Part 8

MIDDLE- AND LONG-TERM ENERGY POLICIES AND ALTERNATIVES

SUPPLEMENTAL HEARING
WITH APPENDIX

BEFORE THE

SUBCOMMITTEE ON ENERGY AND POWER

OF THE

COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE HOUSE OF REPRESENTATIVES

NINETY-FOURTH CONGRESS

SECOND SESSION

ON

ENERGY CHOICES FACING THE NATION AND THEIR LONG-RANGE IMPLICATIONS: PROGRESS DURING THE 94TH CONGRESS TOWARD AN INTEGRATED ENERGY POLICY

DECEMBER 16, 1976

Serial No. 94–157

Printed for the use of the
Committee on Interstate and Foreign Commerce

Part 8

MIDDLE- AND LONG-TERM ENERGY POLICIES AND ALTERNATIVES

SUPPLEMENTAL HEARING
WITH APPENDIX

BEFORE THE

SUBCOMMITTEE ON ENERGY AND POWER

OF THE

COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE HOUSE OF REPRESENTATIVES

NINETY-FOURTH CONGRESS

SECOND SESSION

ON

ENERGY CHOICES FACING THE NATION AND THEIR LONG-RANGE IMPLICATIONS: PROGRESS DURING THE 94TH CONGRESS TOWARD AN INTEGRATED ENERGY POLICY

DECEMBER 16, 1976

Serial No. 94-157

Printed for the use of the
Committee on Interstate and Foreign Commerce

U.S. GOVERNMENT PRINTING OFFICE
80-533 WASHINGTON : 1976

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $3.90

COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE

HARLEY O. STAGGERS, West Virginia, *Chairman*

TORBERT H. MACDONALD, Massachusetts
JOHN E. MOSS, California
JOHN D. DINGELL, Michigan
PAUL G. ROGERS, Florida
LIONEL VAN DEERLIN, California
FRED B. ROONEY, Pennsylvania
JOHN M. MURPHY, New York
DAVID E. SATTERFIELD III, Virginia
BROCK ADAMS, Washington
W. S. (BILL) STUCKEY, Jr., Georgia
BOB ECKHARDT, Texas
RICHARDSON PREYER, North Carolina
JAMES W. SYMINGTON, Missouri
CHARLES J. CARNEY, Ohio
RALPH H. METCALFE, Illinois
GOODLOE E. BYRON, Maryland
JAMES H. SCHEUER, New York
RICHARD L. OTTINGER, New York
HENRY A. WAXMAN, California
ROBERT (BOB) KRUEGER, Texas
TIMOTHY E. WIRTH, Colorado
PHILIP R. SHARP, Indiana
WILLIAM M. BRODHEAD, Michigan
W. G. (BILL) HEFNER, North Carolina
JAMES J. FLORIO, New Jersey
ANTHONY TOBY MOFFETT, Connecticut
JIM SANTINI, Nevada
ANDREW MAGUIRE, New Jersey

SAMUEL L. DEVINE, Ohio
JAMES T. BROYHILL, North Carolina
TIM LEE CARTER, Kentucky
CLARENCE J. BROWN, Ohio
JOE SKUBITZ, Kansas
JAMES M. COLLINS, Texas
LOUIS FREY, Jr., Florida
JOHN Y. McCOLLISTER, Nebraska
NORMAN F. LENT, New York
H. JOHN HEINZ III, Pennsylvania
EDWARD R. MADIGAN, Illinois
CARLOS J. MOORHEAD, California
MATTHEW J. RINALDO, New Jersey
W. HENSON MOORE, Louisiana

W. E. WILLIAMSON, *Clerk*
KENNETH J. PAINTER, *First Assistant Clerk*
ELEANOR A. DINKINS, *Assistant Clerk*

Professional Staff

CHARLES B. CURTIS
LEE S. HYDE
ELIZABETH HARRISON
JEFFREY H. SCHWARTZ
JAMES M. MENGER, Jr.

WILLIAM P. ADAMS
ROBERT R. NORDHAUS
BRIAN R. MOIR
WILLIAM G. PHILLIPS
KAREN NELSON

MARGOT DINNEEN

JAN B. VLCEK, *Associate Minority Counsel*

SUBCOMMITTEE ON ENERGY AND POWER

JOHN D. DINGELL, Michigan, *Chairman*

TIMOTHY E. WIRTH, Colorado
PHILIP R. SHARP, Indiana
WILLIAM M. BRODHEAD, Michigan
JOHN M. MURPHY, New York
BOB ECKHARDT, Texas
RICHARD L. OTTINGER, New York
ROBERT (BOB) KRUEGER, Texas
ANTHONY TOBY MOFFETT, Connecticut
ANDREW MAGUIRE, New Jersey
HARLEY O. STAGGERS, West Virginia
(ex officio)

CLARENCE J. BROWN, Ohio
CARLOS J. MOORHEAD, California
JAMES T. BROYHILL, North Carolina
H. JOHN HEINZ III, Pennsylvania
SAMUEL L. DEVINE, Ohio
(ex officio)

FRANK M. POTTER, *Staff Director and Counsel*
WALTER W. SCHROEDER, *Research Analyst*
PETER S. HUNT, *Research Analyst*

CONTENTS

APPENDIX

MIDDLE- AND LONG-TERM ENERGY POLICIES AND ALTERNATIVES

THURSDAY, DECEMBER 16, 1976

House of Representatives,
Subcommittee on Energy and Power,
Committee on Interstate and Foreign Commerce,
Washington, D.C.

The subcommittee met at 10 a.m., pursuant to notice, in room 2123, Rayburn House Office Building, Hon. John D. Dingell, chairman, presiding.

Mr. Dingell. The subcommittee will come to order.

The subcommittee is very honored today to have two distinguished public servants who have served with real ability and dedication in the difficult area of energy. One we see rather more often than the other, the Honorable Frank Zarb, who is my dear personal friend and also an outstanding public servant with whom I have had both friendship and differences over our years of association. The other is the Honorable Elliot L. Richardson, the Secretary of Commerce, a most respected public servant who has served in almost every capacity in the Government.

The subject of today's hearing is very general. It is, in effect, a review of the present posture of the United States with respect to an energy policy.

The conventional wisdom has been that the United States has no energy policy and that this is the reason for many of the problems which we are currently experiencing. I disagree with this position. On the contrary, I believe that we have a number of energy policies, most of them established at a time during which the availability of energy was never perceived as a problem and the price of energy was inconsequential.

The world in which these policies were derived has disappeared and is not likely ever again to occur. Therefore, we now have to develop new strategies to deal with new kinds of constraints, many of which do not, on their faces, appear to be energy-related. It does not, however, take a great deal of imagination to see that issues such as the Highway Trust Fund, investment tax credits for utilities, Federal research and development priorities, and our regulatory policies do, in fact, have enormous implications for the direction of our energy future.

One of the issues which I believe we ought to understand much more clearly than we yet do is whether and how current policies operate to provide hidden subsidies which distort our economic decisionmaking. The OPEC cartel is not the only factor which prevents the operation of what many persist in calling a "free market."

I believe that we are witnessing a definite, albeit slow, convergence of views on what our national energy policy ought to be. The two major bills which this subcommittee produced last year certainly point in this direction. These bills incorporate a significant series of initiatives on the part of both executive and congressional participants. There is no longer, I think, any serious question about the fact that energy prices are going to go up in the future, but the rate of rise of these prices is far from agreed upon and involves a number of significant economic and social tradeoffs.

A primary responsibility that we have today and will have into the foreseeable future is the need to insure that these increases in energy prices result in neither unjust enrichment to energy producers nor confiscatory foreclosures for those members of society who simply do not have the economic flexibility to withstand sudden economic shocks.

These problems will not be resolved today. I think it most unlikely that they will be resolved in the next few years, but they are going to be resolved. Our job—and by "our" I mean all Americans—will be to arrive at policies that will allow us to conform our behavior to the constraints of a world in which resources will be more and more scarce and the demands upon these resources more and more powerful.

The gentlemen appearing before the subcommittee today are both not only good Americans and good public servants but also important actors in the energy arena. I expect that their influence will continue in the future wherever they may find themselves. They have offered to provide the Congress with a candid overview of the energy situation. I expect that this will touch upon past events and I hope that it will include their judgment as to ways in which we can deal with as yet unresolved questions.

I believe that this effort will constitute a highly useful blueprint for the next administration. The expertise of men such as these, whatever differences in policy approaches they may have from their successors, will be highly relevant. We thank them for their appearance and look forward to their testimony. We are honored to have them with us today. Whatever differences in policy approaches they may have with their successors, these discussions are going to be highly relevant.

Gentlemen, we are honored that you are with us. It is not necessary, I think, for you to identify yourselves for me or for those present in the room, but for purposes of the record, if you could just identify those who appear with you at the committee table.

STATEMENT OF HON. ELLIOT L. RICHARDSON, SECRETARY OF COMMERCE, ACCOMPANIED BY EDWARD MILLER, DEPUTY DIRECTOR OF ENERGY, OFFICE OF ENERGY AND STRATEGIC RESOURCE PLANNING

Secretary RICHARDSON. Thank you very much, Mr. Chairman.

I am accompanied by Mr. Edward Miller, who is the Deputy Director of Energy for the Office of Energy and Strategic Resource Planning in the Office of the Assistant Secretary for Policy in the Department of Commerce.

As chairman of the Energy Resources Council I welcome this opportunity to join Frank Zarb, Administrator of the Federal Energy Administration, in appearing before this subcommittee.

I appreciate your generous opening words, Mr. Chairman, and for myself I would like to say that I have very much enjoyed the opportunity to be associated with Frank Zarb during the months that we have served together on the Energy Resources Council.

Certainly the work of the Council, like the work of this subcommittee, does represent a conscientious and serious effort to deal with problems of enormous magnitude and difficulty. Their import is underscored as we meet by the fact that the OPEC nations are now meeting in Qatar to decide how much more they will charge the world for the privilege of buying their petroleum. Nothing could so vividly on the one side demonstrate the economic interdependence of oil nations and at the same time nothing could so vividly highlight the dependence that all countries now are forced to place upon the importation of petroleum from the OPEC countries.

So, it is timely that as one administration yields to another that we pause and review the course we have been following, assess the extent to which we do in fact now possess an energy policy or, as you suggested, Mr. Chairman, policies, and help to point the direction for the future.

Certainly we who have been struggling with these issues in the Ford administration would like nothing better than to feel that our experience as well as our judgments can be of benefit to the next administration as well as to the Congress as together you seek to supplement existing policies where they are deficient and to supply them where they are missing.

At this time 3 years ago the United States was in the midst of coping with a major international crisis—the Arab oil embargo. This 6-month interruption of U.S. oil imports and the accompanying price rise cost our economy $10 to $12 billion in GNP and helped trigger an economic decline from which we have only recently begun to emerge.

We, in the Department of Commerce, with the FEA, have determined that another oil embargo, should it occur, and of course depending upon its duration, we know that the result would be to trigger a major recession and bring about massive unemployment.

The last time as a result of quick and decisive measures taken by the Government, private industry, and the general public, we were able to weather the embargo—but not without major inconveniences and adverse impacts on employment and the economy in general. The indirect effects of the fourfold price increase 3 years ago remain with us today, in the form of higher costs both of fuel and of goods and services. The current annual expenditure of $34 billion for imported petroleum is a major item in our balance of payments. For countries less wealthy, and less blessed with domestic energy resources, the balance-of-payments impact of the oil price increases was even more serious.

We must not forget the lessons we learned from this earlier embargo, namely, that our Nation's dependence on uncertain sources of fuel must be lessened and that this decreasing dependence must occur within the framework of an energy policy that addresses both substantive and organizational issues. We ignore at our peril the possibility of a future embargo or other events of similar impact on our economic system. Part of the energy problem, of course, is that solutions take a long time to accomplish.

For example, the time required to build a new nuclear electric plant is 8 to 9 years. Coal and oil-fired electric plants require 5 to 7 years. Even the start-up of production from new onshore oil fields can take up to 3 years. Under the Energy Conservation and Production Act of 1976 (ECPA), efficiency standards will be developed for new buildings; but even if these standards are implemented immediately, and this is by no means assured, it will take 50 years for the building stock as a whole to reflect such standards.

Consequently, even if the new Congress takes the strong actions necessary to legislate policies and programs to increase domestic energy supply and reduce demand, the Nation will not see results for many years. Current projections show the U.S. oil and gas reserve base declining in this period, and we will require a transition to a greater reliance on coal, nuclear power and, hopefully, renewable energy resources.

Although it is unfortunate that it took an embargo to make evident the seriousness of the energy situation, we have taken many positive steps to insure that this Nation and, indeed, the world has adequate, secure, and reasonably priced energy resources available for the next decade as well as for the next century.

We have made great strides in stating our objectives, in identifying the major policy issues, in assessing rationally our options, and in initiating actions to resolve the energy situation. Other steps remain to be taken, and we share the urgency of the Congress to continue to move forward.

Today, in reviewing the essential elements of our energy situation my remarks will focus on our fundamental energy objectives, what we have done to achieve these objectives with particular emphasis on the international and interagency coordination issue. Mr. Zarb will discuss our progress—and unresolved problems—in domestic energy resource development, including its relationship to environmental concerns.

In addition, Mr. Chairman, we would like to submit for the record a more detailed white paper entitled "Perspective on Energy Policy" which addresses these complex issues in greater depth. [See p. 44.]

The United States cannot and should not attempt to achieve total energy self-sufficiency. We exist in an interdependent world, an integrated economic community in which the exchanges of energy resources between industrialized and developing nations are as vital as the exchanges of food and capital. At the same time, however, we must continue our active efforts at both the international and the domestic levels to obtain control over our energy destiny. Neither our economy, nor our national security, benefit from overreliance on a few select countries for petroleum and its byproducts.

Past and present administration efforts to achieve these objectives encompass the policy approaches that have seemed to us to be feasible. These include:

Active participation in the establishment and operation of the International Energy Agency (IEA) as a forum for international energy cooperation.

Formulation and implementation of an adequate strategic petroleum reserve program to lessen the potential economic impact of another embargo.

Increased exploration for additional domestic reserves of current energy sources.

Conservation and management of existing energy resources in a manner consistent with national needs.

Expanded utilization of coal and uranium as energy sources.

Development of synthetic fuels.

Increased research and development on the energy-related technological issues, as well as on the environmental, health, and safety concerns associated with expanded domestic energy production.

Coordination and integration of executive branch energy policies and programs.

As I stated earlier, Frank Zarb will discuss in greater detail the efforts focusing on domestic energy resource development. I will address briefly those areas of particular concern to me in my role as Chairman of the ERC.

A major issue—most obviously raised by the synthetic fuels example—is the appropriate role of Government in influencing timely investment by the private sector in the development of large-scale energy resource systems. We must try to anticipate market forces and what the market is capable of achieving on its own—and then assess what role the Government should assume. While we have come some distance in developing this capability already, we still have a long way to go.

With respect to international developments, we have fostered new cooperative dialogs between oil-producing and oil-consuming nations. We also have taken the lead in developing improved consumer country cooperation. Through continued U.S. support, the International Energy Agency (IEA) has become an especially welcome and effective means for energy policy cooperation among its 19 member countries.

An operational, integrated emergency program to lessen the economic impact of a future embargo on Western Europe, Japan, and the United States has been negotiated through IEA and tested successfully. While an embargo of IEA member countries still would create significant disturbances, a more limited embargo would have less impact as a result of the IEA agreement.

The United States is relatively invulnerable to any one country or group of countries refusing to sell to it as long as total production is not cut. In such a situation, tankers would be redirected to assure that the United States were supplied by nations friendly to it, and the embargoing country's oil would be directed elsewhere as a result of the IEA's sharing agreement. At most, such an embargo would be an inconvenience in which some refineries would be cutoff from their traditional source of crude oil.

The crisis about which the United States must worry is a sudden decrease in world oil production. One possibility is a cut in production by the Arab countries in order to apply pressure on the United States or its allies. Although such a cut in production would likely be accompanied by a refusal to supply any oil to the United States, it is the cut in production that is the primary problem, not the refusal to supply us.

Indeed, it is fair to say if there is a crisis to be concerned about it is a situation in which the more likely possibility is a cut in production as the result of concerted action among oil-producing countries.

For obvious reasons, it is in our interest that a high proportion of world oil production come from countries that are unlikely to cut production suddenly. Because the United States is only one of many oil-consuming countries, our ability to encourage directly the expansion of producing capacity in reliable supplier countries is limited.

Nevertheless, both the United States and IEA can provide encouragement through the provision of stable markets as well as through support for the development and dissemination of advanced energy technology and equipment. Thus we should be careful about restricting the access of potentially reliable supplier countries to American goods and services, either directly through export restrictions or indirectly through a materials allocation system in which only domestic users have high priority.

To assure that we are prepared to meet the threat of another energy supply interruption, a Government-wide embargo management strategy should be prepared. Proper development of such a strategy would include analysis of the optimal use of the strategic petroleum reserve in relation to the International Energy Agency program and contingency demand restraint measures; and it would integrate fully our international and national energy management options with monetary, fiscal, and other policies affected by an energy supply interruption or steep price increases.

The President also should be given the authority to impose emergency taxes or fees on petroleum products in such an event, or if there should be rationing, to charge certain users for coupons issued. Such authority is not vested in the President now. I recommend that the Congress consider an amendment to the Energy Policy and Conservation Act which would permit a less complex emergency system and remove prohibitions on taxes, fees, ration coupon, charges, and other price-related mechanisms for emergency use.

An equally important element of our energy independence strategy is an effective domestic energy conservation program. Fortunately, through the efforts of the Congress and the administration in enacting and implementing such legislation as the Energy Policy and Conservation Act (EPCA) and the Energy Conservation and Production Act (ECPA), this effort is well advanced.

The ERC recently established an interagency task force on energy conservation to assess the implementation of existing conservation programs and to prepare a thorough report for the Congress as required in ECPA. I would urge the new administration to continue this effort.

I now would offer a few comments on the frequently oversimplified issue of energy policy management and energy organization.

Natural gas policy provides an example of the complexity that one gets into in coordinating energy policy among different agencies. After describing some of the options that have to be looked at in this area, I will point out how many agencies are involved in trying to formulate a rational policy, taking into account all of the tradeoffs.

Although natural gas production peaked in January 1973, there are still sources of natural gas available which can be developed and delivered to existing users at a cost far below that of foreign oil, whose cost before refining is equivalent to about $2.30 per thousand cubic feet.

Some of this gas is in deposits whose production costs would be above the current $1.42 ceiling for interstate gas.

Additional gas is in the offshore areas that are not yet open to exploration. By permitting gas prices to rise to a free market level and by exploring the Outer Continental Shelf, the United States can substantially increase its supply of domestic gas.

But higher gas prices and increased offshore production alone will not eliminate the current shortage of gas. If it is desired to continue the historic role of gas, it will be necessary to obtain additional supplies of gas from supplemental sources. These sources include liquefied natural gas (LNG) imports, coal gasification and gasifying petroleum products, that is, naphtha. All of these sources appear to have costs that are well above the current costs of gas or of imported oil—and even further above the costs of the domestic gas that can be obtained through deregulation.

In addition, each of these sources has associated problems. Importing natural gas poses the risk both of the interruption of supply and of unilateral price increases. There is well organized opposition to strip mining coal for the operation of gasification plants. Importing petroleum for conversion to synthetic gas subjects us to the risk of embargo.

Key policy decisions will have to be made regarding the extent to which we wish to depend on such high cost sources of gaseous fuels, the optimal means for their development, the extent to which we should permit new users to commit to gas, and the extent to which existing users should be forced to convert to other fuels.

Let us look at the bureaucratic complexities of making these decisions. Supply sources are the responsibilities of several different agencies. ERDA handles synthetic fuel policy. The Department of the Interior leases coal lands from which ERDA will get its gas, as well as the Outer Continental Shelf (OCS). If a private company should take an OCS lease from Interior, any gas produced would be regulated by the Federal Power Commission (FPC). However, the natural gas liquids, including propane, but excluding ethane, extracted from the gas would be regulated by FEA. FEA also controls the use of propane-air mixtures by natural gas distributors through its jurisdiction over propane allocation, and the manufacture of gas from petroleum through its allocation of naphtha for synthetic gas plants. In addition, FEA chairs the LNG task force of the ERC. The Department of Commerce assumes a major role with respect to LNG transportation. FPC, through its pricing decisions, determines how much gas is produced from traditional onshore sources.

Conservation policy is primarily the concern of FEA with Commerce involved in the industrial area. Policy regarding conversion of existing users is sometimes made by FEA requiring conversion to coal, sometimes by FPC denying particular users gas, and sometimes by EPA making rules that virtually require use of gas.

To consider the option of not connecting new users, one would want to draw on the expertise of the Department of Housing and Urban Development and the Center for Building Technology of the National Bureau of Standards.

The gas illustration which I have just described is, of course, just one of innumerable such examples.

As you know, early this year, I directed the ERC to undertake a thorough and comprehensive review of Federal energy organization and report to the President on proposed changes. The ERC study has considered a wide variety of alternative approaches, including establishment of a department of energy and natural resources, establishment of a department of energy, establishment of a smaller energy agency composed solely of FEA and ERDA, and retention of the present system, including the ERC.

Clearly, no organizational structure will comprehend all energy-related functions. Given the interrelationship between energy policies and economic and international policy generally, no one agency will so consolidate energy policy and programs as to obviate the necessity for interagency coordination. For example, conflicts between energy development and environmental protection will always remain to be resolved at a level outside any one agency.

While some consolidation of existing functions has been considered in the ERC study I have just mentioned—and while a well-tailored consolidation would, on balance, now be desirable—I believe it is important to recognize that organizational change may or may not provide a cure. Having headed four Cabinet Departments of Government and served as Under Secretary in a fifth, it is very clear to me that formal organizational structure is markedly less important than the process of decisionmaking.

It is essential to provide for a broad spectrum of participation in the process of energy decisionmaking, and to assure that this decisionmaking is founded upon comprehensive, objective, and thorough analysis. Organizational structure per se, while important, is not a substitute for the processes which can assure responsible substantive policy development.

In no event should we let the possibility of organizational change slow progress on substance. I strongly urge the new administration to decide at the outset on organizational questions, but to proceed vigorously using the present mechanism pending congressional action.

The issues we are raising today are vital to America's future. The necessary further actions must not be delayed. Energy goals and priorities cannot be set in isolation, independent of economic and environmental considerations. It is time for a national reassessment in these areas, and I suggest that in order to develop the consensus necessary to assure continued forward movement in the development of America's energy policy, consideration should be given to national or regional energy forums to discuss and debate the issues.

We have had an extensive dialog between the Congress and the Executive—with progress in some areas and regrettable stalemate in others. The public, however, seems to have lost its sense of urgency—and now, for the difficult decisions which remain, the public must be made a direct party to the debate.

Now, Mr. Chairman, I am pleased to turn to Frank Zarb for a more detailed assessment of domestic energy resource policy issues. The importance of their timely resolution cannot be overstressed. As you yourself have stated, Mr. Chairman:

> The way in which these issues are resolved, directly or by default, will have powerful and permanent effects on national priorities and social goals, and upon the choices which we leave to our descendants.

While many of the most difficult choices remain to be decided, I hope our legacy may be that, through the ERC and the energy-related agencies, we have made an effective start and have built the foundation for a long-term comprehensive national energy policy.

Thank you, Mr. Chairman. That concludes my prepared statement.

Mr. Dingell. Mr. Secretary, you have given us a most powerful statement. I know we all have questions to ask you about your comments, particularly with regard to the structuring of energy affairs within the Government. However, I think it would be prudent for us now to recognize my old friend, Mr. Zarb, for his comments.

STATEMENT OF HON. FRANK G. ZARB, ADMINISTRATOR, FEDERAL ENERGY ADMINISTRATION, ACCOMPANIED BY BRUCE PASTERNACK, DEPUTY ASSISTANT ADMINISTRATOR FOR POLICY

Mr. Zarb. Thank you, Mr. Chairman. I have with me Bruce Pasternack who is with the FEA and certainly no stranger to this committee.

I must say, Mr. Chairman, as I was sitting here reading the first page of my testimony, the first sentence stuck out and, I suppose, I should start with a small confession.

I have testified well over 150 times in the last 2 years and always in my prepared testimony is that first sentence that says, "I am particularly pleased to appear here today to discuss . . ." I must confess to the chairman that there have been occasions over the 2 years that I was not particularly pleased to be testifying at that particular time, and my New Year's resolution is never again to say that unless I mean it.

This is one of the cases where I mean it, so I am going to begin by saying, Mr. Chairman, I am particularly pleased to appear here today to discuss the state of our Nation's energy policy.

As I reflect upon the past few years, I am proud of what has been achieved, although disappointed by the time required to make progress in some areas. We have made great strides in enacting so much new legislation in so short a time—and particularly in a year of a Presidential election. Together, we have also improved the quality of debate and identified the issues more clearly.

I am not unmindful this was an election year and election years have not been noted in our history as being legislatively productive. I must say in this case we have achieved progress even during that particular period.

I have to add quickly that this has been due to your leadership, and I mean that without any reservation, and the work of this committee which kept its eye on the energy issue and the energy debate even during a highly political period.

Mr. Dingell. I thank you for those kind remarks, and I observe that it is in large part due to your hard work and integrity.

Mr. Zarb. Mr. Chairman, some people might find it difficult to understand my statement that I am proud of what has been accomplished. They hear talk of higher prices, higher imports, and no energy policy. Yet, while it is true that our dependence is worse today than before the embargo, we have enacted significant legislation that will be the foundation of our energy policy for years to come, and which will be instrumental in the changing of some of the habits within our society. I suppose to understand where this Nation stands today it is necessary to review how we got a problem in the first place.

Unfortunately, this Nation sold out its interest in an energy future at a time when we were self-sufficient. Rather than invest in developing new sources of U.S. energy as alternatives to oil and gas, we satisfied our growing energy appetite with cheap foreign fuel. There were those who raised a voice in alarm, and warned of ultimate disaster throughout the sixties, but for political or other reasons they were not heard or were ignored. The chromium-plated gunboats that Americans drove in the 1950's and 1960's were indicative of the choice that was made.

