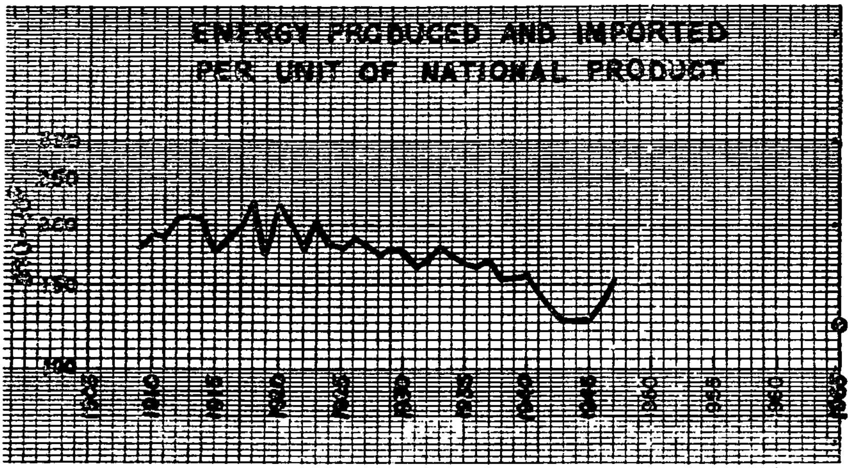


FIGURE 9

I revised my initial judgment and hypothesis about as follows. The level of energy requirement was primarily determined by the level of real GNP. It was indeed subject to increase from the circumstances described above. But not all of the technical changes and substitutions of energy for other inputs act to increase energy per unit of product. Some of the innovations were "output-increasing" or "energy-neutral" or even "energy-saving." Moreover, the ratio of energy to GNP was subject to secular fall because of efficiency gains in energy utilization. These included advances in combustion efficiency, use of insulation, higher temperatures, utilization of exhaust heat, etc. Since the most modern energy techniques at the time of my study (1948–1950) were much more efficient than the average of energy use techniques in use, I thought it possible that the downdrift in the use of BTU per unit of national product might well continue. Obviously an omnibus mechanical projection would not be economic analysis. The bulk of the monograph cited was an effort to decompose the energy aggregate. I projected to 1965, separately, the demands and efficiencies of each of the several energy consuming sectors for each of the several energy commodities, with appropriate regard for economic characteristics [2, pp. 6–47 and tables 1–28; also see 4 re projections generally].

The results of the individual projections from 1947 to 1965 appear in some hundreds of figures relating to energy functions, consuming sectors, activity in consuming sectors, energy commodities and energy efficiency [2, Tables 26, 27, 28]. After these were all tabulated and combined, they gave an increase in demand for energy commodities only about half as great as the contemplated increase in national product. In effect, the projections resulted in a ratio BTU÷real national product indicated by a small circle, "o".

The forces leading to improved efficiency in energy utilization, as projected for 1965, including dieselization of railroads, quite overcome the tendencies toward increased energy utilization by households, electro-metals and electro-chemicals, and from other causes. With the passage of a generation, the *actual* 1965 figure for BTU/GNP turned out to be within 1 percent of my projected figure. By 1965 the BTU/GNP ratio had declined to about 78 percent of 1947. (However my total energy consumption projection was much too low, from error in estimating that real GNP growth would be 3 percent per year; the actual was 4 percent per year.)

3. Prospective energy demands

All of the foregoing concerning the BTU/GNP ratio is prelude to the question of present and prospective demands for energy. Should we expect energy demands to continue to grow more slowly than real GNP as they did for the half century following World War I? If so, then the drain against the long-term supply surve of energy will be moderate. Energy would have to increase by only 3% per year to accommodate a national product growth rate of 4 percent. Or should we expect that the long-term BTU/GNP relationship has changed, and that energy demands will grow as fast as or even faster than national product?

The question has given added force since 1967 because in that year the BTU/GNP ratio turned upward and continued to increase during the next few years. The ratio increased by a total of 10 percent during about four or five years. Does this rise manifest a reversal in the long-term declining trend, or is it merely a short-term phenomenon?

The significance of concern over the BTU/GNP ratio can be made clear by the following numerical illustration in Table 1. Assume real GNP growth of 4 percent per year from 1970 to the year 2000. This is a figure now conventionally used in economic projections and is approximately equal to U.S. experience during the past generation. Now observe the results in the following table, depending on whether the BTU/GNP ratio declines by about 1 percent per year as in the long-term trend; or holds constant; or increases by about 2 percent per year, as it did between 1966 and 1970:

TABLE 1.—ALTERNATIVE LEVELS OF ANNUAL U.S. ENERGY CONSUMPTION (ASSUMING REAL GNP INCREASES AT 4 PERCENT PER YEAR, 1970–2000)

	1970 (actual) 10^{15} Btu	2000 (projected) 10^{15} Btu	Percent increase, 2000 over 1970
If Btu/GNP declines at 1 percent per year from 1970 to 2000	67.4	162	140
If Btu/GNP is same in 2000 as in 1970	67.4	219	225
If Btu/GNP increases at 2 percent per year from 1970 to 2000	67.4	396	488

As the table shows, the need for energy availability is 2½ times as great under the latter assumption as under the first. The *increase* in annual needs is 3½ times as large in the latter case as in the first. Which BTU/GNP ratio we use in our estimating equations really does make a very large difference for the question of energy demands and the availability of energy supplies to satisfy them. The differences in results from the alternative BTU/GNP ratios are much greater than our probable error in projecting GNP.

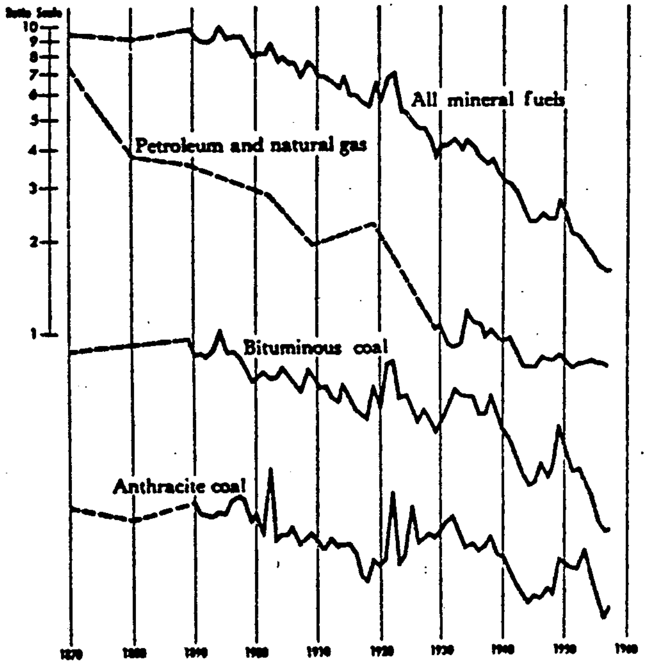
I have not carefully analyzed the details of energy demand in the past 2 decades, nor have I made detailed energy projections since my 1950 study referred to above. But I can offer views based on the lesser evidence available to me. First, the four years of rise in the BTU/GNP ratio justify questions but not a conclusion of reversal in a 50 year trend. It is simply a very short period; and on several previous occasions the BTU/GNP ratio has turned briefly upwards. Already, preliminary 1971 figures show a slight decline from the 1970 ratio. Second, a number of unusual events occurred in this four year period to cause a temporary increase in the BTU/GNP ratio. For example, a shortage of electric power capacity caused heavy use of inefficient stand-by and peaking facilities; and initial difficulties with large generators caused reduced and inefficient utilization, relative to modern design. Third, two detailed projections by the Department of Interior along the lines of my earlier projections study, in which each sector of demand is estimated separately, indicate a decline in the overall BTU/GNP ratio [*8, 12*].