The unfortunate energy course pursued by the United States could be labelled the "Great American Energy Orgy." It led to a 3.5-percent growth in energy consumption each year, much of which is now considered wasted.

United States policy in the 1960's largely neglected U.S. energy sources in the Outer Continental Shelf, Alaska, and enhanced recovery from onshore wells. It left unattended the concern over nuclear power, especially for the back end of the fuel cycle. It ignored coal production, transportation, and consumption objectives; and more importantly, pursued policies which pushed the coal industry backwards.

The American consumer is now paying for these policies:

Oil production peaked in 1970 and continues to decline—although at a slower rate than in recent years. Despite very favorable signs in drilling activity this year, production will continue to slip until Alaskan oil comes on line, and that should be sometime late next year.

Energy demand threatens to resume its historic growth trends. America consumes over 17 million barrels of oil per day, about 600 million tons of coal and 20 trillion cubic feet of gas per year. Our wants are great. Petroleum imports will be higher this year than ever before—averaging about 7 million barrels per day.

Americans are paying more for foreign oil than ever imagined a few years ago. We will spend about $34 billion for foreign oil in 1976, as compared to $27 billion last year, and $2.7 billion in 1970.

Natural gas production is also declining and shortages are growing in certain parts of the country. If the cold weather we are experiencing now continues throughout the winter, there could be adverse economic impacts in some areas.

Nuclear power expansion has slowed as a result of public concerns and private sector difficulties in building new plants, but we now have over 60 plants in operation.

On the positive side, coal production is increasing and will approach 670 million tons in 1976—a record year; and there are encouraging signs for solar energy and some emerging technologies, but there is a long way to go before these newer sources contribute significantly to our energy supply.

Foreign energy is the highest cost energy we have. Thus it makes sheer economic sense to replace foreign sources with domestic energy. It also makes sense from a national security standpoint. Oil disruptions can have significant economic effects and are likely to be a threat even if the Middle East situation is resolved. And I hasten to add, Mr. Chairman, if we have another embargo in the next 2 or 3 years, it will make the last one look like a Sunday school picnic.

If we have learned anything, it is that turning around our energy situation is no simple matter—there are no easy solutions. There is no free lunch here. Every solution that is proposed generates some opposition; none are completely acceptable to everyone. Our energy program cannot be simply a matter of choosing between conservation, solar energy, nuclear power, and coal. We must move forward in all these areas if we are to meet our energy needs and keep our economy free of foreign dominance.

Compounding the difficult choices is the obvious political dilemma faced by legislators. The difficult legislative decisions that must be made today will pay off in benefits many years later. This time delay makes it much more difficult to justify taking such difficult actions now.

Given this background, it is not surprising that people talk about higher prices, higher imports, and no energy policy. We have spent a mere 2 years trying to reverse the thinking that has developed over many years. What we are saying to the American people is that the free lunch we enjoyed in the past must now be paid for. If the American people are misled into believing that the artificial luxury of cheap energy and no sacrifices can continue, an even larger dilemma will result.

The buildings and cars built with the values of the 1960's will have to be replaced by a new generation of equipment. Improving our energy situation will require very tough actions indeed.

It is clear that the United States has the capability to make itself "embargo-proof" within the next 10 years—that is absolutely clear. To keep our dependence upon foreign oil manageable, we will need an aggressive program to increase domestic supply, reduce the rate of growth of demand, provide stand-by authorities for use in the event of another embargo, and develop new technologies. In particular, we will have to move ahead in six key areas:

Increase coal production from current levels of about 670 million tons annually to over 1 billion tons per year by the mid-1980's. That is achievable. Almost all of the increased production will be to meet the needs of American consumers.

Expand oil and gas production in the frontier areas of Alaska and the Outer Continental Shelf (OCS), as well as encourage enhanced recovery from existing fields to replace declining supply. Oil production needs to increase from 8 to 12 million barrels per day by 1985; gas production from less than 20 trillion cubic feet to almost 23 trillion cubic feet by 1985. Both of those objectives we believe are achievable.

Increase the share of nuclear energy in the generation of electric power from about 9 percent to over 20 percent in the next 10 years—also achievable.

Develop supplemental sources of oil and gas, such as coal gasification and liquefaction and shale oil to meet shortages of liquid and gaseous fuels; and expand dramatically the use of renewable sources, such as solar energy and wind.

Build a strategic petroleum reserve of at least 500 million barrels.

Reduce the annual rate of growth of energy demand from its current 3.5 percent to 2.5 percent.

Our legislative scorecard as we look at it over the last 2 years is not bad. Improving the energy situation will require building on the accomplishments of these 2 years and developing a long-range program. Suggesting it will be cheap or easy is a cruel hoax. We must never be so rigid as to be unwilling to reexamine previously formulated plans, but at the same time not slide back into political lethargy or using false hopes to provide easy solutions to political dilemmas.

The program I have set forth is a tall order and, as Secretary Richardson has pointed out, we have made substantial progress in conservation and standby measures, but much less in providing for new supply. There are many reasons why our progress has come earlier in these areas and not in supply incentives.

Conservation has been a popular issue, because it is generally cost-effective, can be identified with individual consumer actions, and protects the environment. But, I would like to caution that conservation is much easier to talk about than to effectuate. I think back not so nostalgically to our debate over thermal efficiency standards for new buildings. The bill was finally passed with the sanctions removed at the last minute simply demonstrating that our ability to come to grips and face some of these tough conservation legislation actions is not going to be easy.

Standby measures make commonsense if the Nation is to prepare itself for another cutoff of supply, and I would add here that a cutoff not need to be a cutoff as we experienced in 1973 and 1974. There are a number of things that could happen to stop a sizable amount of oil from reaching our shores in future years.

Most resource development issues involve large-scale change for local communities, often with environmental effects, and public distrust of the energy industry and Government is high.

Among the key measures to incentivize new production are those which involve raising the price of oil or natural gas. These price questions arose at a bad time—during a recession and soon after large increases in the world price had occurred—and, as a result, they surely were not received favorably.

However, 7 of the 13 original titles of the President's Energy Independence Act are now law in largely the same form as originally proposed. The following major bills have been enacted:

Energy Reorganization Act, Energy Policy and Conservation Act (EPCA), Naval Petroleum Reserves Production Act, Energy Conservation and Production Act (ECPA), Alaska Natural Gas Transportation Act.

As a result of these laws, the Federal Government now has the authority to begin—and just to begin——

IN DOMESTIC SUPPLY

Exempt the first sale of domestic stripper well crude oil from price controls.

Implement the 40-month crude oil decontrol plan, under which domestic crude prices are allowed to escalate by no more than 10 percent annually to provide production incentives.

Provide added pricing flexibility to tertiary recovery and California heavy gravity crude.

Develop at the maximum efficient rate the three Naval Petroleum Reserves in the lower-48 States; continue exploration of the Na-

tional Petroleum Reserve in Alaska, leading to its eventual development.

Implement an expedited selection process for a transportation route to deliver Alaskan natural gas to the lower-48 States.

Dismantle as much of the current petroleum product regulatory system when it proves to be counterproductive.

IN CONSERVATION

Provide conservation grants to States to assist in the development and implementation of energy conservation programs.

Implement appliance energy efficiency labeling.

Set mandatory automobile efficiency standards for 1980 and 1985.

Establish industrial energy conservation targets for the 10 leading energy consuming industries, and mandating reporting of progress.

Develop thermal efficiency standards for all new residential and commercial buildings, subject to Congressional approval of sanctions.

Implement a 3-year, $200 million weatherization grant program for the insulation of homes of low-income, elderly, and handicapped persons.

Provide grants to States for testing innovative utility rate structure designs to achieve a higher degree of conservation.

ON THE STANDBY SIDE

Build a strategic petroleum reserve of at least 150 million barrels of petroleum by 1978 and 500 million barrels by 1982 and perhaps earlier.

Establish standby measures to deal with severe energy emergencies that may arise in the future.

Develop cooperative contingency and planning programs with the International Energy Agency (IEA).

This list is long, and, considering that it represents only 2 years of efforts on the part of the Congress and on the part of the Executive, these accomplishments should not be understated. I suppose I, more than anyone, recognize that we have only begun the process of achieving energy self-sufficiency. Much more remains to be done if we hope to maintain our international leadership role and domestic security. I believe the new administration and Congress must and will address the issue squarely and move forward quickly.

We have today submitted to the subcommittee a detailed white paper describing the major energy achievements, disappointments, and issues facing this country. It is an honest, candid analysis of the energy area as we see it, Mr. Chairman, and I hope you will admit it so that it might appear as part of the record of these proceedings.

Mr. DINGELL. Without objection, so ordered. [See p. 44.]

I thoroughly concur with you that this "White Paper" should be a part of the record and should be reviewed not only by this subcommittee but by the Congress and the American people.

Mr. Zarb, one of the reasons you and I and Secretary Richardson are cooperating in this subcommittee meeting today is to have an evaluation of where we are and what we are doing. I want to thank you and the Secretary for your assistance.

Mr. ZARB. Mr. Chairman, I will quickly go through the last half of my testimony so that we can leave ample time for questions.

The natural gas area—there is no question but that we need to face that again. We need new public policy in this area if we are going to avoid the kinds of problems that we perceive in this coming winter.

In the crude oil area I come to generally the same conclusions.

Let me just summarize the issue of pricing and cover both areas at once.

The thinking people around the world in the area of energy policy have come to a general conclusion that any nation must price its energy used at its replacement value. If we use a barrel of oil and must replace it in the international market, the user must pay or should pay the price of replacement.

Now, obviously, that can't happen overnight and there has to be a phase-in period. But once we have achieved that as a stated goal and the Nation knows that that is where we are heading then consumption habits will be affected, conservation and production will be affected. I would hasten to add that that need not be with full deregulation of prices. It can be a mixture of deregulation and taxes to achieve that end and I expect it will have to be.

The industry that is working on developing solar power will be able to proceed with the economic tradeoff at the end of their investment stream and we will indeed expedite investment in those new technologies if they know that their technology is going to be an economic entity at the time it is completed.

So the Congress, in my view, should once again visit this question of raising prices of gas and oil to their real replacement values and their real value to the consumer and to the marketplace using a mixture of deregulation, decontrol and taxes and, perhaps, set that into place so that the American economy can project what is going to happen in the future.

The debate over energy taxes last year attracted considerable attention. The administration proposed excise taxes on domestic petroleum along with increased import fees, while Congress considered a gasoline tax and other measures.

After starting with gasoline tax proposals of over 30 cents per gallon, the House failed to pass even a 3-cent gasoline tax. One Senator who had a bill to put a 1-cent gasoline tax forward was unable to find any cosponsors to that particular bill during 1976. The point is that taxing and deregulating is going to continue to be a very, very difficult chore. Nevertheless, it needs to be faced squarely if we are going to round out our energy program.

The achievements in energy conservation have resulted in a number of new programs that must now be implemented. The funding, staffing, design, and operation of these programs will be critical to our future. Most of the tough regulatory approaches to conservation have been enacted or were rejected for good reasons. Nevertheless, our work is not completed and there are still some measures to be considered.

Again, I urge the Congress as quickly as possible to reconsider a tax credit for residential insulation. This measure, which can save over 100,000 barrels per day, has twice been deleted in conference committees. I also remain convinced that the thermal efficiency standards proposed by the administration should be passed with tougher sanctions than agreed to by the Congress and I would hope that this area again be revisited.

While there are other conservation regulations in the buildings, industry, and transportation sectors that could be considered, most would have little effect. The key measure to induce conservation, especially in the near term, would be the pricing of energy at its market value through deregulation and through taxes. Only when artificial controls are removed from energy prices can the marketplace receive the proper signals.

In the energy development area some progress has been made but still more needs to be done. In the areas of gas and oil, the role of State and local governments and interest groups cannot be underestimated. The Federal Government must work in harmony with these entities before, not after, final resource development decisions are made. National interests do not always coincide with local interests, but widespread Federal overrides are doomed to failure. I propose that the new administration assess more thoroughly ways to involve local interests in Federal decisionmaking.

The balance between energy, economic, and environmental objectives is delicate, but must be maintained. Careful planning can avoid most of the impacts of energy projects sometimes feared by local residents. Too often we only hear from those who say we must stop growth or those who say that anyone who questions energy development is an environmental "kook."

Instead of listening to the extreme arguments and instead of polarization we need more energy self-sufficiency and better environment. Both can be achieved and we need to do this without each one arguing with the other on a conflicting basis.

In addition, the uncertainties facing investors must be overcome. These include policy uncertainties with respect to environmental standards—such as the Clean Air Act and surface mining—and price controls, as well as geologic uncertainties—such as frontier OCS reserves and leasing schedules. The Congress has an obligation to reduce these uncertainties and provide a stable investment climate.

UTILITIES

One of the key resource development questions relates to the building of new powerplants. In the last few years, utilities experienced a dramatic change in their profitability, financing capabilities, growth estimates, and public acceptance. The United States needs new coal-fired and nuclear capacity if it is to avoid power shortages or greater reliance on oil- or gas-fired power. Assistance to utilities, especially in the face of higher rates already in effect, has not been popular, and most of the administration's initiatives have not been successful.

I urge Congress to review the utility situation carefully and to consider legislation to improve the siting process—without encumbering it with added Federal bureaucracy; to consider new approaches—such as S. 1777—to the coal conversion process; but to weigh the results of FEA's utility rate structure studies before pressing ahead with new legislation.

A key part of the utility problem is the growth of nuclear energy. The United States will need to increase nuclear power's role in its economy or see oil imports grow even more in the future. Many nuclear plants have been canceled or delayed because of financing, siting, or load growth difficulties. There has been greater public concern over the safety of such plants, yet referenda in several States this year and a recent public opinion survey showed considerable support for nuclear power.

This administration has proposed a comprehensive and innovative set of programs to expand nuclear development with careful consideration of safety. Bills to improve the licensing process, transfer enrichment facilities to the private sector and others failed to receive positive congressional action.

Mr. Chairman, this is continuing to be a very controversial area. I think at the very least it should be openly debated here in the Congress so that all of the issues can be brought to the table for the Nation to see which direction it is going to go in this sector. To go without a national review of this particular issue would seem to me to be a mistake.

While I hope and expect that most new energy projects could be developed and financed privately, there may be a need for Federal financial assistance in some areas. The Congress has already enacted several programs to provide financial support for coal, geothermal power, conservation, and coastal zone deevlopment.

Maximum reliance should be placed on private sector financing. Nevertheless, some projects may require Federal financial assistance if they contribute significantly to energy independence, but would not be undertaken in a timely fashion without such assistance.

I still believe that unless we enable the first generation of gasification and liquefaction plants to become a reality over the next 10 years we are not going to learn enough about the environmental economic and engineering difficulties to have that sector expand in a very fast rate after 1985.

In the area of research and development I would spend a few minutes to review where we are. I am concerned, Mr. Chairman, that, as in the space program, after a while the interest and appeal for expanding R. & D. will wane. It has always been the history of new programs and I expect it to take hold in this program at some point in time.

We, therefore, must set our energy research and development priorities carefully. We must look first toward those technologies with the greatest likelihood of being significant contributors and economic in this century. We must be prepared for failure and have contingency plans available in case some of our research efforts do not pay off.

Mr. Chairman, I would like to conclude by saying that I am optimistic about America's future. I have lived with the difficulties of developing and implementing controversial policies. I have seen how easy the process can be frustrated. Yet this committee and others have shown that our political system can work and we have started on a new energy policy for this Nation.

As I leave office I am not discouraged or overly frustrated. I leave with the realization that we have done what was long overdue. This country has the knowledge and, if it has the will, it can overcome formidable obstacles to achieve its goals. I believe our efforts will result in regaining our energy independence and our national pride.

and I am grateful to have served my country and to have served with such people as Secretary Richardson and you, Mr. Chairman, in this endeavor.

Thank you very much.

[Mr. Zarb's prepared statement follows:]

STATEMENT OF FRANK G. ZARB, ADMINISTRATOR, FEDERAL ENERGY ADMINISTRATION

Chairman Dingell and members of this subcommittee, I am particularly pleased to appear here today to discuss the state of our Nation's energy policy.

As I reflect upon the past few years, I am proud of what has been achieved, although disappointed by the time required to make progress in some areas. We have made great strides in enacting so much new legislation in so short a time (and particularly in a year of a Presidential election). Together, we have also improved the quality of debate and identified the issues more clearly.

In my tenure at the FEA, I have appeared before congressional committees well over 100 times. Some may feel that such appearances are a wasted effort, but I believe that in our democratic system, improving the understanding of each others' views and analyses is essential to achieving a final product, called national policy.

Many people would find it hard to understand my statement that I am proud of what has been accomplished. They hear talk of higher prices, higher imports, and no energy policy. Yet, while it is true that our dependence is worse today than before the embargo, we have enacted significant legislation that will be the foundation of our energy policy for years to come.

THE ENERGY PERSPECTIVE

To understand where this Nation stands today with respect to energy, it is necessary to review how we have arrived in this situation.

Unfortunately, this Nation sold out its interest in an energy future at a time when we were self-sufficient. Rather than invest in developing new sources of U.S. energy and alternatives to oil and gas, we satisfied our growing energy appetite with cheap foreign fuel. There were those who raised a voice in alarm, and warned of ultimate disaster, but for political and other reasons they were not heard or ignored. The chromium-plated gunboats that Americans drove in the 1950's and 1960's were indicative of the choice that was made.

The unfortunate energy course pursued by the United States could be labelled the "Great American Energy Orgy." It led to a 3.5 percent growth in energy consumption each year, much of which is now considered wasted.

U.S. policy in the 1960's largely neglected U.S. energy sources in the Outer Continental Shelf, Alaska, and enhanced recovery from onshore wells. It left unattended the concern over nuclear power, especially for the back end of the fuel cycle. It ignored coal production, transportation, and consumption objectives; and more importantly, pursued policies which pushed the coal industry backwards.

The American consumer is now paying for these policies:

Oil production peaked in 1970 and continues to decline (although at a slower rate than in recent years). Despite very favorable signs in drilling activity this year, production will continue to slip until Alaskan oil comes on line.

Energy demand threatens to resume its historic growth trends. America consumes over 17 million barrels of oil per day, about 600 million tons of coal, and 20 trillion cubic feet of gas per year. Our wants are great. Petroleum imports will be higher this year than ever before—averaging about seven million barrels per day.

Americans are paying more for foreign oil than ever imagined a few years ago. We will spend about $34 billion for foreign oil in 1976, as compared to $27 billion last year, and $2.7 billion in 1970.

Natural gas production is also declining and shortages are growing in certain parts of the country. If the cold weather we are experiencing now continues throughout the winter, there could be adverse economic impacts in some areas.

Nuclear power expansion has slowed as a result of public concerns and private sector difficulties in building new plants, but we now have over 60 plants operational.

On the positive side, coal production is increasing and will approach 670 million tons in 1976—a record year; and there are encouraging signs for solar energy and some emerging technologies. But there is a long way to go before these newer sources contribute significantly to our energy supply.

Foreign energy is the highest cost energy we have, thus it makes economic sense to replace foreign sources with domestic energy. It also makes sense from a national security standpoint. Oil disruptions can have significant economic effects and are likely to be a threat even if the Middle East situation is resolved.

If we have learned anything, it is that turning around our energy situation is no simple matter—there are no easy solutions. Every solution that is proposed generates some opposition; none are completely acceptable to everyone. Our energy program cannot be simply a matter of choosing between conservation, solar energy, nuclear power, and coal. We must move forward in all these areas if we are to meet our energy needs.

Compounding the difficult choices, is the obvious political dilemma faced by legislators. The difficult legislative decisions that must be made today will pay off in benefits many years later. This time delay makes it much harder to justify taking such actions now.

Given this background, it is not surprising that people talk about higher prices, higher imports, and no energy policy. We've spent a mere 2 years trying to reverse the thinking that has developed over many years. What we are saying to the American people is that the free lunch we enjoyed in the past must now be paid for. If the American people are misled into believing that the artificial luxury of cheap energy and no sacrifices can continue, an even larger dilemma will result.

The buildings and cars built with the values of the 1960's will have to be replaced by a new generation of equipment. Improving our energy situation will require tough actions.

It is clear that the United States has the capability to make itself "embargo-proof" within the next 10 years. To keep our dependence upon foreign oil manageable, we will need an aggressive program to increase domestic supply, reduce the rate of growth of demand, provide standby authorities for use in the event of another embargo, and develop new technologies. In particular, we will have to move ahead in six key areas:

Increase coal production from current levels of about 670 million tons annually to over 1 billion tons per year by the mid-1980's. Almost all of the increased production will be to meet the needs of American consumers.

Expand oil and gas production in frontier areas of Alaska and the Outer Continental Shelf (OCS), as well as encourage enhanced recovery from existing fields to replace declining supply. Oil production needs to increase from 8 to 12 million barrels per day; gas production from less than 20 trillion cubic feet to almost 23 trillion cubic feet.

Increase the share of nuclear energy in the generation of electric power from about 9 percent to over 20 percent in the next 10 years.

Develop supplemental sources of oil and gas, such as coal gasification and liquefaction and shale oil to meet shortages of liquid and gaseous fuels; and expand dramatically the use of renewable sources, such as solar energy and wind.

Build a strategic petroleum reserve of 500 million barrels.

Reduce the annual rate of growth of energy demand from 3.5 percent to 2.5 percent.

LEGISLATIVE SCORECARD

Improving the energy situation will require building on the accomplishments of these 2 years and developing a long-range program. Suggesting it will be cheap or easy is a cruel hoax. We must never be so rigid as to be unwilling to reexamine previously formulated plans, but at the same time not slide back into political lethargy or using false hopes to provide easy solutions to political dilemmas.

The program I have set forth is a tall order and as Secretary Richardson has pointed out, we have made substantial progress in conservation and standby measures, but much less in providing for new supply. There are many reasons why our progress has come in these areas and not in supply incentives.

Conservation has been a popular issue, because it is generally cost-effective, can be identified with individual consumer actions, and protects the environment. But, I would like to caution that conservation is much easier to talk about than to effectuate.

Standby measures make common sense if the Nation is to prepare itself for another cutoff of supply.

Most resource development issues involve large-scale change for local communities, often with environmental effects, and public distrust of the energy industry and government is high.

Among the key measures to incentivize new production are those which involve raising the price of oil or natural gas. These price questions arose at a bad time—during a recession and soon after large increases in the world price had occurred—and, as a result, were not received favorably.

However, 7 of the 13 original titles of the President's Energy Independence Act are now law in largely the same form as originally proposed. The following major bills have been enacted:

Energy Reorganization Act.
Energy Policy and Conservation Act (EPCA).
Naval Petroleum Reserves Production Act.
Energy Conservation and Production Act (ECPA).
Alaska Natural Gas Transportation Act.

As a result of these laws, the Federal Government now has the authority and has begun to:

IN DOMESTIC SUPPLY

Exempt the first sale of domestic stripper well crude oil from price controls.

Implement the 40-month crude oil decontrol plan, under which domestic crude prices are allowed to escalate by no more than 10 percent annually to provide production incentives.

Provide added pricing flexibility to tertiary recovery and California heavy gravity crude.

Develop at the maximum efficient rate the three naval petroleum reserves in the lower-48 States; continue exploration of NPR–4 in Alaska, leading to its eventual development.

Implement an expedited selection process for a transportation route to deliver Alaskan natural gas to the lower-48 States.

Dismantle as much of the current petroleum product regulatory system as feasible.

IN CONSERVATION

Provide conservation grants to States to assist in the development and implementation of energy conservation programs.

Implement appliance energy efficiency labelling.

Set mandatory automobile efficiency standards for 1980 and 1985.

Establish industrial energy conservation targets for the 10 leading energy consuming industries, and mandating reporting of progress.

Develop thermal efficiency standards for all new residential and commercial buildings, subject to congressional approval of sanctions.

Implement a 3-year, $200 million weatherization grant program for the insulation of homes of low-income, elderly, and handicapped persons.

Provide grants to States for testing innovative utility rate structure designs to achieve a higher degree of conservation.

STANDBY

Build a strategic petroleum reserve of at least 150 million barrels of petroleum by 1978 and 500 million barrels by 1982.

Establish standby measures to deal with severe energy emergencies that may arise in the future.

Develop cooperative contingency and planning programs with the International Energy Agency (IEA).

This list is long, and, considering that it represents only 2 years of efforts, these accomplishments should not be understated. I, more than anyone, recognize that we have only begun the process of achieving energy self-sufficiency. Much more remains to be done if we hope to maintain our international leadership role and domestic security. I believe the new administration and Congress must address the issues squarely and move forward quickly.

We have today submitted to the subcommittee a detailed paper describing the major energy achievements, disappointments, and issues facing this country. I recommend that you review the contents of this "Perspective on Energy Policy" thoroughly, for it is an attempt to present the issues clearly and objectively.

In the remaining time today, I would like to address some of the key areas where progress is possible.

NATURAL GAS

Federal regulatory policy towards natural gas is one of the most crucial issues facing the Nation today; natural gas is consumed by over 40 million residences. over 3 million commercial establishments, and almost 200,000 industrial users. If new natural gas prices remain regulated, market distortions will persist and shortages in the interstate market will continue to grow. Federal price regulation has not been in the best interest of the Nation and I urge the Congress to deregulate new gas prices.

With curtailments still on the rise, I also suggest enactment of the emergency legislation proposed twice by the administration to alleviate short-term problems. Once the pricing and emergency legislation are enacted, the Congress should address the entire regulatory structure of the Federal Power Commission and its enabling legislation.

CRUDE OIL REGULATION

The crude oil pricing debate occupied much of our time during 1975 and again this year. The composite price formula in the EPCA has proven difficult to administer and changes should be considered.

The new administration and the Congress should take a careful look at expediting the phaseout of crude oil price controls, with or without the use of the Composite price concept. If the composite price mechanism is retained, it should operate with maximum flexibility so that its effects are what the Congress originally intended. That is, maximizing every opportunity for the production of domestic crude oil for the benefit of the American consumer.

It has become abundantly clear that the Nation must set a date certain by which domestic crude oil will be priced at its real replacement value, through a combination of decontrol and appropriate tax measures.