At this time I conclude that it is more probable that the BTU/GNP ratio will decline or be constant during the next generation than that it will rise. I do no expect the rate of increase in energy demand to exceed that of real GNP.

4. Energy real cost, historical

As we did in the earlier section of this paper we can address economic availability by examining real costs. That is, we look at what it costs in labor man days to get energy output.

Figure 10 shows what we found. [*1*] The story is the same in fuels as it was for other minerals. Labor input per unit of fuel has declined in each of the fuel commodities, although more slowly in anthracite than in bituminous coal, petroleum, or gas. The cost in man days per unit of energy output in 1957 is less than one-fifth of the 1900 level. Scarcity in long-term economic availability of mineral fuels as measured by real cost has not occurred in U.S. economic history.*



U.S. mineral fuels: labor cost per unit of output, 1870–1957

Note: Solid lines connect points in annual series; dashed lines connect points over a year apart.

FIGURE 10

Our interest, however, is not historical, particularly in view of the current and alleged future energy crisis. And so we now turn to the question of long-term availability of energy supply and its accommodation of economic growth.

5. Energy availability: Long-term supply

It is useful to distinguish at this point the economic concepts long-term supply vs. short-term supply.

Short-term supply is what would be forthcoming at various prices from existing energy facilities (mines, well, tankers, etc.) and the present labor resources which are suitable and readily available. In the energy industries short-term supply tends to be rather inelastic, except for off-peak demand in utilities, and in mines and wells operating below capacity. A good part of the present energy difficulties is short-term supply deficiency, due to limited energy producing capacities and the recent prohibitions in use of high sulfur fuels. Here, as indeed in the entire discussion so far, I concentrate on long-term supply and availability and do not consider the short-term.

*The measure of output is "net"; that is, gross output has been adjusted downward to allow for (exclude) purchased materials. I would have preferred to include capital as well as labor in calculating real cost per unit of energy output. But suitable data on real capital inputs were available only for larger industry aggregates, such as agriculture, minerals, and the overall extractive sector. See Reference 1, Ch. VIII, particularly the charts. These show that labor plus capital cost per unit of net output declines as persistently as labor costs, but a bit slower, in each of agriculture, minerals, and extractive industry overall. The upper two curves in Figure 6, above, relating to the extractive sector overall, show the characteristic relationship between labor plus capital cost and labor cost alone in the sectors for which we have data.

Long-term energy supply is what would be forthcoming after completion of new facilities—construction of refineries, tankers, and electric power plants; exploration and development of new mineral resources; recruiting and training of labor force; and technological advances which are visible or suspected on the horizon. The gestation of new facilities in energy is rather long. It takes up to 15 years for such things as nuclear power plants, development of new oil resources and transportation in remote regions, development of new mines, etc. In energy we might roughly characterize the short-term as (say) 5 years or less, the long-term as (say) 15 years or more, and view the range from 5 to 15 years as an intermediate gray zone. There is no sharp dividing line between short-term and long-term nor even of the intermediate zone in so large and complex a sector as "energy." It would be reasonable also to say that the intermediate zone between short and long is the range from 3 to 20 years.

Our question, now, is "what is the availability of energy supply for economic growth over the long-term of 15 to 50 years?" Numerous studies of this question have been made during the past generation or so.

The early investigations—Barnett (1950), Ayres and Scarlott (1952), Paley Commission (1952), Putnam (1953), and Brown (1954, 1957)—projected demand and supply to 1965 or 1975 or somewhat beyond and found energy resource supply quite elastic. The major studies of the 1960's, such as those by Schurr, Netschert et al. (1960), Landsberg, Fischman, Fisher (1963) and Morrison and Readling (1966), projected energy demands and supplies to year 2000 and/or intermediate points, and also found elastic energy supply. Contemporary studies by National Petroleum Council (1972), Dupree and West (1972), and Darmstadter (1972) project to year 2000 or beyond and find the same results. Virtually all of the competent studies find physical availability of energy ample to meet U.S. demands over the long-term periods considered here. Of course, most of them also identify possible social policy problems, relating to foreign trade, conservation programs, monopoly forces, tax policies, national security, innovations, etc. But there is no doubt in these studies of physical resource sufficiency within present and prospective technology adequate to meet projected U.S. demands.

In most of the serious applied economic research, it is not useful to project beyond 50 years, if so far. The uncertainties are too great. Wholly unforeseen developments can enter. Nevertheless there is interest in the question of energy adequacy in the coming centuries aid millenia, and I'll contribute a few words at this level of speculation.

The famous Pinchot and related writings of the Conservation Movement were pessimistic on energy sufficiency:

"We have anthracite coal for but 50 years, and bituminous coal for less than 200. Our supplies of iron ore, mineral oil, and natural gas are being rapidly depleted, and many of the great fields are already exhausted [*13*, pp. 123–24; *1*, Ch. IV]."

The appearance of controlled nuclear energy has changed this outlook. The available energy resources in uranium and thorium are many times larger than in coal, oil (including shale and tar) and gas. And, because of the character and plenitude of fission materials, cost per unit of power produced would tend to be constant or, more likely, decline from the occurrence of technological advances. There is also solar energy to supplement fission power in space heat. And even beyond fission power and solar energy, "There is in the long run the possibility of producing power from thermonuclear reactions—from fusion of hydrogen as distinct from fission of uranium. No one as yet sees very clearly just how this is to be done, but it is nevertheless a very real possibility." [7, p. 111–1]. With the waters of the sea as the source of hydrogen, there would be no practical natural resource limit to the availability of energy.

C. CLOSING COMMENTS

1. Concerning environmental quality

I have presented in stark and simple form the historical and prospective answers on whether economic growth is compatible with a fixed natural resource base. I have also answered on whether growth is compatible with maintenance and improvement of the quality of the natural physical environment. From the physical and economic cost circumstances there simply is no reason why economic growth cannot proceed. There is no prospect of diminishing marginal returns to real inputs of labor and capital in the acquisition of extractive goods.

And there is no necessity for decline in the quality of the natural physical environment from air pollution, water pollution, and solid waste disposal. Growth, adequate resource availability, and a healthful environment are all fully compatible, if society has the will and the wit to solve the related social problems. Our problems are not in economic or physical incompatibility of growth, environment and resources.

Our so-called problems of growth and environmental quality are really a melange of *social* problems:

The fact that the market economy and the government sectors do not properly assess the costs of pollution when the environment is free for the dumping of wastes;

The fact that there is incompatibility between our traditional strong individualism, on the one hand, and the popular support of greatly enlarged central political decision-making, on the other;

The fact that monopoly forces and market controls are growing rapidly in the natural resource sectors, and these are damaging rational decisions, efficiency, and social relations;

The fact that we are confusing natural resources and environment with quality of life.

On this last point, I offer two lovely quotes and a closing comment.

"The grass is rich and matted, you cannot see the soil. It holds the rain and the mist, and they seep into the ground, feeding the streams in every kloof. It is well tended, and not too many fires burn it laying bare the soil. Stand unshod unshod upon it, for the ground is holy being even as it came from the Creator. Keep it, guard it, care for it, for it keeps men, guards men, cares for men. Destroy it and man is destroyed." (Alan Paton, *Cry the Beloved Country*).

"For man is of a quickening spirit and the earth, the strong, incoming tides and rhythms of nature move in his blood and being; he is an emanation of that journeying god the sun, born anew in the pale South and the hollow winter, the slow murmur and the long crying of the seas are in his veins, the influences of the moon, and the sound of rain beginning. Torn from earth and unaware, without the beauty and the terror, the mystery, and ecstasy so rightfully his, man is a vagrant in space, desperate or the inhuman meaninglessness which has opened about him, and with his every step becoming less than man. Peace with the earth is the first peace." (Henry Beston, *Herbs and the Earth*).