It is also important to remove any Federal regulations that prove unnecessary. FEA and the Congress have recognized that product decontrol is sensible with respect to residual fuel oil, middle distillates, and other fuels. Regulations on gasoline and other remaining controlled products should be reviewed carefully and similarly removed if criteria in the law are satisfied.

ENERGY TAXED

The debate over energy taxes last year attracted considerable attention. The administration proposed an excise tax on domestic petroleum along with increased import fees, while Congress considered a gasoline tax and other measures.

After starting with gasoline tax proposals of over 30 cents per gallon, the House failed to pass even a 3-cent gasoline tax. This experience with energy taxes points out the difficulty in raising energy prices to effect demand reductions, but I believe that the desirability of such taxes (either in the form of Btu taxes or on specific fuels, such as gasoline or natural gas) should be explored.

CONSERVATION

The achievements in energy conservation have resulted in a number of new programs that must now be implemented. The funding, staffing, design, and operation of these programs will be critical to our future. Most of the tough regulatory approaches to conservation have been enacted or were rejected for good reasons. Nevertheless, our work is not completed and there are still some measures to be considered.

Once, again, I urge the Congress to enact a tax credit for residential insulation. This measure, which can save over 100,000 barrels per day, has twice been deleted in conference committees. I also remain convinced that the thermal efficiency standards proposed by the administration should have been passed with tougher sanctions than agreed to by the Congress. The buildings sector provides great opportunities for savings.

While there are other conservation regulations in the buildings, industry, and transportation sectors that could be considered, most would have little effect. The key measure to induce conservation, especially in the near-term, would be the pricing of energy at its market value. Only when artificial controls are removed from energy prices can the market place receive the proper signals.

ENERGY DEVELOPMENT

Irrespective of the progress we make in reducing the rate of growth of energy demand, the Nation's use of energy will continue to expand. We will need large-scale increases in coal production, nuclear power, and use of renewable resources, and will have to reverse the declines in domestic oil and gas production.

The role of State and local governments and interest groups cannot be underestimated. The Federal Government must work in harmony with these entities before, not after, final resource development decisions are made. National interests do not always coincide with local interests, but widespread Federal overrides are doomed to failure. I propose that the new administration assess more thoroughly ways to involve local interests in Federal decisionmaking.

The balance between energy, economic, and environmental objectives is delicate, but must be maintained. Careful planning can avoid most of the impacts of energy projects sometimes feared by local residents. Too often we only hear from those who say we must stop growth or those who say that anyone who questions energy development is a "kook." Instead of polarization, we need harmony, cool heads, and objective analysis.

In addition, the uncertainties facing investors must be overcome. These include policy uncertainties with respect to environmental standards (such as the Clean Air Act and surface mining) and price controls, as well as geologic uncertainties (such as frontier OCS reserves and leasing schedules). The Congress has an obligation to reduce these uncertainties and provide a stable investment climate.

UTILITIES

One of the key resource development questions relates to the building of new powerplants. In the last few years, utilities experienced a dramatic change in their profitability, financing capabilities, growth estimates, and public acceptance. The United States needs new coal-fired and nuclear capacity if it is to avoid power shortages or greater reliance on oil- or gas-fired power. Assistance to utilities, especially in the face of higher rates already in effect, has not been popular, and most of the administration's initiatives have not been successful.

I urge Congress to review the utility situation carefully and to consider legislation to improve the siting process (without encumbering it with added Federal bureaucracy); to consider new approaches (such as S. 1777) to the coal conversion process; but to weigh the results of FEA's utility rate structure studies before pressing ahead with new legislation.

NUCLEAR ENERGY

A key part of the utility problem is the growth of nuclear energy. The United States will need to increase nuclear power's role in its economy or see oil imports grow even more in the future. Many nuclear plants have been cancelled or delayed because of financing, siting, or load growth difficulties. There has been greater public concern over the safety of such plants, yet referenda in several States this year and a recent public opinion survey showed considerable public support for nuclear power.

This administration has proposed a comprehensive and innovative set of programs to expand nuclear development with careful consideration of safety. Bills to improve the licensing process, transfer enrichment facilities to the private sector, and others failed to receive positive congressional action. The President increased safety and waste management budgets dramatically, and proposed in October, a detailed policy on proliferation and safeguards. The measures he announced could go a long way to establishing a safe and reliable international nuclear program and should be acted upon favorably by the new administration and Congress.

FINANCING

While I would hope and expect that most new energy projects could be developed and financed privately, there may be a need for Federal financial assistance in some areas. The Congress has already enacted several programs to provide financial support for coal, geothermal power, conservation, and coastal zone development.

Maximum reliance should be placed on private sector financing. Nevertheless, some projects may require Federal financial assistance if they contribute significantly to energy independence, but would not be undertaken in a timely fashion without such assistance. More Federal money should not be the answer to all problems, but could be important in some selected cases.

R. & D. PRIORITIES

I would like to spend a few moments on energy R. & D. priorities. It is my belief that the R. & D. funds authorized readily today by government will someday begin to wane. We should therefore set our energy R. & D. priorities carefully. We must look first towards those technologies with the greatest likelihood of being significant contributors and economic in this century. We must also be prepared for failure and have contingency plans available in case some of our research efforts do not pay off.

CONCLUSION

I would like to conclude by saying that I am optimistic about America's future. I have lived with the difficulties of developing and implementing controversial policies, and have seen how easily the process can be frustrated. Yet, this committee and others have shown that our political system can work and we have started on a new energy policy for this Nation.

As I leave office, I am not discouraged or overly frustrated. I leave with the realization that we have begun what was long overdue. This country has the knowledge, and, if it has the will, it can overcome formidable obstacles to achieve its goals. I believe our efforts will result in regaining our energy independence and national pride, and I am grateful for the opportunity to have served my country.

Thank you, Mr. Chairman. Secretary Richardson and I would be happy to answer your questions at this time.

Mr. DINGELL. Thank you very much, Mr. Zarb. The subcommittee commends you for your helpful statement and the very fine document entitled "Perspective on Energy Policy" submitted by both you and Secretary Richardson. Gentlemen, these will be very helpful to the subcommittee and to the Nation.

The Chair now recognizes the gentleman from Indiana, Mr. Sharp, who was the first member of the subcommittee present.

Mr. SHARP. Thank you, Mr. Chairman.

I, too want to compliment the Secretary and the Administrator on their diligence and efforts on behalf of an energy policy for this country. Of course, our subcommittee has dealt more with the Administrator than almost anyone else and he has suffered through many long hours of questioning and argumentation on these issues and I certainly think our country has been well served even though we could not always agree on exactly what the policy ought to be.

One of the things that I wanted to do was to go over some of the specific programs that we had placed into law, cooperatively or uncooperatively, and kind of see where we stand, but I am not sure that is an appropriate level of detail for this hearing.

It seems to me that you have provided us a valuable document, the "Perspective on Energy Policy," which I have just glanced through—seems it will be a very valuable thing to help shape the debate in the year to come, but I am not sure that it goes into specifically telling us where we stand on State conservation plans for instance.

What I want to ask you is if such an overview document exists in the executive branch today, to help all of us inside and outside the Government know where are we in the process of implementing the various things that we think we have committed ourselves to.

Mr. ZARB. We do have such a document, Mr. Sharp, that was prepared for the transition team and I will be most happy to submit it for the record. It covers all areas and shows where deadlines have been met, where they have not and why not and in certain cases when they are most likely to be met.

As you know, when those things go into legislative language the implementors are rarely consulted. I would be most happy to give you this document and make sure that it appears as part of the record of these hearings.

Mr. SHARP. Mr. Chairman, I think that might be a valuable thing, assuming it is reasonable, to have it printed as a part of this hearing.

Mr. DINGELL. I think that would be helpful and, without objection, the document referred to will be inserted in the record at the appropriate place. [See p. 160.]

Mr. SHARP. I think one of the values of the argument, as both the Secretary and the Administrator pointed out, so few people comprehend that much has been done, and bringing these various threads together some place where those of us inside and outside the Government have a chance to see them would be very valuable.

Mr. Chairman, that was my essential concern, so rather than going down the specific items of the programs that we have implemented, I think we will wait for that to be supplied for the record.

Mr. DINGELL. The Chair thanks the gentleman from Indiana.

My dear friend and colleague, the senior minority member, Mr. Brown.

Mr. BROWN. Mr. Chairman, thank you very much.

I am delighted that we have this opportunity to say what, as far as I am concerned, is a very fond farewell to both Secretary Richardson and Administrator Zarb.

I think that both of you are deserving of the highest praise of the members of this committee for the way in which you have conducted your responsibilities and also the approbation of the American people for the way in which you have addressed what may very well be the most difficult problem that we will face in this decade, the next 7 years of which hopefully will see us well on the way to the solution to the problems presented by the embargo and the decline of our traditional energy resources and the necessity of developing new ones.

Having tackled that problem, I heard on the air the other day that Secretary Richardson may be interested in tackling a more difficult problem, the governorship of the State of Massachusetts.

Secretary RICHARDSON. I don't know.

Mr. BROWN. Which says a lot for your courage but not much for your discretion I would suggest.

However, being Mr. Everybody in previous Republican administration and even before that Mr. Everything in the State of Massachusetts, I am sure that you are not afraid of taking on anything, so good luck whatever the future may hold for you.

Secretary RICHARDSON. Thank you, Mr. Brown.

Mr. BROWN. I once suggested to Mr. Zarb that since it fell to my lot to support some of the administration's energy policies, when I was therefore retired as a result from the Congress maybe he could speak to Major Beame and I could have the responsibility of selling Big Mac bonds on the sunny side of the street in the Bronx through whatever connections he might have in New York.

Mr. ZARB. I have my connections in Brooklyn, Mr. Brown.

Mr. BROWN. Well, maybe I could do it in Brooklyn, but, in any event, I think that, Frank, in your effort to deal with this committee and with the Congress and the problems of the industry your results have been very impressive. I am sorry that we didn't solve all the problems but I think the Congress and the administration have for the most part been ahead of the perception of the folks at home as to the depth of the problems and I think all of us in the Congress and the administration have done the best we could to bring those problems to full public attention.

I am particularly impressed with this white paper which spells out the options from which the next administration is going to have to select. You do a good job developing the options and a good job, I think, in discussing the pitfalls and problems and the advantages which flow from those options. I can't help but wish that you had been a little more specific in terms of recommendations, but I understand the restraint that is called for under the present circumstances.

In any event, I hope that President-elect Carter gets the opportunity to look at this paper and draw from it.

I would like to address a couple of questions to the paper and to a couple of other issues, if I may, and get your opinion on them for a last bit of guidance to this committee and gain to the new administration in the country.

In the white paper you discuss the options available for the resolution of the natural gas problem. In the list of options at least I did not perceive the mention of the alternative of reregulation; that is, the creation of a statutory mechanism for the gradual natural gas price increase monitored by the Federal Power Commission similar to the EPCA crude oil pricing mechanism which was adopted by the Congress. The Stevenson Btu equivalency bill of last year was probably the closest example to a congressional recommendation to this approach. What are your feelings about such an option, and what are the advantages or disadvantages which you see to that kind of reregulation?

Mr. ZARB. Well, Mr. Brown, that notion is left in there. It may not have been headed exactly that way, but we do discuss the gradual approach which addresses that particular option.

Mr. BROWN. Is this the suggestion that is made on page 19?

Mr. ZARB. That is correct. What we are trying to do there is lay out openly what the options seem to be, knowing that the next administration is going to want to use its own judgments which are the best.

I get back to my comment earlier on pricing. I know this is very controversial and I know it is difficult to sell politically and certainly has not been politically popular. I guess it can be said that after having these kinds of positions and being attacked by both the American petroleum industry and Ralph Nader in the same paragraph of one newspaper story I will never run for the Governorship of Massachusetts.

It simply gets down to the issue of where we are headed in the long term. This is one man's view after 2 years in the trenches. We must face the fact that we are going to have to price all these products at full market value. Gas should probably be priced at its equivalent to oil at some point in time. It certainly should not be cheaper than oil, it gets used in more ways, and under those circumstances we are using a clean, valuable fuel incorrectly.

So my overall view is that each of these energy products should be priced at their real value in the marketplace. I think we can deal with the windfall problems and make sure that no industry gets away with a windfall profit through the use of a good tax mechanism. Only through that approach are we going to have a balanced environment. Environmentalists surely must support this notion and many of them do. Only then are we going to get a conservation adjustment.

Conservation is changing the habits of people over a long period of time. It is not one act or one bill or one standard. People have to buy better equipment and demand better equipment and automobiles than they have. That is why Detroit is producing a car 34-percent more efficient than in 1974, but it takes 8 or 10 years to build a new car fleet.

We will have to build buildings differently. They have to look at this energy equation with different kinds of values. If they do, then we are going to have the slow change toward an ethic which treats energy for its real value and then we are also going to induce proper alternatives because, if you are developing solar energy right now and were raising capital for that endeavor, your stockholders would ask you this question: What are you going to produce by what year and what are you going to compete with?

If you are competing with suppressed pricing in terms of controls or reallocation of existing supplies you are not going to get capital as quickly as you would otherwise because it is only when you can prove an economic penetration that is going to have your product expanded that you are going to get that kind of investment.

So I go back to the macrojudgment that at some point we have to face the fact that the Nation must perceive the day 2 years or 3 years hence that we are going to be at that level using deregulation and taxes to get there. To go back into the system and reregulate, and to condone a process of suppressing prices does not make sense.

I also hasten to add that I don't ignore the social problems here because there are people in this country who are on fixed incomes and are paying more for energy than they can afford right now today.

Mr. BROWN. That is true of food and transportation and a wide variety of things that affect those people and the question is whether we should deal with that as a welfare problem or deal with it as an energy problem.

Mr. ZARB. I add it because I think it should be dealt with as a whole and that the social implications should be judged and dealt with at the same time and they can be in the kind of scenario that I just described.

Secretary RICHARDSON. I would only add, Mr. Chairman, and Mr. Brown, that I fully agree with Mr. Brown's last comment with respect to the social impact of allowing market forces to assert themselves in the pricing of various energy sources. I think that we do need a more adequate, comprehensive policy toward the protection of the income levels of poor people and I think if we had this it ought to take into account, as you suggest, fuel costs as well as costs of food and rent and other costs.

I think we already suffer too much from a piecemeal approach to the provision of various benefits in kind or offsets to existing costs and so I hope that there will be new attention in the new Congress toward the question of income maintenance, including this whole range of issues.

Mr. ZARB. I would like to add a thought, Mr. Brown, since we are at a point of letting it all hang out. As we debated decontrol over the last

2 years there were a number of arguments opposed to it but some of the real arguments were never really articulated and it seems to me we ought to examine them for what they really are.

The decontrol of crude pricing at a more expedited rate, I think, was not blocked because of its economic impact or because of the gap between OPEC and domestic pricing because those could have been accommodated. We could have had a straight line phaseout of crude pricing and we could have done it in a way so that triggers would occur if the economic recovery didn't continue. There could have been any number of protections in that notion. So that really was not the problem.

What the problems were that we did not face squarely were these social implications and how they would be dealt with.

We said they would be dealt with and people could not see them and feel them and didn't believe them and then, of course, the problem of pricing domestic crude at foreign rates so that OPEC would be driving 60 percent of our oil production was distasteful to them because they didn't believe that there would be a sensible windfall tax measure in place.

I say these things simply because they are true and it seems to me that those issues ought to be faced squarely so that good public policy can be made and we can get to that point and do it in a comprehensive form.

Mr. BROWN. I would suggest there was one other problem, too, and that was the public perception of the whole energy issue. For a time there was—and you made reference to it—a longstanding feeling that the energy problem was a conspiracy of the oil industry or the gas industry that some wanted to attack as a matter of making political blame, rather than economic blame or factual blame on what the facts were.

I again compliment you, Mr. Zarb, for having, through your trips, straightened out or disabused the average citizen of some easy faultfinding and having brought about a more general understanding of what the real deep economic and international problems are here.

I have a couple of other questions. One of the basic problems that we are soon going to have to face is the disposition of Alaskan crude oil. As you know, one of the companies located in the State of Ohio is a big player in that Alaskan project and has been fairly deep in the financial markets in order to get the Alaskan oil out. They have developed plans for a crude oil pipeline from Long Beach, Calif., to Midland, Tex., where the oil could either be refined or shipped on to the Middle West and the East.

What is your view of this alternative vis-a-vis a crude oil exchange program with Japan on a continuing basis since the necessity of doing something temporarily may have to embrace an exchange with Japan until the pipeline arrangement can be finally made? There are other options also which have been suggested, including the Panama Canal and a route through Canada. Has your outgoing agency focused in on this problem as yet?

Mr. ZARB. We have, Mr. Chairman, and we have published a report just about a week or 10 days ago that outlines the various alternatives to move that oil from West to East. We talk about the pipeline you referred to and we talk about both Northern Tier and a trans-Canada line. We talk about the reversal of the Sohio line in California and we talk about tanking. We mention the Japanese exchange or foreign exchanges in passing and I quickly add that from a standpoint of national energy policy I think that should not be considered as a viable option.

There is no reason, in my view, that that oil cannot be delivered to the domestic markets in the near and long term and used here for the benefit of the American people for whom it was originally designed. I would oppose and continue to oppose exporting of that oil. It can be tankered through the canal until the necessary pipelines are completed and ultimately we are going to have to have pipelines.

Mr. Brown. Do you feel we have enough Jones Act ships?

Mr. Zarb. Yes, and that is not only our judgment in that matter, but also the Maritime Administration's judgment. I see no reason why we should consider exchange and I would just add this. Those proponents of an exchange always say that we will do it for the time being and then, if we need the oil because of a national emergency, we will just use it at home. In the long term we will develop some answer.

My reaction to that is that if we take the heat off the system now we are not going to get any long-term answer and the notion that we can disconnect the foreign connection and plug it in here overnight in case we need it is nonsense.

Unless we solve the shipping and transportation questions now and unless we solve the refining questions now because we have to have special refining capacity for that particular oil, it just simply won't get done and the ability to diplomatically undo that kind of a transaction is almost laughable because in history that kind of thing just does not occur.

So I must say, Mr. Brown, in many areas I am willing to listen to lots of different options. I have looked at this one very carefully and my personal perception is that that should not be considered as an alternative.

Mr. Brown. We may have some diplomatic problems with at least one State in connection with some of those proposals, but do you consider the problem of such national importance that the Federal Government may have to make a decision in this area if the State is recalcitrant?

Mr. Zarb. Mr. Brown, if we cannot resolve this issue within the private sector and the State and local level within the next 6 months, the Congress of the United States ought to undertake to legislate an answer.

Mr. Dingell. Would the gentleman yield?

Mr. Brown. Yes; I would be happy to.

Mr. Dingell. I think what you have been saying on this matter, Mr. Zarb, is that if we cannot now solve the problems of carriage, tankerage, and refining along with the associated diplomatic problem of oil supplies for Japan, then in the midst of a crisis it would certainly be beyond our capacity to do so?

Mr. Zarb. Yes, sir.

Mr. Dingell. I am happy to hear your comments with regard to the diplomatic problems that we seem to be having with one State. I don't look with great kindness on one State holding up the other 49 for natural gas supplies or for preferential treatment on some matter of local concern. I hope that the incoming administration will view it as do you and, quite frankly, as do I.

I thank the gentleman.

Secretary RICHARDSON. Mr. Chairman, may I just add with respect to the Alaskan oil disposition report that was circulated in draft and for comment among the ERC members and we hope before we leave on January 20 to be able to reach a definite recommendation.

Mr. DINGELL. I certainly applaud that, Mr. Secretary.

Mr. BROWN. I have two other questions, Mr. Chairman, if you would permit.

On pages 29 and 30 of the white paper that you presented you state that the perceived impacts of gasoline decontrol might be mitigated by dealer protection legislation but that that may be no justification for such a bill. I would like to address this question to both of you gentlemen.

Why do you feel that a dealer protection bill may not be justified at this point?

Mr. ZARB. Our language there leaves the debate open so the Congress can make a judgment on what the actual needs are and what form of legislation is required. We have been from time to time impressed with the fact that the independent businessman may need protection similar to the automobile area that the Congress provided protection for in the 1950's so that his equity in his enterprise and interest could be protected given the structure of the current industry. I still believe that should be a viable debate and undoubtedly there could be a possibility that that legislation has to come along with gasoline decontrol.

Mr. BROWN. Before the Secretary answers I might just say that the chairman and I were involved in drafting a bill which perhaps neither one of us thought was perfect but seemed to do the job in as equitable a way as possible.

I had the feeling that in this whole area of franchise legislation we have bitten off only parts. As you suggest, the automobile dealers at one stage of the game and the oil marketers at another got some other franchise legislation that was batted about this committee from time to time. Maybe we are not quite to the place where we can get a single piece of legislation that would embrace all franchise arrangements and it seems to me that if we do open up the gasoline market we may need that franchise bill at least for the time being.

Mr. Secretary, perhaps you would like to comment on the broader aspects of franchise legislation or your feeling about this particular piece of legislation as you will.

Secretary RICHARDSON. Well on this particular legislation we had some discussion of it in meetings both of the Economic Policy Board and of the Energy Resources Council and in general we support it. We think that it would help to afford a measure of needed protection against possible exploitation of gasoline station operators. To a degree perhaps this protection can be derived from existing legislation and from the enforcement of the terms of their contract but, nevertheless, it would probably be a reassuring element in the overall relationship to enact it.

With respect to the broader problem of similar legislation with regard to other franchise operations, I don't really have a considered view at this stage. I think it is something that ought to be watched but I think that my own feeling at the moment is that the burden of proof of the need for a comprehensive Government program has not yet been sustained and I think in general we are at a point now where so much legislation has been adopted for so many purposes that there ought to be a fairly heavy burden of proof on Federal intervention in any new area.

Mr. BROWN. Your position is not unlike this committee's in that we have dealt with it in various aspects but really have not come to a conclusion as to whether we are doing the right thing or the wrong thing or too much or not enough.

I have one final question. I am tempted to ask questions the rest of the afternoon but I will conclude with this question which I don't think you really addressed in much detail either in the paper or in your remarks. I would like to get your comments on it because I think we are going to have to face this problem apparently within the next few days as a result of what happens in the OPEC price increase discussions.

Your paper mentions the need for greater flexibility in the crude oil pricing mechanism. What changes in the law would need to be made to provide this needed flexibility to meet a moving OPEC price target which apparently we are going to have to face if not in the next few days maybe 6 months from now when there is some new OPEC price level set and our legislation freezes us into a position on oil prices that does not or did not take that into full account?

Mr. ZARB. Mr. Brown, I go back to our discussions in December of 1975 when the Congress passed an energy bill using an average price concept and we talked about flexibility and need to leave the program in a way that it can be administered so that we don't lose opportunities for increased production as those opportunities become apparent to the Administrator.

We talk long and hard about that, both the Congress and we together, and in the conference the key conferees and I had personal conversations in both the House and Senate. We talked about the 90-day provision and finally settled on that as being best.

Well, that has not worked too well thus far. The first opportunity for implementing that was in August and because it was hung up with other legislative concerns the conferees asked the administration not to submit it and in return they would do some legislative things in the FEA extension act.

So if we look at the existing bill, we ought to get back to that thought and see how the Administrator and the various committees can come to an agreement as to his flexibility in doing these things and in coming to the Congress for a change in the escalator rate at the end of the 90-day period. That should be a vital part of the program.

Now, having said that, it seems to me that there could be some time profitably spent on the overall question of pricing and taxes. Where are we headed? At what given point in time will this Nation have all of its energy products priced at realistic replacement values in the economy assuming that the Congress comes to that judgment? I have said before that thinking people around the world who worry about the environment and worry about a lot of other things have come to this exact same conclusion.

80-533—77——3

If you do that, then you can work backward in determining what kinds of flexibility the Congress and the administration should have to reach that stated goal. We put that provision in the white paper simply to stimulate the issue and to hope that there would be a consultation between the administration and the Congress in the next session and hopefully come to an agreement which would have a realistic goal in mind as to when this economy is going to be faced with that condition.

Mr. Brown. Of course, you ran into the argument that since OPEC determines the price level worldwide that you don't really have a free market, and we faced that for the last 2 years as a discussion point. Specifically do you see any need for change in the law or do you think that the question of a moving OPEC target all along can be handled in an administrative way under the law?

Mr. Zarb. I think the Congress ought to look at the pricing question again and look at 1 year's experience and that is what we have had with this particular bill, how it has operated and whether it operates consistently and then determine whether or not a change should be made. I should think that a good review after a year of operation of a major new approach is probably in order.

Mr. Brown. In a political sense it occurs to me that a Democratic administration might suggest the market approach to energy policy and have that be greeted with less suspicion in a political sense than a Republican administration might because of the nature of it to the parties and their perception by the public, not unlike the opportunity that the Republican President had to recognize Red China without being thought to be toting to the communists in some way. I would hope that we get that opportunity to see that kind of leadership out of the next administration.

I just want to conclude by thanking both of you for the kind of leadership you have shown in this administration and this field and others and to say that you go to whatever your futures may hold for you with my deep respect and not a little personal affection for both of you. Whatever avenues you pursue, I think I feel again too much personal affection for you both to hope that you wind up as either Governor of Massachusetts or mayor of New York or any of those other jobs that apparently can't be played with any success.

In any event, I want to thank you and thank you on behalf not only of myself but the people in my congressional district for the service that you have rendered to the country.

I know that both of you might have found employment where you would have been better remunerated and perhaps even more appreciated by the public and your families and everybody else with whom you have an association, but the country has been and is deeply in your debt as a result of the service you have rendered and we thank you very much.

Secretary Richardson. Thank you for the kind words, Mr. Brown. I can only say that it is hard for me to imagine Frank Zarb's enjoying anything nearly as much as he has enjoyed these 160-odd, or whatever they were, appearances before this and other committees of the Congress. It is going to be very hard for him to find kicks on the outside anywhere near comparable and it may well be that the mayoralty of New York is the closest he could come.

It may well be agreed that I would not even be considering running for the governorship of Massachusetts if it were not that I can't think of anything else that would meet my combatted instincts, challenge my ingenuity, resourcefulness or teach me as much as the opportunity to work with you and others of the Congress over the years.