We seem to be pouring into the environmental quality bottle all our individual and social yearnings for peace, stability, and quiet; for social justice in the world; and for more meaningful lives. To these we have added our passions for reform of values and improved quality of life generally; and our antagonism toward modern industrial growth and abuses by private enterprise. We may be misled by the beauty and simplicity in the quotations. Environmental quality is only part of our problems, not the whole of them [*3*, *5*].

2. Concerning energy

There are two major energy problems, in my view.

The oil and gas industry, nucleus in the overall energy market and gradually absorbing it, is the greatest aggregation of effective economic and political industrial power which the world and nation have ever known. With only minor lapses, market and political power has been persistent as in no other major industrial sector for almost a century. It began in the days when Rockefeller created the first great U.S. industrial "trust." It continued through the period of international "oil diplomacy"; throughou domestic cartelization by oil companies. Texas, and the Federal Government; through 1957, when Britain and France opened a war in the Middle East to preserve oil supply and Suez transportation; through almost two decades of quotas on U.S. oil imports, at cost to consumers in excess of $5 billions per year. The most recent measures involve "muscling in" on and increasing oil monopoly profits by Middle East and other export countries, the State of Alaska, and the Government of Canada; and reaping enormous economic rents in natural gas by these countries, the Soviet Union, and domestic natural gas producers. The unique qualities of political and economic power in the oil and gas industries abroad are indicated by their partnerships with national governments in the United Kingdom, Netherlands, France, Italy, Japan and other countries, and the U.S. by unusual influence in the Federal Government. The latter includes leading powers in the Congressional establishment and committees; depletion and other tax subsidies beyond those of other industries; major and special advisory and staffing roles in the National Petroleum Council, Interior Department Offices of Oil and Gas, Petroleum Administration for War and

Petroleum Administration for Defense (independent of WPB and DPA which controlled *other* industries during World War II and the Korean War, respectively), Cabinet Committee on Energy Policy, and other agencies—all of these with senior, high quality, dedicated, patriotic people who firmly believe that what is good for the oil industry is good for America.

There are many difficulties visible in the overall energy market. They include environmental pollution, mine safety, capital supply, perfection of synthetic technologies, and expansion of electric power capacity, among others. In all of them we could work out rational, sensible solutions which are consistent with a goodly degree of economic and political freedom. But we cannot be confident of the outcome when we look at the super concentrations of monopoly economic and political power in oil producing companies and governments, and the trend of increase in such power. Currently, for example, the petroleum cartels—governments and companies—are taking advantage of short-term crises and rapidly escalating monopoly gains. Energy prices are being raised in extraordinary degree, far above real costs, now and for the future. This is one energy problem.

The second major problem began 30 years ago and intensifies year by year: the accumulations of potent nuclear materials. Already the "nuclear club" has expanded from two to six or more nations with respect to nuclear weapons and their wastes. The world is hostage to the judgement, wisdom, and sanity of increasing numbers of political and military leaders in avoidance of use and accidents. Now we are moving to a very large and wide-spread use of nuclear power. The numbers of fission and hot waste sites and the volumes of materials will expand enormously. All nations are joing this club. The probabilities of accidents escalate. But, even more, the probabilities of illicit use of weapons and wastes increase. In scores of nations subject to thousands of leaders in each century there will accumulate great stocks of nuclear weapons, fission materials and hot wastes, potent for an hundred thousand years.

How to use nuclear energy and yet avoid nuclear catastrophes—this is the second energy problem.

REFERENCES

(*1*) H. J. Barnett and C. Morse, *Scarcity and Growth*, (Baltimore: Johns Hopkins University Press for Resources for the Future, 1963, 1965.

(*2*) H. J. Barnett, *Energy Uses and Supplies—1939, 1947, projected 1965*. I.C. 7582 (Washington, D.C.: U.S. Bureau of Mines, 1950). The monograph with minor additions subsequently became Chapter IV, pp. 70–168, in H. J. Barnett, *Atomic Energy In the United States Economy*. (Harvard University, unpublished doctoral dissertation, 1952.)

(*3*) "Environmental Policy and Management," Social Sciences and the Environment, ed. M. Garnsey and J. Hibbs. (Boulder: U. of Colorado Press, 1967); "Pressures of Growth Upon Environment," *Environmental Quality in a Growing Economy*, ed. H. Jarrett (Baltimore: Johns Hopkins University Press, 1966).

(*4*) "Natural Resources in the Changing U.S. Economy," *Planning for Diversity and Choice*, ed. S. Anderson (Cambridge: M.I.T. Press, 1968); "Specific Industry Output Projections," *Long Range Economic Projections* (Princeton National Bureau of Economic Research and Princeton University Press, 1954).

(*5*) "Population Problems: Myths and Realities," *Economic Development and Cultural Change*, July 1971; "Population and World Politics," *World Politics*, July 1960.

(*6*) R. Boyd, "World Dynamics: A. Note," *Science*, Aug. 14, 1972, pp. 516–519; H. J. Barnett, "Book Review of World Dynamics, by J. W. Forrester," *Journal of Economic Literature*, Sept. 1972, pp. 851–854; R. Gillette, "Book Review of Limits to Growth by D. Meadows and Others," *Science*, March 10, 1972, pp. 1088–1092; T. Humphrey, "The Dismal Science Revisited," *F. R. Bank of Richmond Monthly Review*, March 1973, pp. 2–13; C. Kaysen, "The Computer that Printed Out W*O*L*F*," *Foreign Affairs*, Vol. 50, July 1972, pp. 660–668; A. Kneese and R. Ridker, "Book Review of *Limits of Growth*, by D. Meadows and others," *Washington Post*, March 2, 1972; T. Oerlemans, M. Tellings, & H. DeVries, "World Dynamics: Social Feedback May Give Hope for the Future," *Nature*, Aug. 4, 1972, pp. 251–255; M. Shubik, "Book Review of World Dynamics, by J. W. Forrester, *Science*, December 3, 1971, pp. 1014–15.

(*7*) H. Brown, J. Bonner, J. Weir, *The Next Hundred Years* (New York: Viking Press, 1957, 1963); also see Brown, *The Challenge of Man's Future* (New York: Viking Press, 1954).

(*8*) W. G. Dupree, Jr. and J. A. West, *U.S. Energy Through the Year 2000*, (Washington: U.S. Department of the Interior, December, 1972).

(9) J. W. Forrester, *World Dynamics*, (Cambridge, Mass.: Wright-Allen Press, 1971.)
(10) H. H. Landsberg, L. L. Fischman, J. L. Fisher, *Resources in America's Future* (Baltimore: Johns Hopkins University Press for Resources for the Future, 1963).
(11) D. H. Meadows and others, *Limits to Growth* (New York: Universe Books, for the Club of Rome, 1972).
(12) W. E. Morrison and C. L. Readling, *An Energy Model for the U.S. . . . to the Years 1980 and 2000.* I.C. 8384 (Washington: U.S. Department of the Interior, Bureau of Mines; Government Printing Office, 1968.)
(13) G. Pinchot, *The Fight for Conservation* (New York: Doubeday, Page & Co., 1910).
(14) U.S. Commission on Population Growth and the American Future, vol. III, Population Resources and the Environment, ed., R. G. Ridker, (Washington, U.S. GPO, 1972).
(15) U.S. Council on Environmental Quality, *Environmental Quality*, Third Annual Report (Washington: U.S. GPO, 1972).
(16) U.S. President's Materials Policy Commission, *Resources for Freedom*, 5 volumes (Washington: U.S. GPO, 1952).