At any rate, it is not always enjoyable. It is always, I think, rewarding and satisfying to feel in relationship to the work of a congressional committee and the Congress as a whole—this sense of satisfaction that I think can only come from the realization that we are strenuously wrestling with major issues of general public concern.

For my part I would like to thank this committee and its members not only for what has been said now but through your other committees with which I have worked over many years.

Mr. Dingell. Thank you, Mr. Secretary and Mr. Zarb.

Gentlemen, I would like to comment.

Mr. Secretary, on page 11 of your comments you recommended that the Congress consider an amendment to the Energy Policy and Conservation Act which would permit a less complex emergency system and remove the prohibitions on taxes, fees, ration coupon charges, and other price-related mechanisms for emergency use.

Without expecting that you give us precise comment at this moment, would you want to address yourself to this point?

Secretary Richardson. Yes, Mr. Chairman. This has been a subject that the Energy Resources Council has recently reviewed in connection with the preparation of contingency plans to be submitted to the Congress.

The EPCA requires the development of a rationing plan and in looking at this it may well be that there is a less cumbersome approach which instead of having to issue coupons to individuals and industrial users would in effect use fees and taxes and can either alternatively or in conjunction be used with such an approach in order to simplify it. We have estimated that the costs of administration of a rationing system would be about $2 billion a year as the total cost of putting it in place and operating it and on an annual basis.

Mr. Dingell. I think it would be helpful, Mr. Secretary, if when you get back you could ask yourself to give us such amplification on those comments as you felt was appropriate.

Secretary Richardson. Be delighted.

Mr. Dingell. Giving us your views and feelings.

Secretary Richardson. Be glad to do that, Mr. Chairman.

Mr. Dingell. Mr. Secretary, you have commented on in your statement with regard to a series of options and alternatives for reorganizing the energy structures of the Government. You have made a number of possibilities that you outlined both on page 16 and earlier. You mentioned particularly at the bottom of page 16:

> The ERC study has considered a wide variety of alternative approaches, including establishment of a Department of Energy and Natural Resources, establishment of a Department of Energy, establishment of a smaller energy agency composed solely of FEA and ERDA, and retention of the present system, including the ERC.

I would suspect that you and my good friend, Mr. Zarb, may not be able to give us any final statements or views on the part of the administration at this time, but if you did have some suggestions that you would like to make to us on this matter, I think it would be very well received by the subcommittee.

Secretary RICHARDSON. Well, I thank you, Mr. Chairman. I probably should in this connection ask not to go into my own personal views on it because we have submitted this report to the President with our analysis of the pros and cons of each of these options and I believe he will want to make his own recommendation probably directly to the Congress before he leaves office.

I think it perhaps sufficient to say that in my view it is desirable to bring about a more efficient degree of coordination than we now have and to do this with a view to some combination of the existing agencies, that really the principal issues, in my view, turn on how many of them you combine and how far you go beyond the range of strictly energy-related functions. My own view on the whole is that the line should be drawn probably around energy-related functions.

Mr. DINGELL. I am anxious to have as many of your views as you can give since this is obviously a question with which we will be dealing in the forthcoming Congress. While we will probably have the problem, I am not sure we will have the views of either yourself or Mr. Zarb.

Mr. Zarb, I was wondering if you had any thoughts or comments to share with us on reorganizing energy management functions in the Government?

Mr. ZARB. As the Secretary pointed out, the President now has an option paper that describes a wide range of alternatives. They are not secret; they run all the way from doing nothing, to a Department of Energy and Department of National Resources, and a number of intermediate options should be examined. They are obviously not the only ones available.

I had hoped, Mr. Chairman, that in this enterprise the Nation would have come to a conclusion with respect to its real objectives in the next 10 years—how we are going to get from here to there, what the Government's role was, and then produce a Government agency that was designed to accomplish a specific mission.

Since the completion of policy debate is going to take some time and since there is a need, at least a perceived need to do something with respect to organization, I see only one problem. The problem is that it is always easy to spend a lot of time working on organizational changes. It seems to me that could be a risk. However, having said that, I think working to avoid duplication and concentrating responsibility with one Cabinet officer or one many probably makes a lot of sense.

I cannot help but believe that the Congress is going to have to address its own organizational structures though. If it gets into this debate, obviously that can last a long time. I would hate to see the Ford momentum of substantive legislation sidetracked, and I hope that does not occur.

Mr. DINGELL. Peripherally, you have both mentioned the problem of natural gas and energy supplies during the winter.

As you will recall, this subcommittee recently held some hearings in which we sought to get some appreciation of the outlook for the winter, particularly with regard to such matters as home heating, industrial use, and curtailments. With the assistance of your two agencies, we achieved some long-range weather estimates as well as some estimates of supply and demand.

The consensus seemed to be that if the winter wasn't very much worse than anticipated, we could probably get through without major disruptions.

Have you any comment you would like to give us on this particular point of current concern? The weather has been quite bad, as you both know.

Mr. ZARB. Since I don't have the data upon which to say what I am going to say, I see no need to caveat what I am about to say by saying I don't have data.

Mr. DINGELL. In this you are not very different from most people. We have been getting a lot of predictions.

Mr. ZARB. I would say our level of concern has increased since our last testimony on the matter.

The degree data we have gotten with respect to the severity of the winter has indicated that most parts of the country have experienced much colder weather than what we consider the norm. Should that continue, we are, indeed, in some parts of the country, going to have the extreme case where we do have shortages, curtailments, which are occurring now and that will have some economic impact in those sectors.

A lot of conversion is taking place to substitute fuel, such as No. 2 oil, but that is a very expensive conversion because the price of No. 2 oil is much, much higher than the historic price of natural gas; so the consumer is going to feel it in the cost of products.

We are working on a reestimate based on the data. We currently cannot give you a date, we are going to publish it; but our level of concern has increased some since the last time we talked about the matter.

Mr. DINGELL. Mr. Secretary, would you like to make a comment?

Secretary RICHARDSON. No; I really cannot add usefully to what Mr. Zarb has already said.

Mr. DINGELL. Gentlemen, one matter of particular ongoing concern to the subcommittee has been the question of strategic petroleum reserves. Mr. Zarb's comments at page 11 indicated that the proposal was ongoing to develop a strategic petroleum reserve of at least 150 million barrels of petroleum by 1978, and 500 million by 1982.

You have never said this, Mr. Zarb, and in fact, I never heard it out of FEA, but I had the general appreciation that one of our major problems in this area has been the Office of Management and Budget, where that program is neither well received nor getting much support. As a matter of fact, it seems to be in substantial trouble down there.

Could you discuss how that process is going forward and whether or not there are any administrative problems in terms of achieving progress in that area?

Mr. ZARB. Mr. Chairman, without commenting on your observation, I would say that we are on target.

Yesterday was the 15th. We were mandated to have reports to the Congress. Your office had a copy of that report on the night of the 14th, and we made it public yesterday. It outlines the format that we would like to use in going forward.

The Congress will have 45 days, starting with, I think, January 3 or 4, and within that period either vote it up or down. It is my guess that you are going to want to have hearings on that plan early in the year, and we have tried to construct it so that it could be amended to accommodate findings that were not apparent at the time we produced the report.

It is my judgment that the 500 million barrels should be in the ground by 1982, and I think the Government will use means of expediting that as we move forward.

The biggest delay thus far has been the preparation of the environmental impact statement on the sites we intend to use, but that seems to be behind us at this point in time; so we are going to be able to move out rather nicely. The country is then going to have to look in 1977 through 1978 as to what level above 500 million it wants to get to.

The authorization bill calls for a billion barrels. There is some argument that 750 million will do the job. The world will continue to spin and there will be changes, and I think the Congress has ample opportunity to take a whole new look at that, as will the new administration.

In my view, it will probably require something above 500 million and possibly 3 billion. Given the changing conditions in the world, we ought to leave some flexibility on that issue.

Mr. DINGELL. There is another question you raised in your comments on page 18 and I would like to hear you amplify on it, if you are so minded.

In the second paragraph, you urged the Congress to review utilities carefully, to consider means to improve the siting process, but to weigh the results of FEA's utility rate structure studies before pressing ahead with new legislation.

Would you want to amplify on the tentative findings with regard to your utility rate structure studies and how this would impact upon the siting process legislation? Have you any thoughts on what this committee ought to consider in terms of planning its agenda for the year ahead?

Mr. ZARB. Yes, sir. In the utility sector there are several worrisome aspects that I am sure will be addressed next year. One is the whole question of utility capacity and what will be required going into the 1980's.

Our experience has been that in some cases that expanding at the utility level creates so much heartburn that utility executives are miscalculating, or at least temporarily ignoring the issue.

The Government now is telling them they cannot burn oil, and we are issuing prohibition orders—I think we have 100 out now and more will go in the next week—prohibiting new construction from being oil- or gas-fired. Given that they have to consider either coal or nuclear—and that is always a local debate of some size—and rather than facing that, some utilities have gone to looking at their 1975 growth rates, making projections off that base, and then concluding they can wait another year or two before coming to the hard decisions because they don't want to fight the battle. That is problem No. 1.

Not insignificant in that is the problem with moving to coal, because there are a number of bureaucratic roadblocks in the system that preclude that. The automatic passthrough of fuel cost increases sometimes work against that, although it is required for other reasons by State regulators if that utility has that available. Sometimes they opt not to go for the more economical fuel such as coal; so that is going to have to be looked at.

Now, given that as a problem, beyond that we have the problem of facility siting. There have been cases in the country where it has taken 7 to 8 years to settle on the site with all the litigation required, and that should not be permitted on an ongoing basis, and some kind of siting legislation surely should be considered. I don't mean to permit building way above what capacity should be, but I think we ought to realistically look at some of these areas in a full employment environment.

If our economy is running at full speed in 1982, some of these areas should be questioned as to whether they are going to have enough power to keep the lights burning. Part of that is the whole question of pricing, so that you won't need capacity to support waste. Time-of-day pricing, quantity discounts, all issues which we have addressed during the course of the last 2 years—is complicated; it is a States' rights issue. In many cases the States have the authority here.

We have done some studies. We have no conclusive results at this time. I am hopeful the new administration will have the studies complete and available shortly after they take over on the 20th with complete discussion of the whole issue of utility siting, pricing, and where we are going to form the basis of very constructive hearings for the American people.

Mr. Dingell. The Chair thanks you and commends you for your assistance to the committee and for a very fine presentation.

At this time the Chair recognizes our counsel and staff director, Mr. Potter, for questions.

Mr. Potter. Gentlemen, I would like to talk to you, to the extent that you are comfortable in doing so, about the OPEC meeting which is presently underway.

Assuming that OPEC counties get their act together and that some form of price increase is settled upon—which I think is not altogether unlikely—have you considered and are you prepared at this time to give us the benefit of your considerations as to what the likely impacts on our economy would be for a price rise, say in the order of 5 to 10 percent?

Mr. Richardson. Mr. Potter, we have reviewed the estimated effects of price increases in the range from 5 percent to 15 percent, and in terms of impact on gasoline prices, heating oil prices, aggregate cost of oil imports and so on, and to take lower end and next to no increases—of course the lower the better—we estimate that average gasoline prices would increase by about 1 cent a gallon in 1977 as a result of a 5 percent OPEC price increase. This assumes that the crude cost increase is spread equally across all products. On the same assumption, heating oil prices would be expected to rise by about 1 cent a gallon also.

In the case of New England, because of its greater dependency on imported products, there might be another tenth of a cent increase. The total cost of crude oil and product impact in 1977 is expected to be about $1.7 billion greater as a result of the 5 percent OPEC price increase, and the increased cost to consumers would be about $2 billion.

As far as the economy as a whole is concerned, we anticipate that the results would be to reduce real GNP about three-tenths of 1 percent by the end of 1977, and by about four-tenths of 1 percent by the end of 1978.

The consumer price index is projected to increase by about one-tenth to three-tenths of 1 percent by the end of 1977 above what it would otherwise be, and one-tenth to three-tenths of 1 percent higher by the end of 1978. This assumes a projected increase of about 5 percent in both 1977 and 1978 from an OPEC price increase. The combined result of these would also be to increase the unemployment rate by about one-tenth of a percentage point at the end of 1977, and another one-tenth at the end of 1978.

This assumes current projections of the unemployment rate at the end of 1977 and 1978 of 6.9 percent and 6.3 percent, respectively.

If you go over to the higher assumption, skipping intermediate stages, 15 percent produces a 2½-cents increase in the price of gasoline, 2½ cents a gallon on heating oil, an increase of $5 billion in the crude oil and product import, increased consumer costs of about $5.7 billion, a reduction of real GNP by nearly 1 percent, nine-tenths of 1 percent by the end of 1977, and by 1.3 percent by the end of 1978.

The consumer price index would be expected to be about four-tenths to seven-tenths of a percentage point higher by the end of 1977, and four-tenths to seven-tenths higher at the end of 1978.

With no OPEC price increase, the assumptions were 5 percent. The adverse effect of the 15 percent OPEC price increase would be expected to increase unemployment by about three-tenths of a point at the end of 1977, and one-half of 1 percent at the end of 1978.

Mr. Dingell. The increase in unemployment would be about 100,000 for every tenth of a percent—am I right? So we could have a perspective on that——

Mr. Richardson. Yes; I believe that is correct, Mr. Chairman.

Mr. Zarb. I would add, Mr. Chairman, that while we have calculated these numbers so we are in a position to answer your questions, the fact that we have calculated some should not be misconstrued by anybody to assume that we believe that even a 5 percent increase is either merited or wouldn't have significant impact on the U.S. economy and the world economy.

I would hasten to add that the economic analytical work here ought to include the effects in other countries of the ultimate impact on the United States.

Mr. Dingell. Referring particularly to the less developed countries?

Mr. Zarb. Those that have more economic challenges than others. The burden of that condition, one way or the other, shifts back here, at least in part, and this is the wrong time in the world economic cycle to have any kind of increase; so our position is unchanged. Even a penny is not justified, and indeed would be terribly damaging to the world economy.

Mr. Richardson. I think what Mr. Zarb has said is a desirable cautionary note with respect to the figures I gave, that those figures themselves, even 5 percent, impacted that enough, given the present stage of our economy and given the debate currently underway as to whether or not stimulus is needed and, if so, how much. But I fully concur in what Mr. Zarb has said.

I would only add on that score, the United States has, as the committee is well aware, made strong representations to the OPEC countries with respect to the possibility of a price increase. We have emphasized our view that it is not, and that the alleged justification, namely, increased costs of imports to the OPEC countries, does not support a price increase; on the contrary, that the net economic impact in those countries of import price increases has been only about 2 percent.

Mr. BROWN. Mr. Chairman, would you yield at this point?

Mr. DINGELL. Yes; I think counsel would be glad to yield.

Mr. BROWN. Let me fully understand what I think I am hearing, and that is, while the impact of any increase upon the United States would be heavy, since we have a more sophisticated economy and greater domestic supply, the impact on other industrialized nations with an oil-based economy, which do not have a strong domestic supply, such as Japan, would be even more devastating than in the United States.

In addition to that, the impact on less developed countries would squeeze out or kill off developing markets for those products of industrial nations and reduce them from rather than a sophisticated development level to literally a back-to-the-foot power and an animal-power kind of economics that they have been trying to get away from.

Is that what you are saying?

Mr. RICHARDSON. Yes; that is exactly it, Mr. Brown, except I would identify, I think, Great Britain and Italy, among industrial countries, as subject to even more serious impact than Japan.

While Japan is 90 percent dependent on imported energy, nevertheless Japan is also enjoying a favorable trade balance, particularly with the rest of the industrial world; whereas an increase in oil imports costs to Great Britain and Italy would only compound the balance of payments problems which are already causing them very severe difficulty.

What you say as to the nonoil-producing, undeveloped countries is, of course, true, that every increase in the cost of energy to those countries represents a reduction in their rate of growth, a reduction in their capacity to produce for export, and a reduction in their ability to import from the rest of the world those other products they need in order to continue the expansion of their rate of productivity.

Mr. ZARB. To give you some feeling for numbers, Mr. Brown, while the impact of 5 percent is $1.7 billion here, because of the nature of the economy in Japan it is $1.1 billion there, almost as high as ours is. The impact on the CPI for a 5-percent increase for the United Kingdom is .16 percent. That is more than one-half of 1 percent in their CPI and one-half of 1 percent for Japan and Italy; given the state of those economies at this given time, those kinds of numbers can be rather damaging, so we are not making these statements literally, not having looked at all of the indicators worldwide.

Mr. DINGELL. What you are describing is very strong ripple effect which flows from any significant price increase at this time——

Mr. ZARB. That is correct.

Mr. DINGELL [continuing]. Which will flow adversely through the world economy and will have effects that cannot be included in a

80-533 O - 77 - 4

simple statement or in a simple set of—I shouldn't call them simple—but in an economic analysis that is easily made?

Mr. Zarb. Yes, sir.

Mr. Potter. Let me follow that up by another question relating to the balance of payments, subject about which I am spectacularly illiterate.

My impression is that for the past 2 or 3 years we have managed to cope with the increased price of imported energy, by exporting food, principally in the form of grains. Grains have suddenly become our major export item, and the United States is assuming more and more importance as a supplier to the agricultural needs of the world. That raises even additional problems.

Aside from the fact that when we export grain we are really exporting oil in the form of grain due to the enormous energy demands of the agricultural sector, American grain export practices raise even more serious problems because of the long-term implications of energy production.

Energy production does have agricultural diseconomies that are not now serious but which, if you look very far toward the future, seem to have some fairly staggering implications.

Have your agencies considered these implications, and do you have a reaction to the general issue at this time?

Mr. Richardson. We don't in the Department of Commerce. I think it is fair to say I have an adequate analysis of these problems over the longer term at this stage.

It is a fundamentally important and exceedingly difficult program because, of course, there needs to be addressed from a world point of view the trade offs between the higher rates of energy consumption utilized by American agricultural production on the one side and the fact, nevertheless, that we are able on this basis to produce food that is indispensably necessary to the survival of millions of people in the rest of the world.

In one sense, the demand for food is highly inelastic and, therefore, even a high rate of consumption of energy may be justified for the sake of being able to generate the surpluses of food which this country is uniquely able to do.

So I see no prospect that the United States can significantly reduce the rate of energy consumption of agriculture, and agriculture is now the most capital intensive industry we have. It passed the petrochemical industry in this respect a couple of years ago, but, as I say, the corollary of this is its sufficiency and capacity to be a source of reserve supplementation for the rest of the world.

Let me add one more thing on the balance of payments. Of course, we are now in a situation where last year we had a large, favorable balance. We have moved back into deficit again, as a result partly of the fact that our economy has moved up somewhat faster than the rest of the world, with the result that we have increased our energy imports faster than we have increased our exports.

Mr. Zarb. I would just add, Mr. Potter, that we have looked at the balance-of-payments issue as part of the economic problem in energy. As I mentioned earlier, there is an economic reason to achieve a higher degree of self-sufficiency, and there is a national security reason.

I guess our findings could be summed up in one word: Worry. When you go from $2.7 billion in 1970 to $27 billion in 1975, $34 billion in 1976, we could be at $37 billion in 1977, even without an OPEC price increase, and you cannot count on agriculture continuing to expand at the rate it has in its exports, it gives you an economic reason to be concerned; and the answer lies in eliminating our dependence on that very expensive, outrageously priced imported crude and use less of energy and more of our own when we need to use it.

Mr. POTTER. I have the sense that the direction of this country, in terms of energy production and consumption, has been toward more and more capital intensive technological means of dealing with the problem.

Mr. Zarb, you and I have talked about the question of whether or not this is the ultimate sustainable future that we can anticipate. I also note Secretary Richardson has given considerable thought to this issue himself. I am troubled by some of the comments in your document, "Perspective on Energy Policy," which imply that with the inertia in the system there really is no way we can begin to turn it around much before the end of the century.

Maybe I am a little more optimistic that there are, in fact, things that can be done. I noticed in yesterday's Washington Post an ad that says an answer to OPEC comes up every morning. It is an ad for solar hot-water heating systems. You see things like this with increasing frequency. You see things like architects beginning to design homes which use passive solar energy like big windows on the south.

I have the sense that we may be moving a lot more quickly in the direction of using renewable energy than tends to be recognized in agencies like ERDA where the emphasis has been on big buck technological systems.

I worry about—I might say I am obsessed by—the longer term implications of those decisions. That is not really a question but I know it is an issue that you both have interested yourselves in, and I wonder if you would care to comment?

Mr. RICHARDSON. May I comment very briefly first? The ERDA point you made, with reference to big buck research projects, we have in the Energy Resources Council in two or three meetings pressed pretty hard the question on how ERDA goes at the allocation of research funds, and the kind of answer we got reminded me of the kind of answers they used to get with respect to questions of the allocation of the National Institutes of Health research funds among critical diseases and so on.

There are limits to the amount of money that can be effectively used in given research areas which are a function partly of the amount of hardware and equipment that is necessary in order to conduct the research, a function also perhaps even more at a given time of the number of people who are equipped to do worthwhile work, who have an interest in doing it, and these factors do have a very significant impact on the ratio of research funds that are going, for example, to solar energy.

All I can say is that you can push on this, and ERDA and Bob Seamans and his colleagues are pretty convincing on why they are doing what they are doing, and why it does not make sense to do more.

In any event, I think that the public and the Congress and the Energy Resources Council or its counterpart, or any new head of any Federal agency should certainly continue to try to be sure that we are doing all that we can justifiably do and maybe just a little more in order to make sure that the progress in necessary alternative directions is as rapid as it can be. As to why it isn't likely to be more rapid, I defer to the more knowledgeable gentleman on my left.

Mr. ZARB. The issue of more hard capital intensive technology or more soft technology going into the year 2000 is, I think, a very important question, and those of us that think about this problem—and I intend to continue to think about it as a private citizen—ought to continue examining and reexamining the question of bringing on the software technologies more quickly than the system thus far has anticipated was possible.

In making public policy, you have to deal with the fact that you feel you know that the soft technologies are so far off that we need to concentrate on these heavy technologies, surely between now and the year 2000.

I would hasten to add, even those proponents of a soft technology energy economy in the year 2010, displacing the nuclear and coal capability to some extent with reusable forms of fuel, quickly point out this is only possible if you eliminate price controls and subsidies to existing systems; and if you do that, then you are going to be pricing the product at real value, and then the software technology has an even chance of being appreciated.

I think, Mr. Potter, that we ought to continue working with what we know and forming public policy around what we know; but we ought to continue to reassess in the coming years whether some of these other technologies can be brought on a lot more quickly—solar, wind, use of the tides—what is the economic crossover point for them, what are the things that Government can or cannot do to expedite their utility in an economy? It is a good question; it should not be ignored or forgotten even in the coming debate that will continue next year.

What would be wrong to conclude at this time, lacking that kind of information is that we ought to just wait for the soft technologies to take over. I don't feel comfortable with that conclusion at all.

I believe we ought to continue to work with what we know and, if this ultimate path can be useful, the Government might want to steer its policy in a slightly different direction; but I surely wouldn't do it until we were sure we could get it done within a reasonable length of time.

Mr. RICHARDSON. Could I add just a reference to the discussion of R. & D. priorities in this white paper which I think quite well, in a very succinct manner, deals with some of the tradeoffs that have to be addressed.

Just to take the question, at what stage do you conclude that the existing state of the art justifies large-scale commercialization or do you wait a while until you get a better mechanism for the purpose? These are, as Mr. Zarb says, among the kinds of questions that are going to need a lot of hard, continuing thought.

Mr. BROWN. Would you yield on that point for a minute so I might make an observation?

If you allow the free market economy to come into play in the energy area, you tend to bring in the development of new and exotic fuels in a much more gradual and less shocking way to the economy, first, and then, second, if you allow the existence of private development stimulated by that free market economy, you may just come up with something that is the school solution.

I give you as an example the development of the live virus polio vaccine by Albert Sabin, when all the money was on the Salk approach. Salk gets all the attention because that is where the Government spent its money, and he was first. The one now generally used is Albert Sabin's, which was essentially financed by private funds, and he went off sort of aberrationally on his own, and I am not sure we might not get the same result in energy again if the market stimulates somebody to find that answer, rather than relying on the Government to make all the decisions.

Mr. RICHARDSON. I agree with that, but I think the Salk-Sabin vaccine example is a good one. I was in HEW as Assistant Secretary for Legislation back in the days when we were dealing with the issues of moving forward and what should be the governmental role on polio vaccinations and so on, and knew about Salk.

I don't recall that we were aware that the Sabin vaccine existed, and we were faced with what we thought was a responsibility to immunize children against polio at the earliest possible date following awareness that we knew how to do it.

Now, I have one little paragraph on page 8 of my testimony that bears on this whole issue of when does the Government move in, in the case of not just energy R. & D. but large-scale commercial applications of any new technology.

If we didn't have to concern ourselves with the exhaustion of nonrenewable energy sources or exhaustion to the point where continued use depends only on very high cost techniques, then we could say that then we would be safe in saying the market will take care of the problem over time.

It seems to me, however, that a determination of U.S. policy today must take into account the potential for the ultimate exhaustion of petroleum resources and their worldwide decline toward the end of the century, and then based on those projections work back toward a judgment about what other alternatives that then must be in place; and having made that determination, make sure that what the X Government projections are likely to be in terms of bringing these resources on line by the necessary time; and only having done this analytically, is it then possible to determine what the shortfall is going to be in the capacity of market forces to produce those resources when needed.

If there is a shortfall, is the kind of thing that ERDA is working on, then you need to say, OK, what do we need to do to accelerate the pace, what are at least the standby capabilities of Government in the form of loan guarantees and so on?

At any rate, it is by this route, it seems to me, we ought to get to the formulation of the long-term strategies for Federal supplementation of what will otherwise happen.

Mr. BROWN. I share your concern about the utimate determination of existing energy resources, as I also share your enthusiasm for a Government strategy in this area and supported the original ERDA legislation, and, as a matter of fact, have been fairly aggressive in supporting the development of synthetic fuels which, unfortunately, never came to the House for consideration in the Congress just terminated. So we are of a mind on that.

I am delighted that we are also of a mind, however, on what was the most positive part of my comment, and that was that we retain in whatever national strategy we have the opportunity for private development of future energy needs, those sort of individuals who say that the Government strategy may not be working as rapidly or in as productive an area as I think I could work if I had a few bucks of my own here, and have the opportunity, such as Albert Sabin, to go leaping off into some generally not scientific area not approved by the bureacracy in the scientific community or governmental community, and find a breakthrough that we hadn't anticipated. That is all I want us to be sure we keep in our system.

I want the Government in that energy development field too, but I surely want somebody—if you can find me a Thomas Alva Edison, I will make my donation to him, I think.

Mr. RICHARDSON. I may even add a still broader comment on this score, which I think bears a lot on Frank Potter's interest and probably the chairman's and all of yours, the problem of growth and the direction of worldwide resources.

I keep coming—having thought about this quite a lot—I am inevitably led to the conclusion that the answer has to be not less technology but more. I do not think that a no-growth policy is compatible with anything resembling three systems of self-government, and this takes you to the question, How does a country like the United States maintain a growing economy in the face of the increasing capacity of other countries around the world to do most of the things we now know how to do, or learn how to do in the last 20 years?

Take, for example, the production of textiles, shoes, electronic products, radios, and so on. The only way to do this is to continue to encourage all forms of technological development including the Sabins and the Thomas Alva Edisons, and that has led to a set of concerns that we only have recently begun to address in the Department of Commerce in a systematic way.

I am sorry I am leaving because I would like to have stuck with it longer. But we have seen a decline in the ratio of GNP devoted to Research and Development, and we have seen an even more rapid decline in the formation of new science-based companies. I think these are disturbing trends, and I think we need to develop a sense of what has happened and understand what is happening here, what have been the market forces, and/or it may have been the suboptimal effect of Government policies that have brought this about.

Mr. BROWN. Including tax policy.

Mr. RICHARDSON. Including tax policy. I think we have to understand why this has come about before we can make sense in terms of what ought to be done about it; but I do think—without elaborating the point further, I do think this is a very important point; it addresses itself to the question of whether or not there are going to be Thomas Alva Edisons, and if there are, whether they can finance their ideas and so on, and that in turn is fundamentally related to the subject of energy as part of the whole question of technology policies' development and so on.

Mr. ZARB. One interesting experience that I have had in the last several years is to go out and talk with some of the scientists that work in these sectors.

At some point the committee might want to consider various outside scientists who are focusing their whole lives on energy issues and advancing technologies.

I spent several hours at the University of Arizona talking to people who are working on collector devices for solar energy, and when you get to talk to folks like that who really are not connected with the Government and are doing a lot of work, it gives you a perspective you don't otherwise have, and I should think it would be awfully interesting for the Congress to hear from a wide range of these people who are out there working in some university laboratory on some of these issues, and let them tell you where they really think they are and what their obstacles seem to be.

Mr. POTTER. You have raised an issue in your antepenultimate answer to the question of existing energy subsidies that was also touched on by the chairman in his opening statement. Because we have talked about it before, I know that FEA is looking into this question to see if it can identify where those hidden subsidies hit and how they distort the theoretically free marketplace.

If it is possible for that study to be completed within a reasonable compass of time, I wonder if it would be appropriate to have it inserted in the record at this place?

Mr. DINGELL. I think the record can remain open for a reasonable period of time but I am not sure whether a study of that kind can be quickly completed.

Mr. ZARB. I am not sure it would be ready by then, but it will be underway, and I am sure my successor would be most happy to submit it to the committee.

Mr. DINGELL. It is something we intend to pursue with some vigor, and we will try to encourage your successor to pursue it with vigor.

Mr. ZARB. I will consult the dictionary to find out what antepenultimate means.

Mr. POTTER. There are some other documents that might be useful to have in the record as well. One I know that you have read, Mr. Zarb, and I suspect Secretary Richardson, with his catholic interests, has read as well. It is an article that appeared in the October 1976 issue of Foreign Affairs, by Amory Lovins, entitled, "Energy Strategy: The Road not Taken." It is a provocative article which raises a number of the issues that we have been talking about. I think it would be helpful for the record to have it included.

Mr. DINGELL. Without objection, the document referred to will be inserted in the record at the appropriate place.

[See appendix to this hearing, p. 171.]

Mr. POTTER. I am resisting the temptation to ask all of the questions that interest me about the issues that you have raised. The chairman informs me that that is prudent.

Thank you. Thank you both.

Mr. DINGELL. Gentlemen, the Chair does thank you both. I must reiterate the high respect and affection that this subcommittee has for you both, and for your ability and dedication to the public interest throughout the course of the difficult responsibilities you have shared. We are delighted to have had at least one last chance to visit with you before you return to civilian life.

Mr. ZARB. Thank you, Mr. Chairman, and Merry Christmas.

Secretary RICHARDSON. Thank you.

Mr. DINGELL. Adjourned, subject to the call of the Chair.

[The documents referred to during the hearing follow:]

Perspective on Energy Policy

Elliot L. Richardson
Secretary of Commerce

Frank G. Zarb
Administrator
Federal Energy Administration

December 16, 1976

PREFACE

Domestic and international events of the last few years have had a dramatic effect on our energy situation and prospects for the future.

Internationally, the United States helped establish the International Energy Agency which will continue to provide an effective vehicle for international cooperation among energy consuming nations. We have negotiated and brought to operational readiness an integrated emergency program to enhance the ability of all consuming nations to withstand the economic impact of a future embargo, and we have successfully tested a program for managing the international allocation of oil during supply emergencies. We are also fostering a new cooperative dialogue between oil producers and consumers to find a long-term solution to our respective problems.

On the domestic front, we have participated in an intensive debate on national energy policy. At times the debate seemed mired in conflict, but five major pieces of energy legislation have now been enacted into law. These provide for a range of supply, conservation, and standby measures which lay the foundation for improving our energy situation.

However, the Nation has not confronted the choices and issues fully. A wide range of actions is still needed, and the debate will continue.

While the foundation is in place, our energy dependence has worsened. The U.S. imports more oil from the OPEC nations than ever before and foreign oil bills keep rising.

The following Perspective on Energy Policy focuses on the many broad energy issues currently confronting this Nation. It has been prepared in the hope that the Congress and the new Administration will assess the varied initiatives that may be undertaken to resolve these issues, debate their effectiveness, settle their differences, and enact whatever additional energy legislation is necessary. This Perspective on Energy Policy is not intended to be an exhaustive analysis of our energy problem, but rather, an overview of those areas where accomplishments have been made, those areas where changes are needed, and those initiatives which should be analyzed in greater depth. It does not shy away from considering new initiatives and is not merely a brief for previous policies. We hope that it usefully serves its purpose.

ELLIOT L. RICHARDSON
CHAIRMAN
ENERGY RESOURCES COUNCIL

FRANK G. ZARB
EXECUTIVE DIRECTOR
ENERGY RESOURCES COUNCIL

TABLE OF CONTENTS

SECTION 1

THE ENERGY SITUATION

Background

- The oil embargo in late 1973 was a shock to most of the American people and demonstrated the extent to which our energy situation had deteriorated. Most Americans still assumed that the United States supplied most of its own energy and still dominated the world oil pricing system. However, beginning several decades earlier, the roots of our current energy problem were beginning to take shape.

- Coal

  -- Coal is the United States' most abundant energy resource (about 90 percent of our reserves). During the early part of this century, coal supplied most of the nation's power. As the popularity of the automobile increased, as environmental protection became a national concern, and as railroad travel deteriorated, the demand for petroleum and natural gas grew and replaced coal in many uses.

  -- As a result of these trends, coal production has only recently exceeded levels reached in the 1920's and its percentage of total energy demand has fallen dramatically (from accounting for almost 80 percent of our energy in 1920, coal had fallen to less than 20 percent by 1973). Coal production should be about 660-670 million tons in 1976 (as compared to about 600 million tons in 1973).

- Oil

  -- Domestic petroleum production increased initially in response to rising demand. While energy demand was growing at about 3.6 percent annually, oil consumption was up about 4.6 percent. However, oil exploration peaked in the 1950's and declined until 1974, for several reasons:

- Domestic oil production had become less profitable because of rising costs and depressed prices caused by the availability of inexpensive foreign oil;

- Exploration and development by the oil industry in frontier areas was restricted because of environmental concerns;

- The better drilling prospects were exhausted over time;

- State production rate limitations reduced profitability.

-- Additions to proved reserves also declined and domestic U. S. crude oil production reached its all-time peak of 9.6 million barrels per day (MMB/D) in 1970 (as compared to 8.1-8.2 MMB/D in 1976). An encouraging trend in 1976 has been the increase in exploration activity (drilling reached a 14-year high).

-- As a result of rising demand and declining supply, U. S. imports grew. Imports were:

  - very small in the 1950's

  - 3.4 MMB/D in 1970 (or 23% of U. S. oil consumption)

  - 6.2 MMB/D in 1973 (or 35%)

  - 7.0 MMB/D (est.) in 1976 (or about 40%)

-- With rising imports and rising prices came a higher bill for foreign oil. In 1970, the U. S. paid about $2.7 billion for imported oil; in 1975, the bill had risen to $27 billion and was about $34 billion in 1976. Most of the increase in imports has come from Arab sources, since those are the sources with extra production capacity.

- <u>Natural Gas</u>

-- While natural gas production rose substantially during the 1960's, its growth rate began to decline in 1969, mainly due to price controls on the interstate market.

-- Natural gas production peaked at 22.6 Tcf in 1973 and declined to under 20 Tcf in 1976. Most of the decline has been in interstate sales, causing growing natural gas curtailments in the Mid-Atlantic, Midwest, and other areas.

- Nuclear

  -- Although nuclear power has accounted for an increasing share of electricity generation, its growth has been slowed by the lengthy licensing process and siting problems due to safety and environmental concerns.

  -- The United States now has 63 operating nuclear plants, supplying about 9 percent of electric power.

- Others

  -- Other sources of energy, such as solar and geothermal, are growing, but do not contribute a significant share of U. S. energy needs.

The Rise of OPEC

- The domination of the Organization of Petroleum Exporting Countries (OPEC) over world oil production and prices has been largely a phenomenon of increased world demand and abundant OPEC resources. The Middle Eastern and North African members of OPEC possess 70 percent of the world's known, easily recoverable oil reserves.

- In 1960, Venezuela, Saudi Arabia and several other Middle Eastern nations formed OPEC to gain control over the price and production levels of crude oil in their respective countries. Ultimately, OPEC gained such absolute control over its oil that oil company concessions began to be effectively nationalized and the price for their oil was increased sharply. In October 1973, the Arab members of OPEC effected an oil embargo.

  -- The effect of the embargo on the U. S. was appreciable. GNP dropped by between $10 and $20 billion and unemployment increased by approximately 500,000. Consumer prices increased by about 10 percent in 1974, one-third of this due directly to higher world oil prices. The embargo demonstrated clearly the need to re-evaluate our domestic and international energy policies.

<u>U. S. Reactions to the Embargo</u>

- <u>Government Energy Organization</u>. An initial reaction to the embargo was to reorganize government energy functions which, until then, had been widely dispersed.

  -- During the embargo, the President established (on December 4, 1973) the Federal Energy Office (FEO).

  -- The Administration submitted and Congress enacted, in 1974,legislation to create a Federal Energy Administration (FEA); to abolish the Atomic Energy Commission; and to create the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC). Congress also established an Energy Resources Council (ERC) in the Executive Office of the President.

- <u>Project Independence</u>. During the embargo, President Nixon announced a program called Project Independence to achieve energy self-sufficiency by 1980.

  -- In March 1974, the FEO began work on a report to assess the feasibility of Project Independence. The report was derived from a major analytical effort to forecast energy supply and demand growth through 1985 and to examine the constraints affecting energy. The <u>Project Independence Report</u> indicated that energy self-sufficiency by 1980 was impossible, but that an aggressive program of resource development and conservation could eliminate any adverse impact of future embargoes by 1985.

- <u>Administration Strategy</u>. The fundamental approach taken by the Administration to solve the energy problem was to develop new sources of supply consistent with environmental protection; remove restrictive government controls from the energy marketplace; encourage conservation through pricing and, where appropriate, regulation; and develop standby authorities to deal with a future embargo. The Energy Independence Act of 1975, proposed by President Ford, embodied these principles.

  -- The major efforts proposed to increase domestic supply were the elimination of price controls from crude oil and natural gas; authorization of production from the Naval Petroleum Reserves; reduction of regulatory lag in the licensing and siting of nuclear plants; conversion of power plants from oil and gas to domestic coal; acceleration of Federal coal development and OCS leasing programs; and a program of financial support for synthetic fuel commercialization.

-- To encourage conservation, the Administration proposed mandatory thermal efficiency standards for all new buildings; appliance labeling; an insulation tax credit; a system of import fees, taxes, and decontrolled prices; voluntary automobile fuel efficiency goals; and a weatherization assistance program for low-income families.

  - In addition, programs were adopted to try to make the Nation aware of the critical nature of the energy problem and to provide information to private citizens, industry and commercial concerns on how to use energy more efficiently.

  - The attempt to educate the Nation regarding the seriousness of the energy situation was undermined by public suspicion that the energy crisis was a creation of the oil industry to justify higher prices and generate windfall profits.

-- To protect the United States from the severe impact of another embargo or other supply disruption, the Administration also submitted legislation to the Congress for the creation of a strategic petroleum reserve, and emergency standby authorities to reduce the economic impact of a supply interruption.

- Congressional Response. There was an immediate negative reaction in the Congress to the Administration's energy program. With the economy in the midst of a recession and the public not yet ready to adjust to even higher prices, the Congress fought the decontrol/import fee program successfully. The Congress did not respond favorably to the notion that windfall profits taxes and rebates could alleviate their concerns.

  -- The initial approach put forward by the Congress involved increased regulation. There were proposals for further allocation, more stringent price controls, rationing, and import quotas. Each of these programs had major drawbacks (including severe regional inequities) and ultimately were not enacted or were changed radically.

-- The Congress (especially the House Ways and Means Committee) conducted a long debate over energy taxes. Various tax proposals were considered, including taxes on gasoline and all petroleum products. Most of the attention focused on a gasoline tax.

  - The United States' gasoline tax is much smaller than that of almost every other consuming nation. For example, Japan's gasoline tax is about 55 cents per gallon; Italy's is about $1.70; but ours is only about 12 cents (including State taxes).

  - They considered gasoline taxes varying from 3 cents per gallon to over 30 cents, but all were rejected. This reaction points out the difficulty of imposing higher prices of energy.

-- After a long debate over crude oil pricing stalled most of the pending energy legislation, a compromise was reached in December 1975, when the President signed the Energy Policy and Conservation Act (EPCA). It was a controversial bill. The oil companies believed the continuation of price controls in the bill would hamper domestic production and exploration activity, while consumer groups argued that prices remained too high.

-- Three major pieces of energy legislation have been passed subsequently in the last year:

  - the Naval Petroleum Reserves Production Act;

  - the Energy Conservation and Production Act (ECPA);

  - the Alaska Natural Gas Transportation Act.

-- As a result of these Acts, the Federal Government now has the authority and has begun to:

  <u>In Supply</u>:

  - Exempt the first sale of domestic stripper well crude oil from price controls;

- Implement the 40 month crude oil decontrol plan, under which domestic prices are allowed to escalate by no more than 10 percent annually to keep pace with inflation and provide production incentives;

- Provide added price increases for tertiary recovery and California heavy gravity crude;

- Develop at the maximum efficient rate the three Naval Petroleum Reserves in the Lower-48 States; and continue exploration of NPR-4 in Alaska, leading to its eventual development;

- Implement an expedited selection process for a transportation route to deliver Alaskan natural gas to the lower-48 States;

- Dismantle as much of the current crude and product regulatory system as feasible.

In Conservation:

- Provide conservation grants to States to assist in the development and implementation of energy conservation programs;

- Implement appliance energy efficiency labeling;

- Set mandatory automobile efficiency standards for 1980 and 1985 of 20 mpg and 27.5 mpg, respectively;

- Establish industrial energy conservation targets for the ten leading energy consuming industries, and mandatory reporting of progress;

- Develop thermal efficiency standards for all new residential and commercial buildings, subject to Congressional approval of sanctions;

- Implement a three year, $200 million weatherization grant program for the insulation of homes of low-income, elderly, and handicapped persons;

- Provide grants to States for testing innovative utility rate structure designs to achieve a higher degree of conservation.

In Standby Measures:

- Build a strategic petroleum reserve of at least 150 million barrels of petroleum by 1978 and 500 million barrels by 1982;

- Establish standby measures to deal with severe energy emergencies that may arise in the future;

- Develop cooperative contingency and planning programs with the International Energy Agency (IEA).

Outlook for the Future

- Domestic consumption of petroleum products will continue to increase as the economy recovers and before conservation programs take effect, although at a slower rate than pre-embargo trends. Petroleum consumption in 1975 was about 3 MMB/D below what would have occurred had pre-embargo trends continued. "Lower-48" crude production will decline until Alaskan North Slope oil comes to market in late 1977. Imports may average over 8 MMB/D in this period.

- By 1985, however, through judicious policies, this Nation can greatly expand its domestic energy production and cut the rate of growth in energy demand, and still meet its economic objectives. If there are restrictions on energy development, if fewer reserves are developed than expected, or if price controls are extended, our dependence on foreign oil could rise well above today's level.

- The amount of oil discovered and produced depends upon the extent of reserves, the Federal OCS leasing program, and whether oil prices are high enough to justify more production. Domestic crude oil production could increase to considerably over 10 MMB/D in 1985 (from about 8.1 MMB/D in 1976).

  -- More intensive use of secondary and tertiary recovery in current fields and new discoveries can keep onshore production about constant. If aggressive OCS leasing and development schedules are followed, OCS production could increase substantially by 1985.

  -- If world oil prices fall or domestic prices are regulated over a long period, production could be at about today's level in 1985. The more expensive enhanced recovery techniques and some frontier area production, such as that from Alaska, would not be economic at lower prices.

- Total domestic energy supply is forecast to increase substantially between now and 1985, with all major fuels besides petroleum playing a larger role:

  -- Coal production could increase to over a billion tons, from current levels of about 670 million tons, unless long-term utility demand alters significantly and environmental and transportation issues are not resolved.

  -- Natural gas production could reach about 22 Tcf, if deregulation occurs, but would be less if current price regulations continue;

  -- Nuclear power could grow from current levels of 9 percent to over 20 percent of electricity generation; however, uncertainty in demand growth, financial difficulties and licensing delays can lower this projection significantly.

- Each of these supply increases, while technically and economically feasible, will not be forthcoming unless pricing and government regulatory policies encourage it. In addition, if one or more domestic energy sources do not achieve these projected levels, oil imports will make up the shortage because other domestic fuel sources could not compensate for the loss.

- Higher energy prices should cut energy demand growth during the next ten years, reducing the growth rate to between 2.5-3.0 percent from the historical rate of 3.6 percent. Even if a very active conservation program reduces energy demand further(by the equivalent of 3-4 million barrels per day), the growth rate would still be a little over 2 percent through 1985. Electricity generation will continue to grow about twice as fast as overall energy demand, but at reduced levels from historical rates. Consumption patterns will gradually shift from oil and gas to coal and nuclear power.

- If the appropriate actions are taken, import needs could be reduced to approximately 4 MMB/D by 1985. If oil and gas price controls remain in effect through 1985, however, imports could be closer to 10 MMB/D and,if energy development cannot proceed as planned, imports could be more than 10 MMB/D.

- Emerging technologies will not play a significant role in stabilizing our energy situation in the next ten years. Solar, geothermal and synthetic fuels will make only a small contribution to domestic energy supplies by 1985--about 1 percent of total use. While the technology for these sources exists, they must be proven economically viable on a commercial scale.

Post-1985 Outlook

- The post-1985 prospects for maintaining independence are less certain. Declining reserves of oil and gas will need to be offset by significantly increased use of nuclear power, synthetic fuels, solar, geothermal, and other technologies. However, the major contribution from solar, geothermal, and synthetic fuels will not be felt until after 1990.

- Electricity is projected to continue to increase its market penetration. It could represent about 37 percent of energy use in 1990, as compared to 28 percent in 1974. The major economic choice in electricity generation by 1990 will still be between nuclear power and coal. However, actual capacity additions will be determined by other factors as well, such as environmental standards, financial health of utilities, peak to average load growth, and infrastructure to transport coal.

- If electrical energy grows at the anticipated rate, there will be a strong need to increase coal production (to over 1.3 billion tons in 1990) and to resolve the nuclear fuel cycle problems.

- Oil and gas production is likely to decline again around 1990; Alaskan production would also decline in this period, unless significant NPR-4 reserves are proved and produced.

- As consumers adjust to higher energy prices, the growth rate of energy consumption could increase in the post-1985 period.

- With demand increasing and supply of oil and gas either stable or declining, oil imports in 1990 could be over 10 MMB/D, unless synthetic fuels or other new technologies expand more rapidly than anticipated.

-- However, by 1990, a number of existing OPEC countries can be expected to have dropped out as exporters of large quantities of oil. Many of the countries will have passed their peak of production and/or will have developed domestic markets of such size that they will not have substantial production available for export.

-- The reduced number of major exporters could represent a physical difficulty in meeting U. S. import requirements by 1990, unless major new sources of oil are found in countries that are not currently active as exporters.

-- If shortages of crude oil occur, prices would increase and certain energy sources now considered uneconomic would look more attractive for investment.

- Natural gas appears to be the fuel most likely to be in short supply in the 1985-1990 period. Unless an economically feasible approach can be found for producing synthetic gas from coal in large quantities, either growing quantities of imported liquid natural gas may have to be used or intensive conversion to other fuels pursued.

SECTION 2

FEDERAL REGULATORY POLICY

NATURAL GAS

Background

- Natural gas is a vital fuel that is consumed by over 40 million residences, over 3 million commercial establishments, and almost 200,000 industrial users.

  -- Domestic natural gas production peaked at 22.6 trillion feet (Tcf) in 1973, but has declined to an expected 19.5 Tcf in 1976. Additions to proved reserves reached a low of 6.5 Tcf in 1973.

  -- Until recently, the Federal Power Commission (FPC) has controlled prices for natural gas sold for resale in the interstate market (all but the producing States located mainly in the South) by placing a ceiling price of 52¢ per thousand cubic feet (Mcf) on this gas--about one-fourth the equivalent Btu price of oil. The low price for gas has been a major factor in causing demand to exceed supply in the interstate market, and curtailments of gas customers in this market have grown.

    - Gas curtailments reported by interstate pipelines to the FPC rose from about zero in 1970 to about 25 percent of firm requirements in the current year.

    - Natural gas on curtailing pipeline systems is allocated among distributors and direct pipeline customers according to FPC guidelines, with residential and small commercial customers receiving highest priority; followed by large commercial and industrial feedstock and process users; industrial users without alternate fuel capability; and gas used for boiler fuel or by interruptible customers.

    - A very cold winter this year could create spot shortages of alternate fuels to replace curtailed gas volumes, despite large inventories. Cold weather could also reduce availability of emergency supplies.

-- Intrastate gas prices on new contracts have risen steadily over the past few years averaging almost $1.30 per Mcf in 1975 and an expected $1.60 in 1976. Correspondingly, the portion of all annual new gas reserves dedicated to the intrastate market has increased from about 35 percent in the late 1960's to 87 percent in 1975. The increasingly serious supply situation for interstate pipelines can be summarized most simply by noting that in 1965 they had access to known reserves that would last them an average of almost 20 years. At their current rate of sales, this "sales-life index" had dropped to 10 years by 1975 and was less than 5 years for at least one major pipeline.

-- The outlook is for continued declines in domestic gas supplies, particularly in the interstate market, unless major changes in the pricing or distribution system occur.

Proposals Offered

- In 1973, President Nixon proposed deregulation of new natural gas; in January 1975, President Ford also proposed that the wellhead price of new natural gas (production first introduced into interstate commerce after January 1, 1975) be deregulated.

  -- If prices were deregulated, FEA estimates that natural gas production could reach 22 Tcf per annum by 1985, with over 12 Tcf sold interstate; under continued regulation at the previous regulated price of 52¢ per Mcf, total production is projected at less than 18 Tcf, with only 6.6 Tcf sold interstate; under continued regulation at the current regulated price of $1.42 per Mcf, total production is projected at about 21 Tcf, with 10 Tcf sold interstate.

  -- Since only new gas would be deregulated, the price impacts on consumers would be gradual. Further, if low regulated prices continued, natural gas would not be as available to residential users, would have to be replaced by more expensive oil and electricity, and average residential fuel bills would be higher than with deregulation.

- The Senate, in 1975, passed a phased deregulation bill (S. 2310) under which new onshore natural gas prices would be deregulated immediately and offshore gas prices after five years.

- The House came within a few votes of passing S. 2310 (which President Ford had indicated he would sign), but passed H. R. 9464 instead, which rather than removing regulation, extended controls to the intrastate market. The House and Senate bills were never brought to conference. Among the reasons cited for rejecting deregulation are:

  -- The price of natural gas would rise considerably and natural gas producers do not need the $1.75-$2.00 per Mcf prices that could result from deregulation in order to produce new gas. The argument was made that allowing such prices would be letting OPEC dominate our domestic gas market.

  -- Since lead times for new production are long, consumers would be confronted with higher prices and still see rising curtailments for a few years. Additionally, if distributors roll-in (or average) the price of more expensive gas with less expensive existing supply, excess demand would continue. The counter-argument to this is that averaging the prices reduces the consumer impacts.

  -- There is no guarantee that increased production would result from deregulation and, in fact, there were many charges that gas producers were withholding natural gas from the market awaiting deregulation.

  -- The curtailment situation and discussion of economic effects was manufactured by the Administration and the gas industry to bring pressure for deregulation.

-- Deregulation in a time of shortage could result in bidding up the price of new gas to an excessively high price and above the long-run equilibrium price.

- The National Governors Conference proposed an approach under which new gas prices would be deregulated for a test period of five years, after which the question would be reassessed. While this plan provides for deregulation until 1981, the lead times for new production and already declining reserves would make it difficult to show dramatic improvement as a result of the temporary deregulation. Further, as a practical matter, it would be difficult to roll back natural gas prices after a five year period of deregulation.