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Restrictions of Demand in Response to Prospective Materials Shortages and Threats to Environmental Quality

As we look into the future over the next few decades it seems reasonably clear that the "supply" of raw materials cannot keep up with the "demand" without increasing pressure on the environment. We do not anticipate a sudden shortage of materials. Instead, raw materials will be found in thinner concentrations, mixed more and more with unwanted materials, and in increasingly remote, deep, or otherwise inaccessible places. Thus, each pound of refined material will require an increasingly greater effort before it is put into usable form and place. This effort, while in part a requirement for labor, is mainly a requirement for more energy and capital equipment (which itself requires more energy and other materials) per unit of finished material.

I do not know what the additional energy and material costs per unit of materials will be, but when these additional costs are coupled with inevitable growth in population over the next few decades the solution of environmental problems becomes correspondingly more remote. For this reason those of us who are concerned about environmental quality want to see as much attention given to reducing the demand for materials as for increasing the supply.

Demand for materials can be reduced in three ways without seriously reducing our level of life: (1) eliminate waste; (2) substitute labor for materials: (3) eliminate uses for which satisfactions are relatively trivial or for which alternative satisfactions are readily at hand.

Profligacy of the American economy—as producers and as consumers—is notorious. However, waste, including trivial uses of materials, is so common a part of our way of life that only an outsider (one who is technologically sophisticated but accustomed to tight use of materials) readily perceives its magnitude. (Part of my definition of waste, however, is another's insistence upon consumer sovereignty—e.g. the teen-ager who drives his car to school a mile away and spends the afternoon and evening cruising around the neighborhood.) Sharp reductions in the demand for materials is certainly feasible if enforced by appropriate legislation. I list a few examples:

Transportation

(a) Reduce appropriations for highway construction. Most existing highways will adequately handle 50 MPH traffic.

(b) Increase motor vehicle license fees for new cars, with substantial drop-off in fees for ownership of older cars.

(c) Eliminate use of off-road powered vehicles such as trail bikes and snowmobiles by outright prohibitions and high excise taxes. The Forest Service, Bureau of Land Management, and the National Park Service should bar all such vehicles from lands under their jurisdiction. Restrict use of motorboats on lakes and rivers under jurisdiction of federal agencies or where supported by federal funds. These steps will turn attention to people-powered or wind-powered vehicles and crafts.

(d) Use highway funds for creation of bikeways, pedestrian malls, walking and horseback trails, and canoe trails (as well as mass transit). These facilities should be urban, suburban, rural, and wild. Extensive bikeways should be provided over city streets. Systems of bicycle-public transit-automobile parking facilities should be created to allow optimum transportation combinations for communities of varying population density and sprawl. (Paragraphs (c) and (d) propose a substitution of human energy for mechanical energy.)

(e) Long distance travel should be discouraged by improved long distance telecommunications that facilitate group meetings. Federal funds for highway and airport construction subsidize travel, whereas telecommuniactions are largely paid for by the customer. As a consequence, present federal financing policies distort the ways in which alternative facilities are used. Has there been adequate economic analysis of full social costs of these alternatives and differences in degree of public support? What are possible technological developments via closed circuit television, miniaturization?

The foregoing are devices for economizing on use of vehicles. Other ways in which the demand for materials can be reduced, by substituting labor for materials, are as follows:

Increased use of labor

(f) Packaging. Much material is wasted by single-use packaging. Packaging saves the labor of the clerk in the store, provides eye appeal to the housewife, and saves her some work. What are the social costs and benefits of returning to the cracker barrel economy? What are the social costs and benefits of forcing the housewife to return containers for refill and of using yesterday's newspaper to wrap today's fish? (Prohibiting throw-away beer cans and bottles is only a partial solution, albeit important.) What would be the net material effects? Would the corner grocery store (and other kinds of neighborhood shops) come back, allowing a reduction in transportation?

(g) Encourage the substitution of labor for materials in the production of goods and services wherever significant environmental advantages or material savings are gained. Examples are: increased use of farm labor instead of using pesticides and chemical fertilizers; manual instead of powered lawn mowers, caddies instead of golf carts. These substitutions can be accomplished by use of heavy excise taxes on offending items. The proposed substitutions will contribute other beneficial side-effects: e.g., summer employment of teen-agers, reversal of population movement from country to city and corresponding reduction in social costs of urbanization, and improved health of people who exert themselves.

A number of other steps can be taken that will have diffused effects but will reduce the demand for materials:

(h) Eliminate tax advantages for marriage and procreation. These should be treated in the same way as any other recreational activity.

(i) Eliminate consumption expenditures as a cost of doing business in computing business tax liability.

(j) Revise public utility electric and gas rate schedules to eliminate quantity discounts. (If anything, rates should progress upward with increments of use.)

(k) Put the federal research establishment to work on the question of economizing materials used in production and transportation. (Up to now the main preoccupation of industrial engineering has been to save labor.)

(l) Revise, wherever necessary, tariff, trade, tax, and financial policies to stimulate use of natural products (e.g. fibers) over synthetic, since the former probably impose less strain on the environment. (I assume that proper agricultural practices are followed to protect soil resources and minimize non-point pollution.)

A group of steps should be taken to stimulate changes in design and production processes in order to minimize waste and maximize recycling:

(m) Assess full social costs of waste discharges to land, air, and water against the discharger.

(n) Stimulate and support research in product design and production processes that reduce materials use, extend longevity, and facilitate recycling.

(o) Revise tax laws and freight rates to remove differentials in favor of virgin over recycled materials and differentials in favor of raw over finished goods to reduce cross hauls.

(p) Assure industries engaged in recycling and use of recycled materials parity of treatment in capital markets with industries dealing in virgin materials.

The most important way of reducing the demand for materials is also the hardest to undertake: elimination of demand-creating machinery. We have accepted the advertising industry as a socially necessary instrument that helps avoid depression. With material shortages in view, an industry designed to create discontent, simulate stylistic obsolescence, retard attention to durability, and stimulate demands that have adverse environmental effects, is an anachronism and should not be supported by public policy. In the face of the first amendment to the Constitution, however, no direct attack on the advertising industry seems possible. Even if we intend to reach a full-cost accounting of environmental strain in order to incorporate such costs in price, we are likely to underestimate such costs. Moreover, we are unlikely to give due regard to the needs of our children and grandchildren by relying solely on available economic computations since the "market" deals overwhelmingly in short-run values. I see no way of approaching the problem head on. The following suggestions will, however, reduce the scope of advertising where improper incursion into the public domain has been allowed:

(q) Stipulate standards of performance for all materials and products for which standards are relevant: textiles, shoes, hardware, prepared foods, drugs, cosmetics, household appliances, automobiles, etc. Standards would relate to durability, economy, performance, and maintenance. A sentiment could be encouraged that would counter fashion consciousness and contrived obsolescence.

(r) Eliminate junk mail.

(s) Restrict allowable time for commercials on television and radio; support non-commercial and educational radio and television much more lavishly than at present.

(t) Eliminate advertising costs as a deductible cost of business except for classified ads that are strictly informational.

(u) Restrict all outdoor advertising—urban and highway—on aesthetic grounds if no other; allow informational kiosks, etc.

Finally, the turn-around of culture and activity that is called for will require leadership from the top. Whether and in what fashion we respond will utlimately be a matter of taste rather than inexorable physical constraint.

The array of steps that I have listed will have a variety of short run effects on the level of employment and its distribution among industries. Since the rate at which some activities will grow may be different from the rate at which others will decline, changes in taxation, subsidization, and direct stimulation or prohibition should be undertaken over a reasonable period of time—say five years. Terminal points should, however, be firmly set, so that private sector as well as public sector planning can be undertaken in an environment of reasonable certainty.

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