- In July, 1976, the FPC issued Opinion 770 in which the major action was to increase the national base ceiling rate for new gas (wells commenced after December 31, 1974) from 52¢ per Mcf to $1.42 per Mcf. That decision was reaffirmed by the Commission on rehearing in the issuance of Opinion 770-A on November 5, 1976.

  -- This action could increase natural gas production to over 21 Tcf by 1985 (about 1 Tcf less than with deregulation) and would increase the interstate share of market in 1985 from about 6.6 Tcf under the previous controlled price to about 10 Tcf. However, the interstate share would be about 2 Tcf less than with deregulation and there would still be market distortions favoring selling new onshore gas in the intrastate market.

  -- The rates established by the FPC in Opinion 770-A are in effect, but being challenged by parties on both sides in the U.S. Court of Appeals. If past experience is a guide, final confirmation or modification of these new rates may take one year or more.

- In September 1975, the Administration proposed temporary emergency legislation to the Congress to alleviate the effects of curtailments. The legislation would have allowed pipelines and high priority users to obtain intrastate gas at unregulated prices for a limited period. This legislation became embroiled in the deregulation debate and was not passed.

- In the fall of 1976, the Chairman of the FPC indicated that he would welcome temporary emergency authority to allocate natural gas between pipelines. Although such allocation authority would only be used in severe emergencies, the natural gas industry believes it penalizes pipelines and customers who have been prudent and is the first step to a Federal allocation system. This outcome is especially likely if forced transfers between pipelines are made at prices below market levels.

Remaining Problems

- The price regulation issue is tied up in the courts and even if resolved at the $1.42/Mcf level for new gas, market distortions will remain against interstate users.
- Natural gas curtailments continue to increase. After alerting the public to the problem last year, warm weather, and the economic slowdown reduced the effects of the shortage. The Administration was accused of magnifying the problem and distrust continues.
- Natural gas shortages are distributed unevenly, concentrating in the mid-Atlantic and parts of the Midwest.
- Along an individual pipeline, one distributor may be adding new high priority residential customers, while others may be denying new hook-ups. Also, the current prioirty system sometimes provides little incentive for utilities to induce residential conservation, since gas volumes that are conserved by one distributor company could, either through petition to the FPC or a subsequently altered

base period, be reallocated by the interstate pipeline for higher priority loads in another distribution area.

- Because most gas is still cheaply priced old gas (29¢ per Mcf rather than $1.42), and because both pipeline and retail rate structures are generally not reflective of the costs of incremental gas supplies (be they new supplies or from storage), natural gas is clearly mispriced at the retail level. One effect is to create grossly inadequate incentives for conservation. Another is to insure that virtually any price can be paid for supplemental gas supplies, since when averaged in, the resulting prices of natural gas are still below the prices of most competing fuels. This could lead to uneconomic investments.

New Initiatives

- Two broad philosophical approaches exist to deal with the natural gas price and supply issue. The alternatives are to allow the market price to work by effectively permitting natural gas wellhead prices to reach the market clearing level, or to continue regulating price and/or supply. There are several options:

  -- Deregulate the price of new natural gas. This approach is the current Administration's proposal and the limitation to new gas deregulation is intended to provide maximum incentives for new production to reduce windfall profits for producers, and to allow more gradual increases in consumer gas costs. Deregulation could be either immediate or phased-in over a few years. However, there is no guarantee that additional revenues will be used for increased exploration and consumer impacts could be greater than expected due to abrogation of old contracts.

    - There is also a potential transition problem in that under average cost pricing, new gas prices could be bid up only to the rolled-in market clearing price.

    - Price deregulation could also be initiated with a temporary cap at the estimated long-run price, but such a cap could become permanent which would be counter-productive.

-- Complete deregulation at the wellhead coupled with a windfall profits tax. This approach eliminates the problems of defining new gas equitably, encourages recompletion of wells, and produces government revenues. The consumer impacts would be substantial, even if a rebate system is used with the windfall profits tax; designing such a tax equitably is difficult; and the industry's loss of revenues could affect adversely new development plans, if no "plowback" provision were enacted.

-- Five-year experimental deregulation of new natural gas. This approach would enable the Congress to see the effects of price deregulation on natural gas production before making a complete commitment to removal of price controls. Thus, it may be more palatable to the Congress than complete deregulation. This approach may not stimulate offshore and frontier area gas production due to the uncertainties in the future price potential; with lag times inherent in the system, five years may be too early to judge accurately future production response. If regulation is reimposed, it would likely be at higher price levels since large rollbacks would be politically difficult to accomplish.

-- Maintain current regulations (given upholding of Opinion 770-A). While this alternative imposes the least consumer impact, it sustains the distribution distortion between the interstate/intrastate market, does little to alleviate the curtailments situation, will stimulate less production by 1985 (1 Tcf) than under deregulation, and will increase the average annual residential fuel bill by 1985 by over $20 (or almost 10 percent of what the bill is estimated to be with deregulation), because of substitution of higher priced alternate fuels.

-- <u>Maintain current regulations and impose Federal excise tax on wellhead price</u> to bridge gap between interstate and intrastate prices. This alternative allows the free marketplace to operate at the end-user level, thereby reducing curtailments. It reduces the potential for producer windfall profits (as compared to deregulation), and the revenue gain could be rebated to consumers and/or used to finance other energy projects.

- This approach, however, does not ensure attraction of new onshore gas to the interstate market. In addition, the Congress has shown little inclination to pass excise taxes of this nature and the potential for Congressional disapproval is high given its effect on consumer costs.

-- <u>Extension of regulations to intrastate market</u> at the recent FPC announced level for new gas (or current intrastate market average price). This alternative would require both State and local distribution priorities to be consistent with Federal priorities and extend Federal pricing and allocation regulations to the intrastate market. It would eliminate the intrastate/interstate market distortion. The production increases would be about the same as with the FPC price increase, but a larger share would move into the interstate market as there would no longer be a price advantage in dedicating new reserves to the intrastate market.

- However, this alternative requires extensive Federal Government intervention into the intrastate market, and could conceivably raise constitutionality questions. It does not eliminate the inherent inequities of the current curtailment priority system, nor does it eliminate the need to allocate available supplies. It will not stimulate as much increased production as under deregulation and likely will continue to price gas below its commodity value, thereby promoting inefficient use.

- The Administration and the FPC have sought two emergency measures from the Congress to alleviate curtailments: direct end-user purchases from the intrastate market and 180 day emergency purchases by pipelines at free market prices. The new Administration will have to decide whether this approach is still applicable:

  -- Direct end-user purchases from the intrastate market by high priority curtailed customers are already sanctioned by the FPC, although not yet definitively tested in the courts. Emergency purchases at free market prices by gas companies are also currently allowed, but only for 60 days. To date, the Nation has been able to handle the curtailments situation without any emergency legislation, and distribution companies and end-users are becoming better prepared to offset potential curtailments.

  -- Nevertheless, severe economic impacts can still be encountered, even with this legislation, as there is no guarantee that individual pipelines will voluntarily assist each other. This legislation could provide only about 200 Bcf of emergency gas into curtailed areas due to the limited spot intrastate market for gas.

- Other potential measures exist to deal with curtailments:

  -- <u>Seek standby mandatory allocation authority</u> between pipelines. The small volumes of gas needed to be allocated among pipelines would preclude severe impacts of curtailments and would ensure government protection of high priority end-users during an emergency. However, this alternative provides a strong disincentive to pipelines to secure added gas supplies and to take high financial risks for supplemental gas supplies (e.g., LNG and SNG). The establishment of equitable criteria for allocation would be difficult, reimbursement problems with pipelines would be encountered, and there would be large administrative complexities.

-- Place a ban on new growth of firm customers, particularly high priority customers at the distribution level, where distributors are served by pipelines experiencing curtailments. Many States are already imposing moratoria on residential book-ups. This approach would reduce the vulnerability of existing customers to shortages, would prevent distributors from securing more gas supplies by industrial to residential load switching, and would eliminate the paradoxical situation of adding new customers at a time when old customers cannot be served.

  - But, it would require Federal pre-emption of State and local authorities and would also encourage continued use of available gas for existing low priority uses. Further, it would make a business decision that gas companies could not expand markets in the years ahead and thus stifle the free enterprise system.

- Due to apparent inequities in the existing priorities system and other administrative problems in implementing the Natural Gas Act, several regulatory reform measures are currently under consideration by the FPC:

  -- "Conservation Gas" Distribution. Distribution companies have had success in inducing high priority customers to conserve natural gas. However, under the current FPC priority system, the gas volumes that are conserved ("conservation gas") could be reallocated by the pipeline to another distribution company in order to maintain uniform priority end-use allocations along the pipeline and to prevent use of the "conservation gas" by lower priority users. This, in effect, stifles the incentive for distributors to induce conservation, since the gas could ultimately be shifted to a high priority user served by another distributor.

- The FPC could adopt a policy of prohibiting reallocation of "conservation gas" in order to encourage conservation. Such a policy could, however, increase energy regionalism and would relinquish "conservation gas" for lower priority users.

- This policy can be implemented by FPC rulemaking and does not appear to require new legislative authority. At least one State (New York), has permitted incentive pricing for "conservation gas," whereby the conserving customer receives not only the incremental cost of the alternate fuel, but also a premium from the customer who would otherwise be curtailed.

-- Pricing of supplemental gas. Another issue which must be resolved is how to price higher cost supplemental gas, including synthetic gas from coal, substitute gas from oil products and natural gas liquids, imported liquefied natural gas, and Alaskan natural gas. FPC's current pricing authority extends to the prices charged by interstate pipelines to its distributor customers, but not generally to the burner-tip since the prices charged by distribution companies are under the jurisdiction of state public utility commissions.

  - A new amendment to the Natural Gas Act could be considered to require that distribution companies adopt the same pricing procedure as the interstate pipelines. This approach would ensure conformance by all regulatory bodies and ensure that end-users pay full cost of consuming supplemental fuels, where the FPC deems it practicable. It would eliminate the artificially high demand for supplemental fuels created by rolling-in their price with lower cost supplies.

- The disadvantages of this approach are that it involves a pre-emption of State and local authorities; it is not yet clear that incremental pricing to the burner tip is administratively feasible, in any case, where curtailments exist; and it may reduce supplemental gas supplies at the same time a natural gas shortage exists.

-- National LNG siting authority. Importers, pipeline sponsors and State and local governments have asserted that the current Federal regulatory procedures for determining site selection for LNG facilities are inadequate and have led to long delays. A new legislative initiative could require Federal LNG siting standards and/or criteria for site selection. However, since each project is different, national standards may have little meaning, and could pre-empt local jurisdiction. It is not likely that such a proposal would be received favorably by the Congress.

- Alaskan natural gas. Under the recently enacted Alaska Natural Gas Transportation Act, the FPC will have to recommend to the President a transportation system (if any is deemed to be in the public interest) by May 1, 1977. The "system" recommendation is not simply a matter of choosing how the gas is to be transported, but involves a number of things including a price determination of the Alaskan gas at wellhead and a determination of how it is to be priced when sold to and by an interstate pipeline (rolled-in or incremental); the extent to which the proposed alternatives satisfy certain distribution requirements specified by the Act; and the evaluation of the safety, reliability, financial feasibility, cost, environmental impact, and impact upon competition of the alternatives. On the basis of the FPC recommendations and a variety of other inputs, the President will decide whether a transportation system should be approved and, if so, designate the system. The Congress shall review and, if found acceptable, approve the Presidential decision.

Conclusions

- Natural gas pricing and regulation may be the most crucial energy legislative issues facing the Congress. If the decline in domestic production is not reversed, shortages will grow and there will be adverse economic and social impacts. To improve our natural gas picture, several key actions are needed:

  -- Congress, as a high priority, should enact legislation to deregulate the price of new natural gas either immediately or phased-in over a few years.

  -- Congress should adopt the emergency legislation proposed by this Administration to mitigate the short-term curtailments problem.

  -- The new Administration and the Congress should review the issues and possible initiatives associated with "conservation gas;" pricing of supplemental gas; and siting of LNG import projects.

  -- The Administration and the Congress should expedite consideration of Alaskan natural gas transportation systems.

CRUDE OIL

Background

- Crude oil and petroleum product price controls were imposed by the Cost of Living Council in August 1973, and were continued in effect by the Emergency Petroleum Allocation Act of 1973.

- Only controls over petroleum prices remain of all the price controls imposed in the early 1970's; the oil industry claims that controls are inhibiting production incentives, and consumer groups contend that controls provide sufficient production incentives, while still holding domestic prices below cartel prices.

- Despite price controls, the average cost of petroleum products to American consumers has more than doubled since 1973, primarily as a result of higher world oil prices.

Proposals Offered

- In January 1975, President Ford proposed to the Congress a plan to remove price and allocation controls from crude oil and petroleum products by April 1975, in conjunction with a windfall profits tax and a program of import fees and excise taxes.

  -- FEA estimated that immediate decontrol could reduce imports by 500,000 to 1 million barrels per day by 1977.

  -- There was an overwhelmingly negative reaction to this proposal in the Congress, mainly because Congress feared the economic impact of decontrol during the recession and because of an inherent distrust of the oil industry by much of the public.

- A long, often bitter debate ensued over crude oil prices, and after several alternative proposals (e.g., extending the price control phase-out over a 39-month period) were offered by the President and rejected by Congress, a compromise was reached with the signing of the Energy Policy and Conservation Act (EPCA) in December 1975.

-- Under the EPCA, average domestic crude oil prices were to be rolled back to $7.66 per barrel effective February 1976 (from over $8 per barrel). This "composite" price was allowed to escalate over a 40-month period at the annual rate of the GNP deflator plus a 3% production incentive (but at no more than 10 percent). Price controls are to expire in May 1979.

-- The pricing provisions of the EPCA were its most controversial features. There was considerable opposition in industry to allowing a 40-month extension of Federal controls, and placing previously uncontrolled "new" and stripper oil prices under controls.

- The President signed the Energy Conservation and Production Act (ECPA) in August 1976.

-- The ECPA allows a full 10 percent annual rise in the composite price regardless of the GNP deflator and releases stripper well production from price controls. Stripper well production is that from properties producing less than an average of 10 barrels per well per day and represents about 70 percent of the wells in this country, although only about 13 percent of production.

- Using authorities provided in the EPCA, the FEA has proposed and Congress has allowed price and allocation controls to be removed from residual fuel oil; middle distillates; military jet fuel; and naphtha, gas oils, and other products. Thus, about half of refiners' output has been decontrolled, with gasoline, natural gas liquids (propane, butane, natural gasoline), commercial jet fuel, and aviation gasoline being the most important products still controlled.

Remaining Problems

- There is some uncertainty about the ability to hold to the May 1979 termination date for controls, given the likelihood that domestic prices are likely to be considerably below foreign prices at that time, and the American people may not be willing to accept an immediate price rise (currently the difference is about $5.00 per barrel). Further, the composite price system has proven difficult to administer. It is now a three-tier price system: lower tier (averaging $5.16 per barrel); upper tier (averaging $11.93); and decontrolled stripper and Naval Petroleum Reserve oil.

- While price controls are in effect, the FEA has administered a crude oil "entitlements program" to assure that all consumers share equitably in the benefits of price-controlled oil. Under this program, refiners with the access to more than the national average of price controlled crude oil are required to purchase entitlements (worth about $8.00 per barrel) from refiners largely dependent upon upper-tier and foreign oil. The program has resulted in an income transfer of about $2 billion per year, mainly from the Southwest to the East Coast, and has also benefited customers of Northern Tier and offshore refiners (e.g., Puerto Rico).

- Decontrol of remaining controlled products (except for propane, which is in short supply and is projected to remain short until natural gas production increases substantially) appears to be warranted based on supply/demand analyses. Failure to decontrol products in the near-term could lead to shortages and market distortions.

- There are some fundamental regulatory policy issues that must be resolved. These include:

  -- <u>Crude oil price freeze</u>. The Administration and Congress made an early estimate of the expected prices and proportions of "new" and "old" oil which turned out to be incorrect. Thus, initial estimates of the composite price were about 3 percent lower than the actual average price. To compensate for "overshooting" the composite price and to account for other regulatory and legislative changes made in 1976, FEA has frozen the price of upper and lower tier crude oil since July 1976. The extra revenues gained by crude oil producers (approximately one percent, or $240 million) must either be returned to the public by means of a continued price freeze or crude oil price rollback, or Congress would have to be willing to make appropriate adjustments in light of the composite price miscalculations.

-- Domestic production of heavy, high sulfur crude oil. Price differences due to quality differentials of crude oil remain unaffected by the entitlements program. Environmental regulations have increased these traditional pricing differences between heavy and lighter oils and production may be shut-in if the problem persists. This problem is particularly noticeable in California.

-- Production incentives. As required by the EPCA, a report is due to the Congress by February 15, 1977, setting out the effects of the production incentive factor on domestic production and exploratory activity. At that time, Congress has the opportunity to review and change this factor in the average price escalator.

-- Canadian crude oil allocation. As Canadian crude oil exports are reduced (they have declined from almost one million barrels per day in 1973 to about 250,000 B/D expected in 1977), many Northern Tier refineries may be unable to obtain adequate feedstock. Changes may be needed in the regulatory program to assure continued supplies to some of these refiners.

-- Pricing of Alaskan North Slope crude oil. In April 1977, the FEA must submit to the Congress its recommendations concerning the pricing of North Slope crude oil. Among the factors that will affect the decision are the disposition of oil and whether its first sale price will be included in the composite price.

-- Small refinery subsidy. The entitlements program contains substantial preferential treatment for small refiners, but there is a need to review the necessity for such a program and the appropriateness of the current level of subsidy.

-- Encouragement of refinery expansion. A report is due to Congress in March 1977, discussing options for encouraging new refinery construction in the United States. There is concern over whether the existing regulatory program is operating to encourage enough expansion of domestic refinery capacity.

-- Mandatory Oil Imports Program. A major review of this program has been conducted concerning its need, continuation of fee-free allocations, and regional impacts. Decisions as to possible revisions must now be made.

Possible Initiatives

- New price control phase-out schedule. There are three basic options to modify the current price control formula:

  -- Propose a new phased decontrol schedule of about 2-2 1/2 years, with no composite price formula. A simple phase-out schedule may be more palatable now that economic conditions have changed and in light of experience with the complexities of a composite price approach.

  -- Maintain a composite price system, but provide greater administrative flexibility and adjustments to move prices closer to world levels in a shorter period of time. Additional quantities of high cost production (such as tertiary recovery) could be allowed to sell at market levels outside the composite price structure.

  -- Reverse the trend towards decontrol and announce that price controls would be maintained indefinitely and that escalation would continue solely at the rate of inflation.

- Product decontrol. Each of the remaining products under controls must be considered separately if removal of controls is proposed. Initial findings are indicated below:

  -- Motor gasoline can probably be decontrolled without any price increases in addition to those that would occur under controls. The perceived possible impacts of removal of allocation controls could be mitigated by a form of dealer protection legislation such as was finally considered by the House of

Representatives in the 94th Congress; however, there may be no justification for the bill.

-- Commercial jet fuel and aviation gasoline seem to satisfy conditions for decontrol (as set forth in the EPCA). While opposition might be expected by certain groups, stand-by regulations could reduce objections.

-- Propane, butane, and controls over allocation of naphtha to SNG plants may not meet legal decontrol standards since there appears to be declining supply and rising demand. One of the difficulties with propane is that its price is based principally on that of natural gas and historical gas processing costs, causing it to remain underpriced in relation to propane produced from crude oil. Further, propane supply has declined along with natural gas production, since about 70 percent of total propane supply is extracted from natural gas.

Conclusions

- There will continue to be serious issues associated with the petroleum regulatory system. While resolution of most of these issues should await completion of the appropriate regulatory proceedings, it is clear that there is a need to remove any regulations that are not necessary (such as controls over gasoline). Further, the composite pricing system for crude oil has proven to be complex to administer; it was never envisioned to operate with a long freeze on price escalation. Thus, it is recommended that Congress adopt a simpler system that would expedite the phase-out of crude oil price controls, with or without use of composite prices. If the composite price system is retained, it should operate with greater flexibility to provide for maximum production incentives.

ENERGY TAXES

Background

- The taxing power of the Federal Government provides an adaptable tool for modifying investment behavior, stimulating conservation, discouraging use of particular fuels, and raising revenues for social redistribution or funding energy development. However, many believe the tax system is primarily a revenue raising mechanism and should not be used to provide subsidies or incentives for particular social or economic objectives.

Proposals Offered

- In January 1975, President Ford asked Congress for a variety of energy taxes to reduce consumption immediately. These included:

  -- An excise tax of $2 per barrel on all domestic crude oil production, accompanied by an equivalent import fee.

  -- A 37¢/Mcf excise tax on natural gas.

  -- A windfall profits tax on petroleum to be coupled with price decontrol.

  -- A tax credit of up to $150 for homeowners to buy and install insulation in existing residences.

  -- An increase in investment tax credits and changes in accounting rules for utilities.

  -- Rebates of the energy tax revenues.

- Congressional attention focused initially on the import fee and decontrol provisions and, after those were defeated or rescinded, the rest of the President's energy tax proposals were not enacted. The opposition stemmed mainly from concern over raising energy prices to consumers in the face of a recession and recent OPEC price increases, as well as doubt that higher prices really do dampen demand. The homeowner's insulation tax credit was deleted twice in Conference Committees.

- The House Ways and Means Committee considered a wide range of energy taxes including various gasoline and petroleum excise taxes, energy conservation trust funds, and a graduated tax on new cars linked to vehicle fuel efficiency. The Congress defeated the energy tax initiatives proposed by its Ways and Means Committee and only minor energy taxes were passed.

- A gasoline tax was considered as a means for discouraging discretionary use of automobiles. For every additional tax of 10¢ per gallon, consumption would drop by about 150,000 barrels per day (about 2 percent). The United States has the lowest gasoline prices and taxes of any nation in the International Energy Agency. Among the difficulties with a gasoline tax are the following:

  -- Any gasoline tax would need a clear rebate formula to reduce regressive effects.

  -- A gasoline tax accounts for only 40 percent of oil consumption, thus concentrating on automobile use which may be less elastic than other uses. The other 60 percent of petroleum consumption should also be considered for a reduction in demand through taxes.

  -- A gasoline tax would have varying effects by region (rural and western consumers would bear a disproportionate burden), and by industry (the recreation/tourism and automobile industries would be affected adversely).

Possible Initiatives

- Broadly based or Btu taxes. Substantial reductions in energy use could be achieved by a very large tax on all energy use. Energy consumption would drop about 16 percent with a tax of $1.35 per million Btu, with offsetting income tax rebates.

  -- While such a tax could raise large revenues and reduce consumption, energy prices would go up dramatically (such a tax is the equivalent of about $8.00 per barrel) and the whole tax system might have to be revamped to eliminate regressive effects on consumers and to offset the transfer of funds from the private to public sector.

-- Indiscriminate application of Btu taxes would discourage use of those energy resources whose use we may wish to encourage, i.e., synthetic fuels, coal, solar, etc. There is little logic in subsidizing certain energy sources and then taxing away the energy produced from these sources. Further, energy Btu taxes could dampen economic progress in critical areas of employment.

- Excise taxes for specific conservation objectives. A major defect of the Btu tax--its broad focus--could be corrected by targeting a conservation excise tax on specific fuels (e.g., oil and gas); specific fuel using equipment (such as automobiles); or specific uses of a particular fuel (e.g., outdoor gas lights; gasoline used in automobiles; or taxes for boiler fuel use of oil and gas). Although such taxes would be more specific than a Btu tax, they raise some political problems due to their discriminatory nature.

- Import fees. Imposition of substantially increased import fees can reduce consumption and discourage imports, but would lead to higher unearned revenues for some domestic producers of oil and gas (e.g., currently decontrolled stripper well oil). Regional effects are reduced as long as the entitlements program is in effect, but would be substantial after price controls expire. Import fees have administrative advantages, since they can be imposed by the President without new legislation, as long as the factual findings necessary under the Trade Expansion Act can be made.

- Market adjustment taxes. Under continued price regulations, both domestic crude oil and interstate natural gas will continue to be sold to end-users at prices substantially below marginal import prices. While decontrol of prices, possibly accompanied by a windfall profits tax, would be a more desirable approach for dealing with this problem, a basis exists to correct such distortions by taxing controlled fuels which compete with imports, to bring them into price parity with imports. Revenues from these taxes could be rebated through income tax reductions, used as income transfers and social adjustment factors, or earmarked for specific energy-related expenditures (such as R&D or financial assistance).

-- The adoption of such taxes could tend to perpetuate and institutionalize existing price regulations. Nevertheless, if distorted prices are frozen into the structure of the economy, as in the case of energy intensive capital goods with long lifetimes, they can have particularly adverse effects.

- Investment incentives. Favorable depreciation schedules, tax exemptions and tax credits can be used for the purpose of providing investment incentives for energy development and conservation. The size and risk of potential targets vary considerably. Beneficiaries of previously considered proposals have ranged from individual homeowners to large utilities, and credits have been considered for items ranging from insulation and solar water heating to state-of-the-art desulfurization equipment and nuclear generating facilities. An administrative problem arises because many investments are for purposes other than conservation.

  -- Loan guarantees have been suggested as an alternative to tax incentives, particularly for not-for-profit institutions and firms with no profits. Loan guarantees can be effective in correcting credit market imperfections and situations in which private lenders perceive excessive risk, e.g., for large or unusual ventures. The Government can, through insurance principles, spread the risk associated with any one loan over a large number of loans. Apart from removing credit market imperfections, loan guarantees are not likely to encourage private investors to undertake risky projects unless subsidies are also provided, e.g., through non-recourse arrangements or guarantee fees inadequate to cover the Government's administrative costs and probable losses.

Conclusions

- The debate over energy taxes should be reopened. Taxes can be an effective way to cut consumption or modify investment behavior. Ideally, the best way to provide the correct market signals would

- be to remove artificial price controls. However, since controls are now in effect, the Congress should review the need for broad (e.g., Btu) or specific (e.g., gasoline and/or natural gas) energy taxes. In addition, investment incentives for business (e.g., tax credit for purchase of coal-fired equipment) or homeowners (e.g., insulation tax credit) should be adopted.

FUELS POLICY

Background

- While oil and gas account for less than 10 percent of the U.S. energy reserves, they represent over 75 percent of our energy consumption. The domestic production of both of these fuels is declining and reserves are being depleted.

  -- In contrast, the Nation has sufficient deposits of coal to last for several hundred years. We also have substantial uranium deposits.

- The basic disparity between available energy resources and our current utilization prompts consideration of a fuels management policy. The fundamental question is to what extent should the Federal government have a role in allocating the use of fuels (e.g., substituting coal or electricity for oil or gas) or sectoral distribution of use (e.g., forcing natural gas out of boilers and into residential use), versus encouraging the market to operate?

  -- Technically, electricity can be substituted (generally at higher costs) for gas in some industrial processes; for oil and gas in space heating; and for oil in some limited transportation use. Electricity generated from coal or nuclear power uses resources in greater domestic supply than are oil and gas.

  -- In general, electric resistance heating using electricity from oil or gas is uneconomic, because of the lower efficiency of electricity and its price. Electricity used in heat pumps or heat storage systems is more efficient than resistance heating.

Proposals Offered

- The first indirect fuels policy in recent years occurred with the Clean Air Act Amendments of 1970, which led to shifts from coal to oil or gas. (Utility oil consumption increased by 125 percent from 1969 to 1973.)

- Beginning in 1970, declining natural gas supplies forced interstate pipeline curtailments of natural gas. More recently, the shortages have resulted in FPC allocation policy guidelines which generally are based upon particular end-uses of the gas. (The FPC policy to date has been to protect residential and small commercial customers, as well as those industrial uses that are most difficult to convert to alternate fuels.)

- The Federal Energy Administration has played a role in fuels management by not allocating supplies of feedstocks for new synthetic gas plants, and has been reviewing the environmental impacts of its policy. Its preliminary analysis also shows that the conversion of petroleum products into gaseous fuels is an inefficient use of relatively scarce oil.

- The FEA's coal conversion program is the first direct fuels management policy to be legislated. The original legislation authorized the FEA to (1) prohibit any electric power plant and any major fuel burning installation (MFBI) from burning oil or natural gas as its primary energy source, provided it had the financial and physical capability to burn coal and met environmental specifications; and (2) require by "construction order" new power plants to be built with the capability to burn coal.

    -- In the EPCA, the initial ESECA authorities were renewed and extended to cover issuance of construction orders to new MFBI's, and to require the recipients of such orders to burn coal. Under this extension, many more power plants will be candidates for prohibition orders.

- The Congress has considered fuels management in a number of areas:

    -- A modified coal conversion program has been considered by the Senate Public Works Committee (S. 1777). The bill, which is described in Section 5 (Electric Utility Regulatory Reform), has not been reported out of Committee.

-- The Congress has also considered allocation priorities for natural gas, but has yet to develop a program in that area. Proposed programs to date have not put forth a clear rationale for deciding upon priorities. Any priority system should be developed in concert with other aspects of natural gas policy (such as price policy). Absolute priority for residential customers (new and old) could result in greater demand for residential use (because it would be cheaper than alternatives). This growth would have to be satisfied by conversion of existing industrial uses, and it is not clear that the cost of conversion would be worth the benefits.

Remaining Opportunities

- To replace use of dwindling oil and gas supplies, the greatest potential for near-term fuels substitution is in the electrical generation sector; the least amenable sector in the next 10 years is transportation.

  -- Oil and gas represent almost one-third of electricity generated. Oil-fired power plants are concentrated most heavily on the East Coast, because of availability of previously less expensive imported oil. Utilities using gas are located primarily in the South Central region, because of locally abundant natural gas. (About 12 percent of the natural gas consumed in the United States is used in Texas and Louisiana utilities.)

  -- In some cases, the same power plants that converted from coal to oil in the early 1970's to meet air quality requirements are now being forced back to coal. This creates confusion in the business community and a lack of confidence in the stability of government regulatory policy.

- Industry uses about 9 Tcf of natural gas annually, and 3 MMB/D of oil. Most industrial gas is used as a boiler fuel or for process heat and could be replaced by coal or petroleum (although sometimes at considerable expense). About 18 percent of petroleum consumption is in industry and, while most use is non-substitutable, there is some potential for conversion to coal.

- An efficient way to use oil and gas, as well as coal, is to extract as much energy as practical in the form of electricity and then utilize the waste heat for other purposes. When applied to buildings this process is referred to as total energy, where a small generating plant supplies electricity and then the remaining heat supplies hot water and space heating. In industrial processes, high pressure steam can be generated and then expanded through an electrical generator to give low pressure steam suitable for heating or process purposes (often referred to as "co-generation").

- In the residential/commercial sector, the primary potential for fuel conversion is in the construction of new buildings using electricity for space heating purposes. Replacement of oil or gas heating with electricity in existing homes will normally be quite uneconomic.

- Virtually no fuels management can occur in the transportation sector until (and if) electric car use is more widespread. (Congress recently overrode a Presidentail veto of a bill to increase substantially the R&D effort on electric cars). There is some possibility for replacement of diesel rail by electric rail, but costs are high.

<u>Possible Initiatives</u>

- Oil and gas use for electrical generation can be reduced by cutting the rate of construction of new oil- and gas-fired capacity; reducing use of existing capacity; reducing use of electricity in peak hours (where fuel is often oil or gas); and converting existing units to coal. This policy would reduce dependence on expensive, relatively insecure, and dwindling resources, and is likely to be required as domestic oil and gas reserves are depleted. A program such as S. 1777 could accomplish these objectives, but at significant cost and potential adverse environmental impact. Key questions are the time period during which this change occurs; the extent to which the Federal government should require it by direct regulation; and the possible need for changes in environmental regulations.

- In the residential/commercial sector, the Federal government could attempt to ban or suggest limitation of new connections of gas for heating purposes and impose a stiff tax on replacing furnaces. Such a program would increase use of natural gas for existing industrial users and, if electricity use increased, would lower system efficiencies, and eventually require winter-peak generating capacity. These problems could be mitigated by greater use of heat pumps and home storage systems.

- New rate structures and regulatory changes may be needed to encourage co-generation.

- The magnitude of the intervention that is implied by a comprehensive fuels management policy cannot be minimized. The regulatory structure that would be required to specify so basic and so universal a set of decisions is probably unprecedented in the American peacetime experience. When the exceptions procedures and the possible litigation are combined, it is likely that comprehensive fuels management policies would stimulate a more complex procedural process than that already in effect. The implementation of a comprehensive fuels management plan would also be a significant and possibly irreversible step in the direction of a fully planned economy. A comprehensive fuels management policy would also have to take into account regional supply, consumption patterns, and environmental differences.

Conclusions

- On the surface, it may seem attractive to manipulate the use of various fuels in order to derive the greatest end-use efficiencies and to minimize environmental impacts. Further, given the current regulatory environment, the appropriate market signals are not being communicated. The Federal government should continue to pursue opportunities to reduce the use of oil and gas in power plants and major industrial facilities in order to expand the use of coal. A concept like that in S. 1777 (with modifications) should be adopted.

-- However, the Federal government must also be careful to avoid massive intervention in the energy marketplace. The regulatory structure that would arise from a comprehensive fuels management policy would be virtually unadministerable, costly, and probably inequitable. Indeed, a much more desirable approach would be to remove price controls and allow the marketplace to allocate fuels.

SECTION 3

ENERGY CONSERVATION

Background

- Domestic energy consumption is projected to grow at between 2.5-2.8 percent annually through 1985, as compared to 3.6 percent before the embargo.

- The United States' conservation efforts to date have been rated near the bottom of all consuming nations in the International Energy Agency. The principal reasons for our low ranking are the continuation of oil and gas price controls, low tax on gasoline, and failure to enact (prior to the ECPA passage in August) most of the Administration's proposed conservation measures.

  -- Nevertheless, if legislation already passed is implemented fully, these measures could save over 2 million barrels per day by 1985, and should result in a more favorable ranking by the IEA.

- The current market price of domestic energy does not fully reflect the true value of energy to the economy and considerable energy is wasted.

- Energy conservation has become a popular political issue; yet, it is often difficult to receive widespread support for specific proposals, since any additional regulation involves restricting personal or business choices.

- Conservation provides an effective mechanism to improve use patterns in efficiency of services, to slow the trend of increasing reliance on imported oil, and "buys" time to develop alternative energy supply technologies to meet increased energy demand in the future.

  -- However, conservation alone cannot solve our energy problem. The potential energy savings from additional regulation are limited; in fact, without higher energy prices or considerable restriction of economic activity, most of the potential savings from regulation can be achieved from measures enacted already.

Proposals Offered

- In January 1975, the President proposed to Congress a wide range of conservation proposals encompassing price increases, mandatory and voluntary standards, as well as a comprehensive public education program. The following were requested specifically:

  -- Crude oil price decontrol, accompanied by windfall profits tax and rebates;

  -- Petroleum and natural gas excise taxes;

  -- Voluntary automobile gasoline mileage increases by 1980;

  -- Mandatory thermal efficiency standards for all new buildings, with strict sanctions;

  -- A tax credit for homeowners providing up to $150 for purchasing and installing insulation in existing residences;

  -- A weatherization grant program to provide grants for low-income and elderly people to install insulation in their residences;

  -- Voluntary appliance efficiency standards;

  -- Mandatory appliance and automobile efficiency labeling to enable consumers to see the cost of operating equipment over a period of time;

  -- Mandated reforms of State Utility Commission processes to include the application of conservation practices in establishing rates;

- In December 1975, the Congress passed the Energy Production and Conservation Act (EPCA) which included provisions for:

  -- Phasing out price controls on domestic crude oil;

  -- Requiring appliance manufacturers to provide energy efficiency labels to consumers on major appliances and establishing voluntary energy efficiency targets for the appliance industry;

-- Establishing mandatory automobile fuel efficiency standards of 20 miles per gallon (mpg) by 1980 and 27.5 mpg by 1985;

-- Establishing voluntary industrial energy conservation targets for the 10 leading energy consuming industries, and mandatory reporting on progress in meeting these targets;

-- Providing conservation grants to States to assist in the development and implementation of energy conservation programs;

-- Requiring mandatory conservation standards for Federal agencies.

- The House Ways and Means Committee, in its consideration of energy tax legislation, debated the merits of a range of gasoline excise taxes which were subsequently deleted from its bill (H.R. 6860). Included in the House-passed H. R. 6860 were such conservation measures as tax credits for business and residential insulation, business use taxes on petroleum and natural gas, and recycling tax credits. This bill was never passed by the Senate.

  -- An insulation tax credit for homeowners was passed by the Senate as part of the Tax Reduction Act of 1975, but deleted in Conference. It was also included in H. R. 10612, a general tax reform measure, but was deleted in Conference and remained pending in the Senate upon adjournment of the 94th Congress.

- The Energy Conservation and Policy Act (ECPA) passed in August 1976, included the following conservation programs:

  -- Mandatory energy performance standards for new residential and commercial buildings, but without the sanctions requested by the Administration. The experience with this bill clearly illustrates the difficulty in enacting mandatory conservation legislation;

  -- A $200 million low-income and elderly weatherization grant program;

-- A $2 billion obligation guarantee program, aimed at conservation retrofit of buildings and industrial plants. This program provides loan guarantees for conservation and renewable resource investments;

-- Authorization for a $200 million demonstration program to determine the feasibility of a national program of subsidies to stimulate retrofit of existing dwellings;

-- A $13 million grant program to State regulatory commissions to demonstrate alternative utility rate forms and related conservation measures.

- A number of other conservation measures have been proposed by various groups or individuals, including mandatory reduction of industrial energy use and increased funding for mass transit. Most of these measures did not pass because costs exceeded their benefits.

Remaining Problems

- While legislation has been enacted to effect substantial conservation savings (programs enacted are projected to reduce demand by over 2 MMB/D by 1985 as compared to otherwise projected demand levels), few savings will be realized unless existing programs are implemented effectively.

- Further savings could be obtained depending upon the level of Federal intervention in the marketplace, and the prices charged for energy consumption, yet there remains debate over the effectiveness of either more regulation or higher prices.

- A national awareness of the benefits of conserving energy still needs to be instilled.

- The Federal efforts to plan and implement conservation are fragmented organizationally.

Possible Initiatives

- There are differing philosophical approaches as to the Federal role in stimulating conservation.

- There are a number of specific conservation measures which the Federal Government can enact or implement administratively to stimulate further conservation and end-use efficiency in all sectors. Some of the measures in the list below are probably not cost-effective or likely to have much impact, but have been included for completeness.

  -- Transportation

    - Gasoline excise tax. As indicated in Section 2, a substantial gasoline tax could save considerable petroleum and has a strong near-term impact.

    - Voluntary fuel economy standards for trucks and buses. While automobiles now have to meet mandatory standards, efficiency of trucks and buses could be improved and save 125,000 B/D.

    - Revision of CAB air transport load factor standard. Airplane load factors are now about 55 percent; an increase to 65 percent, while causing greater inconvenience to passengers, could save almost 70,000 B/D.

  -- Residential/Commercial

    - Insulation tax credit for homeowners. This tax credit reduces the burden of first costs and can save over 100,000 B/D.

    - Mandatory lighting efficiency standards. Efficient lighting standards have been identified, but enforcement of this measure would be extremely difficult.

    - Utility insulation financing. Under this proposal, gas utilities would be encouraged to install efficiency improvement devices in homes and investment costs would be capitalized and recovered through a cost of service charge. Such a program could save considerable gas, but raises regulatory and economic issues (See Section 5, "Electric Utility Regulatory Reforms," for more details).

- Mandatory beverage container deposits. A recent FEA study indicates that national legislation in this area could save about 85,000 B/D and have significant environmental improvements. Four States currently have these laws, but the industry believes there would be adverse economic impacts from widespread adoption.

-- Industry/Electrical Generation

- Financial incentives or standards to increase in-plant self-generation of power. Encouraging industrial plants to generate their own power is a desirable way of using waste heat and saving energy.

- Conduct energy audits. Energy audits of major industrial plants could be required and reported. Such a program could be expensive and may not save much energy.

- Efficiency standards for industrial equipment (e.g., boilers, electric motors). Such standards could save about 200,000 B/D by 1985, but such savings would be achieved most easily voluntarily, in response to market forces.

- Disallowance of the expensing of energy costs for tax purposes. This change in the tax laws could provide greater conservation incentives, but possibly at a significant cost to energy intensive industries.

- Utility rate reform. Such measures as peak-load pricing and minimizing use of inefficient peaking generators have considerable potential for reducing peak loads and saving energy. A report on these initiatives is due to Congress in February 1977.

-- Taxes and Tax Credits

- In general, further initiatives in the area of tax credits (business insulation, installation of more efficient equipment, etc.)

and taxes (Btu, business use of petroleum and natural gas, etc.) could be utilized to induce conservation in all sectors.

- Various feasible energy taxes, their potential conservation effects, and relative advantages and disadvantages are discussed in Section 2, "Energy Taxes."

Conclusions

- The United States' energy policy must include both a strong conservation effort and an aggressive program to develop domestic supply. The legislative achievements in energy conservation over the past two years will result in significant reductions in demand and improved efficiencies. Yet, with the exception of conservation induced by higher prices and some limited regulatory measures, there is little that can be done to reduce demand in the next few years. The benefits of all conservation measures should be weighed against the cost of implementation and regulatory burdens they impose. The following actions should occur:

  -- Congress should enact the Administration's proposed tax credit for insulation.

  -- The Congress and Executive Branch should monitor closely the implementation of existing programs, especially the thermal efficiency standards for new buildings. Tough sanctions may be needed to make the buildings program work.

  -- The ERC has established a task force on energy conservation to deal with implementation of existing programs and to prepare a thorough analytical report to Congress as required by the ECPA. The new Administration should continue this effort.

SECTION 4

ENERGY DEVELOPMENT: THE BROAD ISSUES

Background

- It is clear that irrespective of whether conservation programs prove successful and domestic energy prices are decontrolled, the Nation's use of energy will continue to expand. Even if energy demand growth were held to about 2 percent annually (an ambitious goal), domestic energy consumption would be about 87 quadrillion Btu's (quads) in 1985 and 96 quads in 1990, as compared to 71 quads in 1975. (Note that one quad is the equivalent of about one-half million barrels per day, or about 40-45 million tons of coal per year.)

- In addition to conservation, there are only two alternatives to meeting our increased energy needs: develop more domestic sources or increase reliance upon imports. To keep imports relatively constant, it is likely that the Nation would have to:

  -- Increase coal production from current levels of about 670 million tons annually to over one billion tons per year by the mid-1980's.

  -- Expand oil production in frontier areas of Alaska and the Outer Continental Shelf (OCS), as well as encourage enhanced recovery from existing fields to replace declining supply.

  -- Increase the share of nuclear energy in the generation of electric power in the next ten years from about 9 percent to over 20 percent.

  -- Develop supplemental sources of oil and gas, such as coal gasification and liquefaction and shale oil to meet shortages of liquid and gaseous fuels.

  -- Expand dramatically the use of renewable resources, such as solar energy.

- While considerable progress has been made in enactment of legislation in the conservation and standby areas, little progress has been made to legislate measures to increase domestic supply:

  -- Only the Naval Petroleum Reserves production and Alaskan natural gas transportation legislation, and extension of coal conversion authorities have occurred.

  -- Some progress has been made toward decontrol of oil prices, but the price deregulation proposal for natural gas and most proposed environmental amendments were not enacted.

- There is a growing recognition of the role that must be played by State and local governments and interest groups in decisions on new energy projects. Cancellation of major energy facilities, such as Kapairowitz (Utah) and several nuclear plants, as well as defeat of legislative proposals to aid the siting process, point out clearly the need to work with local interests.

- There is also a growing regionalism in energy, which often conflicts with national policy interests, but cannot be ignored. Issues such as oil prices in New England; OCS development off the Atlantic Coast; coal and oil shale production in the Western States; oil and gas production in the South Central Region; oil and gas transportation through California; and Alaskan development are all large regional issues.

- There is a continual need to balance energy goals with environmental objectives and economic factors.

<u>Proposals Offered</u>

- The approaches tried by the Executive and Legislative Branches of the Federal Government can be divided into two basic areas: regulatory override/expediting and environmental/energy balancing.

- In the regulatory override or expediting area, there were several legislative initiatives:

-- Energy Facility Planning and Development Act. In January 1975, the President proposed to Congress a bill which would encourage States to develop and apply a comprehensive and coordinated process for expeditious review and approval of energy facility siting applications. This bill did not receive much attention in the Congress mainly because it created a Federal role in an area traditionally under State and local jurisdiction.

-- Energy Independence Authority (EIA) Act. In the EIA, which is a $100 billion financing assistance bill, there is a provision for expediting the regulatory process at the Federal level for projects deemed critical for energy development. It would establish the FEA as the coordinator of a streamlined permit process for all new facilities which require Federal licensing. This portion of the EIA Act did not receive serious consideration as the rest of the EIA bill became stalled.

-- Nuclear Licensing Act. The Administration asked Congress to pass legislation to reform the nuclear facilities licensing process by providing for early site review and approval, and encouraging standardization of nuclear facilities design. This bill was not enacted.

-- Outer Continental Shelf Leasing Amendments. The Congress devoted considerable time to a bill which would have altered significantly the current OCS leasing procedures. The bill would have modified the current bonus bidding practice and provided an expanded role for States, but was not enacted before the close of the 94th Congress despite strong Congressional support.

-- Alaska Natural Gas Transportation Act. In February 1976, the President asked the Congress to enact legislation to expedite delivery of Alaskan natural gas to the lower-48 States. The Congress enacted and the President signed such legislation.

- In the area of energy and environmental interactions, there were a number of proposals:

  -- Clean Air Act Amendments. The Administration and the Congress developed numerous proposals for amending the Clean Air Act. The key issues concerned the following:

    - Significant deterioration, where courts have ruled that in areas where air quality is superior to national standards, significant deterioration of that air quality must be prevented. This interpretation could preclude much energy development and legislative clarification was sought. It is one of the most serious environmental issues.

    - Compliance date extensions, where the Administration has sought an extension of the dates in which existing power plants must be in compliance with air quality regulations to allow time to develop permanent pollution control systems.

    - Non-attainment policy, in which the existing Clean Air Act precludes construction of new air polluting facilities in areas where they may interfere with attainment or maintenance of ambient air quality standards. Concern has been raised about the effects on hydrocarbon emitting facilities, such as refineries.

    - Auto emission standards are largely a problem of fuel economy and conservation, rather than resource development, although obviously enmeshed in the Clean Air Act debate.

  -- Surface Mining Legislation. Surface mining legislation has been introduced into the Congress every year since 1971; Congress has passed such legislation twice, and has failed to override Presidential vetoes (which were argued mainly on grounds of economic impact and production loss) both times. Lack of uniform nationwide minimum reclamation standards has been decried by environmental groups. Although some States have stringent standards, proponents of Federal legislation say that these standards are often weak or not being enforced. The Interior Department has issued new regulations for local mining on Federal lands, and has recently decided to apply to Wyoming State regulations to Federal coal land development in that State.

-- Impact Assistance. The President, in February 1976, asked the Congress to consider comprehensive Federal energy impact assistance legislation. This one billion dollar loan, loan guarantee, and grant program would provide financial assistance to all areas affected by Federal energy resource development in the next fifteen years. The assistance would utilize a variety of financing mechanisms to help plan and finance energy-related public facilities prior to energy production, and assistance would be repaid from future taxes and revenues. The Congress passed legislation that provides assistance for coastal development, but not for inland projects such as coal, oil shale, tec.

-- Nuclear Safety and Waste Disposal. See Section 6.

Remaining Problems

- There remains a strong need to resolve most of the major resource development and environmental issues raised above. It is particularly important that uncertainty be reduced with respect to coal development (Clean Air Act and surface mining legislation), nuclear power, supplemental sources of natural gas, and synthetic fuels commercialization.

- A major issue is likely to confront the new Administration regarding the disposition of Alaskan oil. Between the time the trans-Alaskan oil pipeline legislation was approved and expected delivery next year, conditions changed and it now appears that a surplus of about 500,000 barrels per day may be available for movement from the West Coast.

  -- The surplus was caused by lower demand as a result of much higher prices and greater conservation awareness; the decision to commence production from Naval Petroleum Reserve #1 in California; and greater incentive to use enhanced recovery techniques at existing California fields.

-- The surplus was caused by lower demand as a result of much higher prices and greater conservation awareness; the decision to commence production from Naval Petroleum Reserve #1 in California; and greater incentive to use enhanced recovery techniques at existing California fields.

-- There are several possible alternatives for movement of oil from the West Coast. These include a Trans-Provincial Pipeline through Canada; a northern-tier pipeline to Minnesota; the SOHIO project to construct a marine terminal in California and use an abandoned gas pipeline to deliver oil to the Midwest; and a Central American Pipeline project.

-- In addition, some have suggested that Alaskan oil be sent to Japan in exchange for Middle East crude for the Gulf Coast. While such an approach would reduce transportation costs, there are important reasons why this alternative is not desirable.

- Another key energy development issue will be a decision on an Alaskan natural gas transportation system. Under existing legislation, the President will have to make a recommendation on such a system to the Congress in 1977, for its consideration. His recommendation will also consider financing questions. There are currently three competing proposals for this multi-billion dollar project.

- The dispute over the need for power and the possible impacts of having too much or too little energy is another important issue.

Possible Initiatives

- Amendments to the Clean Air Act. This issue will be considered again by the Congress and a whole new strategy may be desirable. Among the options that should be considered is a separation of the stationary source and automobile emission provisions into two separate bills. There may also be consideration of a sulfur emissions tax.

- Surface Mining Legislation. The need for Federal surface mining laws will be reconsidered by the 95th Congress.

- OCS Leasing Amendments. The Congress is likely to take up again possible reforms to the OCS leasing practices of the DOI. Among the alternatives that will be reviewed are changes in the bidding system; greater participation by States and local governments in the decision-making process; and the adequacy of current environmental safeguards.

- Alaskan Oil Distribution. Proposals may have to be developed if review of the Alaskan oil distribution study indicates a need for legislative or administrative action.

- Coal Slurry Pipeline. Legislation which would allow the right of eminent domain to coal slurry pipelines will probably be reconsidered by the Congress.

- LNG Siting and Safety. To assure that needed liquefied natural gas projects are expedited, there may be a need for administrative or legislative action. Such action could consist of national siting standards; Federal regulatory reform; more participation by States; or greater expenditures for safety and risk analysis.

- Siting Programs. There may be an opportunity to streamline Federal regulatory processes for siting new facilities, and providing incentives to states to develop siting programs. One such incentive might be an energy resource planning activity as part of an inland impact assistance program or modification of the State conservation grant program to include resource development planning.

- Changes in State/Federal Relationships. Since State and local governments and interest groups have such a strong voice in energy development decisions and since attempts at Federal overrides have proven to be difficult to pass, there could be a further involvement of these groups in the Federal decision-making process. The key questions revolve around the extent of involvement; whether such involvement be in an advisory role or with some veto ability; and whether funds should be provided for such participation.

Conclusions

- The United States will have to continue expansion of domestic energy development in order to preserve its economic and national security. But such development will not take place unless the Federal government takes the appropriate steps to ensure that environmental standards are met, and that State and local interest groups are involved in the decision-making process. Further, the following actions are proposed:

  -- The Congress should review the entire regulatory process involved in siting new energy facilities and propose methods to improve the process where feasible.

  -- The Congress should attempt to reduce uncertainty concerning the ground-rules for environmental standards and development on Federal lands.

SECTION 5

ELECTRIC UTILITY REGULATORY REFORM

Background

- Electricity consumption has grown at a considerably faster rate than overall energy demand in the past few decades (7 percent annually from 1947-1972 vs. about 3 1/2 percent for all energy), primarily because of its versatility of use and variety of sources. While its use is essentially pollution free, its generating stations often concentrate pollutants in a single and highly visible source.

- Prior to the embargo, the electric utility industry was known for its stability, characterized by rising consumption and declining prices. The embargo, and subsequent price increases, led to large fuel cost increases. Consumer reaction to higher prices, energy conservation awareness, and the recession brought about a relatively flat growth rate in 1974-1975.

- The inability of utilities to obtain adequate rate relief to cope with higher fuel prices, escalating capital costs of nuclear and coal plants, uncertainty about demand growth, and environmental problems, resulted in major cutbacks in 1974 in plans for generating capacity. At one point, more than 75 percent of planned nuclear plants were postponed or cancelled.

  -- In 1975, market conditions improved somewhat and a record $3 billion of rate relief was granted and market to book value ratios have improved; however, the basic uncertainties about load growth, financing capability, and siting difficulties remain. Utility reserve margins remain high (about 35 percent).

  -- Nuclear and coal-fired power plants are the cheapest base load plants, but are the most capital intensive (a 1000 MWe nuclear plant costs about $600 million to build, in 1975 dollars, as compared to $240 million for an oil-fired plant) and easiest to defer. Given their long lead-times (7-10 years), if they continue to be deferred and considerable load growth resumes, utilities may have to build oil- or gas-fired plants to meet customer needs in the 1980's.

Proposals Offered

- The Administration proposed a number of measures over the last two years to deal with the utility problem. These include:

-- The Utilities Act of 1975 was designed to assist the financial health of public utilities by reducing regulatory lags involved in approving proposed rate changes and assuring that rates adequately reflect the full cost of generating and transmitting electricity. To reduce the cost of capital for needed utility expansions and stimulate equity rather than debt financing, proposals for tax changes were also presented, including increased investment tax credits for public utilities and preferred stock dividend tax deductions.

- Legislation to provide a stronger role for the Federal Government in the utility rate setting processes has met with strong resistance in the Congress, as utility regulation is the traditional province of the States, and some claim that the necessity for higher utility rates has not been demonstrated adequately.

-- The Energy Facilities Planning and Development Act of 1975 would require that States have a comprehensive and coordinated process for expeditious review and approval of energy facility applications, and that final State energy facility decisions cannot be nullified by actions of local governments. This proposal was not passed mainly because of its attempt to interpose Federal regulations on local decision-making.

-- The <u>Electric Power Facility Construction Incentives Act</u> of 1975 (proposed by the President's Labor-Management Committee and endorsed by the Administration) was designed to provide tax incentives to stimulate the construction of new electric power generating facilities other than those fueled by petroleum. This legislation allowed an increased investment tax credit, extension of five-year write-off of pollution control equipment, depreciation of construction work in progress (CWIP) as expended and optional dividend reinvestment with deferred income taxation. The first three benefits are conditioned on inclusion of CWIP in the rate base and normalization of tax deferrals and credits. This bill was not enacted.

-- The <u>Energy Independence Authority Act</u>, which was proposed to supplement and encourage private capital investment, would finance energy projects that would contribute directly and significantly to energy independence, and would not otherwise be financed without government assistance. EIA financial assistance would require as a condition of assistance to a regulated utility, sound and expedited regulatory response from rate commissions. It would include agreement by the regulatory commission to a rate covenant with EIA and the regulated utility to assure adequate earnings to protect EIA's investment. This bill was not enacted.

-- Amendments were passed by Congress to the <u>Energy Supply and Environmental Coordination Act</u> (ESECA). These extend and broaden the mandate to convert oil and gas boilers to coal, where practicable, and to order plants to be designed for and use coal.

-- The <u>Nuclear Fuel Assurance Act</u> of 1975 would encourage the development of a competitive private uranium enrichment industry to fuel expected nuclear power plant needs. This bill, as discussed in Section 6, was barely defeated in the Senate late in the 94th Congress.

-- Amendments were proposed to the Clean Air Act to resolve regulatory problems resulting from court decisions regarding "significant deterioration" of air quality, and to extend compliance dates for air quality standards through 1985 (to allow use of intermittent control systems in isolated power plants and require other sources to achieve control as soon as possible). These amendments, as discussed in Section 4, failed to pass.

-- The Nuclear Power Plant Siting and Licensing Procedures Act intended to shorten and improve the licensing process for nuclear facilities, would allow licensing procedures for reactor sites and standardized reactor designs to be completed at an early point in time. This bill was not enacted.

- As indicated above, the amendments to the ESECA coal conversion authorities were the only Administration initiatives passed by the 94th Congress in the utility area. Primary attention toward utilities in the 94th Congress centered on consideration of S. 1777 in the Senate Public Works Committee and H.R. 12461 in the House Interstate and Foreign Commerce Committee, although neither bill was reported out of Committee.

-- S. 1777, as discussed in Section 2, would extend and broaden FEA's coal utilization authorities. Under ESECA, the FEA can identify existing utility and industrial boilers that should be converted from oil and gas to coal, or new utility or industrial facilities that should be constructed to burn coal. In each instance, FEA must justify its orders. These ordering authorities expire June 30, 1977.

-- S. 1777 would extend the ESECA conversion and construction order authorities. New utility oil and gas construction, however, would be prohibited completely (with certain exceptions). The burden of proof would shift to the utility to receive a permit from FEA. S. 1777 was not considered by the Senate due to the priority of

Clean Air Act amendments in the Public Works Committee.

-- H.R. 12461, considered by the House Interstate and Foreign Commerce Committee, approaches the utility issue by mandating certain ratemaking practices on a national basis (regardless of uniform applicability), providing for automatic adjustment clauses under certain conditions, limiting the inclusion of construction work in progress in the rate base and excluding it entirely from bulk power rates, and other measures. The bill involves a complex set of regulatory changes.

-- In addition to these programs, load management demonstration programs have been funded by the Congress for the past two years, and the recently enacted Energy Conservation and Production Act authorizes a $13 billion utility demonstration program and mandates the development of proposals on utility rate reform. A report on rate reform is due to Congress in February 1977.

- There are several reasons why the utility proposals have not received a more positive reaction:

  -- Almost all the utility rate relief proposals involve higher costs to consumers in an area where costs have already risen dramatically (the average residential electric bill increased by 45 percent from 1973 to 1975).

  -- Assistance to utilities is never a popular public issue, since most consumers think utilities are already in good financial health.

  -- Siting and regulatory decisions are traditionally made by local authorities and attempts at Federal override meet with strong "states' rights" opposition.

  -- Environmental quality concerns often conflict at a local level with national energy policy considerations. Nuclear power, in particular, has undergone considerable public scrutiny in the past year.

Possible Initiatives

- Coal Conversion. Converting existing power plants is a long and arduous process. To date, almost half of the 74 existing units identified as candidates for conversion have actually started burning coal. Legislation such as S. 1777 may be needed to amend and extend current ESECA authorities.

- Rate Guidelines. As mandated by the ECPA, the FEA is currently assessing the utility rate setting process. The study and any proposed guidelines will consider load management, changes in declining block rate structure, cost of work in progress, fuel adjustment clauses, and the normalization of accounting practices.

- Investment Tax Credits. There are a number of alternatives for using tax credits as an incentive to the greater use of coal and nuclear power in the generation of electricity:

  -- A greater investment tax credit for the electric utilities building new nuclear and coal power plants; solid waste utilization and coal gasification facilities for electric power generation; capital investments to convert existing natural gas and oil powered plants to coal; and capital investments in load management and environmental control devices;

  -- Legislation which would provide that no tax credit be given for any oil- or gas-fired facility, except those fueled by gas produced from coal. However, such legislation may not be necessary if a new coal conversion approach is adopted, and could affect the ability to build any needed peaking equipment.

- Regional Generation. To promote bulk power generation of electricity, the Congress could consider legislation authorizing States and their regulatory bodies to enter into agreements providing for the formation of regional wholesale generating companies which would construct all future base loaded facilities in their service area and be governed by FPC rules on bulk power generation. This legislation could require adherence by participating utilities to minimum rate guidelines. Opposition to this proposal can be expected on the basis of Federal interference in State rate setting processes.

- Utility Conservation Financing. One approach that has been considered for stimulating conservation is to have gas (and possibly electric) utilities install insulation or make other conservation investments in individual homes and charge the cost of the insulation against the utility's rate base, rather than against the householder directly. The rationale for such a proposal centers on the high cost to a given utility of obtaining supplemental gas supplies (synfuels, LNG, etc.), relative to the cost of installing equivalent insulation. The theory is that if the entire rate base benefits from installation of insulation in individual homes, then the entire rate base should support the cost of such installation, just as the entire rate base supports the cost of additional supply alternatives.

  -- Utility insulation financing, charged against the rate base as a whole, could contribute significantly to overcoming many of the major obstacles to widespread insulation investment. These include somewhat high initial costs, long payback periods, uncertainty regarding ultimate cost effectiveness, and difficulties encountered in dealing with the financing and supervision of the household improvement industry.

  -- However, the reluctance of utilities to invest directly in the conservation business and possible legal problems would have to be overcome. Potential opposition by insulation businesses which might object to competition from the utilities on antitrust grounds and bondholders who might question the security of insulation investments, as well as opposition by consumers who have already installed insulation, would also have to be addressed.

- Merger Policy. The traditional position of the Department of Justice has been to oppose utility mergers as reducing competition. Since there are economies of scale associated with larger plants, and since competition between adjacent utilities is small, there may be a need to review merger policy.

Conclusions

- Electricity consumption is expected to continue to grow at about twice the rate of energy demand. If coal and nuclear electric generation capacity is not started now, it is possible that power shortages would result after 1980 and utilities would turn to oil and gas as a source of power. To reduce the possibility of such a result, the following actions are needed:

  -- The Congress should broaden, through amendment and extension, the Government's existing coal conversion authorities.

  -- The Congress should consider additional investment tax credits for utilities to encourage greater use of coal and nuclear power in the generation of electricity.

  -- However, any Congressional action on electric utility rate reform should await completion of the FEA Report to Congress mandated under the ECPA.

SECTION 6

NUCLEAR ENERGY

Background

- By substituting for oil and natural gas in electricity generation, nuclear power permits the use of these scarce domestic fuels for purposes where no other alternatives exist. It can also substitute for coal in many instances where environmental considerations and economics do not allow use of fossil fuels.

- This country is now in its 18th year of commercial nuclear power production, with 63 plants totaling over 46,000 megawatts (MWe) authorized to operate and supplying about 9 percent of our electrical generation. Another 173 plants totaling nearly 190,000 MWe are planned or under construction. Nuclear plants now supply the equivalent of over 1 MMB/D of petroleum.

- Most planned nuclear power plants or additions in capacity were postponed or cancelled in 1974-1975 due to uncertainty over load growth, utility financing difficulties, and siting problems.

- High capital costs, coupled with the difficulty of raising funds, and uncertainties over the price and availability of uranium (particularly after the failure of a major uranium supplier to meet contract requirements), have affected the economics of nuclear power and led to a reassessment of plans by many utilities. Nevertheless, electricity generated in current light water nuclear reactors is economically advantageous to fossil fuel electricity production in many areas.

- Recently, nuclear power has faced considerable criticism, which has added to uncertainty about its future. The criticism has been directed at various aspects of the regulation of nuclear power, including siting decisions, waste disposal, possible sabotage, safety, and reprocessing, as well as the question of the proper Federal role in nuclear development.

- The Federal Government has had a major role in nuclear development, since the days of the Manhattan Project during World War II, when the primary objective was to develop a new and powerful weapon.
  - -- In the post-war period, the Atomic Energy Commission was established to maintain civilian control over weapons development and to regulate the use of fissionable nuclear material.
  - -- In the mid-1950's, the "Atoms for Peace" program was established to utilize, for peaceful purposes, the technological base established by the military programs, and was the beginning of Federal involvement in nuclear electric power generation.
  - -- The government-sponsored research to develop power reactors, regulated safety, and produced the enriched uranium fuel needed to power the reactors in three facilities which had been built originally for weapons production. The pervasive role of the Federal Government has been attacked by some critics.
- There has been increasing concern over the course of the U.S. non-proliferation policy, with many people fearing misuse of nuclear power by other nations. The United States has participated in about 30 bilateral agreements on nuclear cooperation.

Proposals Offered

- Licensing and Regulation. The Atomic Energy Commission was abolished in 1974 mainly because of concern that an agency responsible for both the regulation and promotion of nuclear power could not perform both functions efficiently and without bias. The independent Nuclear Regulatory Commission was created to license nuclear facilities; protect the health, safety and environment; and to review antitrust considerations.

-- At the same time the Energy Research and Development Administration was created and charged with the responsibility for nuclear and nonnuclear R&D.

- The Administration asked Congress to enact nuclear licensing legislation to improve the efficiency and timeliness of licensing of nuclear facilities. The licensing and regulatory process have slowed due to challenges from various sectors of the public on safety and environmental grounds, and the reactions of the regulators and the industry to these challenges.

  -- Slippages in nuclear facility construction are of concern because they can result in electricity shortages; need to purchase high cost power from other utility systems; the construction of oil- or gas-fired facilities with shorter lead times to replace deferred nuclear capacity; or higher electricity generating costs due to the large capital expenditures and inflation.

  -- The licensing legislation would encourage standardized plant designs and decouple site and safety reviews. The bill was not enacted by the Congress.

- An important aspect of the siting and licensing of power plants is the need to define Federal and State roles clearly. Nuclear initiatives on the ballot in July in California and in five States in November were defeated by considerable margins. However, earlier in the year California passed three bills relating to siting, nuclear waste disposal, and spent fuel reprocessing.

  -- These bills raise serious legal issues about the roles of the States and the Federal Government in regulating nuclear power. Legal research is now underway with respect to this question.

- <u>Uranium Resource Exploration</u>. There has been a dramatic increase in the budget for uranium resource assessment. The United States has sufficient reserves and probable resources of uranium ore to fuel some 300,000 MWe of capacity for 30 years of operation. Less than half that capacity is expected to be in operation by 1985. Whether or not additional (non-breeder) nuclear plants can be fueled beyond this 300,000 MWe capacity depends on how successful the industry is in the coming years in finding new uranium resources. Continued exploration and development effort will be required to convert resources into reserves. Higher uranium prices will probably serve as an incentive to continue exploration for resources and the construction of mining and milling facilities to develop these new sources.

- Uranium Enrichment. The Nuclear Fuel Assurance Act proposed by President Ford and narrowly defeated in the Congress would authorize ERDA to enter into contracts with private firms to finance, build, own, and operate enrichment facilities. It would foster creation of a private, competitive enrichment industry. The bill was defeated primarily because of concern over allowing private companies to take over these operations and general anti-nuclear sentiment.

  -- Uranium for use as fuel in light water reactors must be enriched in the fissile isotope U-235 to a concentration of approximately 3% by weight. Naturally occurring uranium contains only 0.7 percent U-235 by weight, the rest being U-238. Currently, the United States is the major supplier or foreign enriched fuel. Contracts have been signed for some 300,000 MWe of capacity, of which one-third represents foreign commitments.

  -- The Administration proposed legislation in 1975 to establish prices for uranium and enrichment services reflecting their fair value.

- Reactor Safety. There remains some concern about the safety of nuclear power plants, despite the record of over 200 plant years of operation without a single death from a nuclear accident in a commercial facility, and the Rasmussen study, which assessed the probabilities of catastrophic accident as being extremely low. The major thrust towards reducing public concern and assuring safety has been massive budget increases for reactor safety research and development.

- <u>Spent Fuel Reprocessing and Plutonium Recycle</u>. Uranium fuel used in current nuclear reactors produces power, slightly enriched uranium, some radioactive waste products, and plutonium which can be chemically separated. The uranium and plutonium can be recycled and used to generate nuclear energy, thereby offsetting the need for additional uranium resources. Nuclear development in the United States has been based on the assumption that reprocessing and plutonium recycling would occur.

  -- Three facilities have been built by private industry. Two of these facilities have been abandoned because of technological problems. The third plant is partially completed, but awaits a final decision by NRC on commercial use of plutonium recycle.

  -- The major concern in reprocessing is the recovery of plutonium, the key material needed to make nuclear explosives. Once separated in a reprocessing plant, plutonium conceivably could be diverted or seized by terrorists. Several major industrial nations plan to operate reprocessing facilities.

  -- In October 1976, President Ford asked ERDA to define a reprocessing and recycle evaluation program, complementing NRC's environmental analysis, and he invited other nations to join in the evaluation. He also encouraged ERDA to change policies that assumed reprocessing would proceed, to encourage prompt expansion of spent fuel storage facilities, and investigate alternatives to reprocessing. The President called upon all nations to restrain the transfer of reprocessing technology.

- <u>Nuclear Proliferation</u>. The potential benefits of spent fuel reprocessing and plutonium recycling must be balanced against the danger of nuclear weapons proliferation. Expanded use of nuclear power internationally occurs for a variety of reasons, including peaceful and potential military use. The United States has participated in the Nonproliferation Treaty (NPT) and used its market influence to impose restraints. As its share of the nuclear material, equipment, and technology market declined, the U.S. leverage on restraints has been reduced. In October 1976, President Ford called for the following measures:

-- He directed the State Department to pursue establishment of a new international regime to provide for storage of civil plutonium and spent reactor fuel. He urged the International Atomic Energy Agency (IAEA) to implement this concept.

-- He urged an upgrading of the IAEA's safeguard functions and an investigation of the possibility of an international convention on physical security.

-- He indicated that the United States would, at a minimum, respond to violations of a safeguards agreement with an immediate cutoff of supply of nuclear fuel and cooperation.

-- He announced that U.S. nuclear export policy would favor nations adhering to the NPT; foregoing reprocessing or enrichment facilities; or participating in an international storage regime.

-- He directed ERDA to pursue programs to provide design information for international safeguards and other controls, support an international plutonium management regime, establish an international system of assured fuel supplies and demonstrate waste management technology.

- The issue of nuclear proliferation and diversion has been of increasing Congressional concern. A number of bills were introduced, including measures to prohibit domestic plutonium recycling; to control

80-533 O - 77 - 9

export of nuclear facilities and materials; and to expand safeguards to reduce possibility for theft, diversion or sabotage.

- Nuclear Waste Management. In addition to dramatic budget increases for waste management, the President asked ERDA to demonstrate all components of waste management technology by 1978 and to have a complete repository for such wastes in operation by 1985. He also urged international discussions on the possibility of establishing centrally located, multi-nationally controlled nuclear waste repositories.

  -- Nuclear wastes are highly radioactive and must be isolated from the environment for centuries. The principal problem is confining the radioactivity, not finding enough storage space (total volume of commercial waste through 2000 will be about 70 cubic feet). The technology has been demonstrated at a small scale, and most experts believe deep underground storage is the most practical method.

Remaining Problems/Possible Initiatives

- Votes on nuclear referenda this year by about 20 percent of the population and a recent public opinion survey show that most Americans favor nuclear power. Nevertheless, some individuals and groups remain opposed to its expansion.

- Almost all the legislative and administrative proposals cited above have yet to be enacted or implemented.

- Major decisions will be needed or need to be reaffirmed on the following subjects:

  -- Extent of nuclear power use in the United States;

  -- Federal/State roles in regulating nuclear power;

  -- The role of the United States as a supplier of world markets;

-- Enrichment capacity and pricing of services;

-- Reprocessing;

-- Proliferation;

-- Waste Repository;

-- Breeder Reactor.

Conclusions

- The use of nuclear power must continue to expand. Nuclear energy has a record of safety, and has been shown to be economic and have little environmental impact. Major decisions will have to be made or reaffirmed regarding the role of nuclear power and the extent and nature of reprocessing, enrichment, waste disposal, proliferation, and funding of the breeder reactor. In addition, the Federal agencies and the Congress should adopt the measures recommended by the President in October with respect to nuclear fuel cycle.

SECTION 7

ENERGY FINANCING

Background

- Over the past few decades, energy investments have accounted for about 25-30 percent of total fixed business investment in plant and equipment. Projections indicate that this trend is likely to continue in the next ten years, with expected energy investments of almost $600 billion (in 1975 dollars), amounting to about 30 percent of fixed business investment.

  -- The total expected energy investment, while enormous, is anticipated to be manageable in the aggregate. Nevertheless, specific sectors, such as electric utilities, may find it difficult to raise capital unless regulatory practices act to maintain their financial health.

- The Federal Government now has specific authority to implement a number of energy financing programs, with minimum Federal exposure of at least $5 billion. These include:

  -- Coal loan guarantees;

  -- Conservation obligation loan guarantees;

  -- Geothermal loan guarantees;

  -- Price-Anderson nuclear indemnification program to provide government insurance to vendors and utilities in excess of available private insurance, and thus remove a possible bar to private investments;

  -- Weatherization grants;

  -- Energy conservation and renewable resource demonstrations;

  -- Coastal zone impact aid;

  -- Coal impact loan program to States affected by Federal coal development;

  -- REA loan financing for electricity related items;

  -- Liquefied natural gas tanker subsidies and mortgage guarantees.

- A number of Federal mechanisms could be used to encourage investment in needed energy projects, including:

  -- income tax credits, penalties and refunds;

  -- excise taxes (see Section 2 for tax options);

  -- guaranteed or subsidized loans;

  -- Federal grants;

  -- Federal ownership;

  -- price supports;

  -- government market purchase guarantees.

- The issue to be resolved is whether the existing market mechanisms, in the absence of further government intervention, will channel necessary investments to meet our evolving national goals for conservation and energy resource development.

Proposals Offered

- During the past two years, the Administration has submitted several financing proposals to the Congress to facilitate and expedite the construction and operation of a wide variety of energy facilities. These proposals had one or more of the following objectives:

  -- to expedite commercial development of emerging energy resources and conservation technologies which are deemed economic and environmentally sound;

  -- to provide financing to overcome key bottlenecks to orderly development of energy facilities and resources;

  -- to provide economic assistance to localities impacted by Federal energy resource development activities;

  -- to provide financing assistance to those segments of the economy which must make significant capital expenditures to satisfy Federal regulations on fuel mix and environmental control of energy uses.

-- to improve knowledge with respect to commercialization of new technologies.

- Among the financing proposals were the following:

-- Synthetic Fuels Commercialization. A Federally sponsored Synthetic Fuels Commercialization Demonstration Program was first proposed to the Congress in January of 1975 and subsequently submitted as part of the ERDA budget. As negotiated with the Congress, but failing by one vote on a procedural question in the House, it would have provided $2 billion of Federal assistance (primarily loan guarantees) to commercial facilities for synthetic gas, coal liquefaction, and oil shale production.

-- Energy Independence Authority (EIA). On October 10, 1975, the President forwarded legislation to the Congress to establish an independent government financing authority with financial resources of $100 billion to provide loans, loan guarantees, and other financial assistance for the development of private sector energy projects which would not be financed without government help. The projects that could be assisted would be at the commercial stage (not R&D) and could include conservation and transportation facilities, as well as resource development proposals. The EIA would also expedite the regulatory process at the Federal level for projects deemed critical for energy development, by establishing the FEA as the coordinator of a streamlined permit process for all new facilities requiring Federal licensing. The bill did not pass.

-- Nuclear Fuel Assurance Act. In May 1975, the Administration submitted to Congress legislation to, in part, authorize ERDA to negotiate cooperative agreements providing temporary government financing, technological and contractual assurances to private ventures wishing to finance, build, own and operate uranium enrichment plants. The bill was not enacted.

-- Electric Utilities Construction Incentive Act. Proposed in June 1975, this legislation would accelerate the construction of electric power generating facilities by increasing the investment tax credit to 12 percent for all electric utility facilities except those that are oil- or gas-fired; extend until 1981 rapid amortization of pollution control equipment, and apply rapid amortization to converting or replacing oil-fired generating facilities; allow depreciation of construction expenses for other than oil- or gas-fired facilities prior to the completion of the project if such expenses are included in the rate base; and allow deferral of taxes on dividends, if they are reinvested in the utility. The bill was not enacted.

-- Federal Energy Impact Assistance Act. This legislation was proposed in February 1976 and authorizes up to $1 billion for loans, loan guarantees, and planning grants for States and local communities for energy-related public facilities and infrastructure prior to construction. The Congress addressed part of this question in the Coastal Zone Management Act Amendments (July 1976). This legislation provides $1.2 billion of loans and grants to coastal States over the next ten years for construction of public facilities to reduce the impacts of offshore fossil fuel development and production, but ignores inland resource development (i.e., coal and synthetic fuels).

-- Residential Insulation Tax Credit. This proposal was submitted to Congress by the Administration in January 1975. It allows homeowners a tax credit of 15 percent of the first $1,000 invested in materials and installation of residential insulation over a three year period (maximum of $150 tax saving). The bill has passed both Houses at various times, but was deleted twice in Conference Committees.

-- Weatherization Program. The Administration proposed and Congress adopted (in the ECPA) a three year, $200 million weatherization grant program for the insulation of homes of low-income, elderly, and handicapped persons, and Native Americans.

- The Congress adopted several energy financing proposals that were not proposed by the Administration. These include:

-- Coal Loan Guarantee Program. The EPCA and ECPA have authority for $750 million of loan guarantees to small coal producers for opening new coal mines or re-opening existing underground mines; most of this assistance must go for low sulfur coal.

-- Amendments to Mineral Leasing Act. The Congress overrode a Presidential veto and enacted amendments to the Mineral Leasing Act which increase the State share of royalties from Federal leases from 37 to 50 percent.

-- Conservation Obligation Guarantee Program. The ECPA authorizes up to $2 billion in obligation loan guarantees for conservation investments by industry, small business and non-profit institutions, provided conservation investments would pay off and applicants satisfy a test that credit is unavailable elsewhere.

-- State Conservation Grant Program. The EPCA and ECPA provide a total of $255 million in grants to States (over three years) to assist in the development and implementation of energy conservation programs.

-- Energy Conservation and Renewable Resources Demonstration Program. The EPCA provides $200 million to the Department of Housing and Urban Development (HUD) to undertake a national demonstration program to test the feasibility and effectiveness of various forms of financial assistance for encouraging conservation measures. FEA is authorized to establish a demonstration program to test various mechanisms (grants, low interest loans, interest subsidies, etc.) for encouraging energy conservation improvements or use of renewable resources, such as solar heating or cooling, in existing residential buildings.

- Congress also considered a number of other financing measures, including additional tax credits for household insulation, solar heating, heat pump replacements for resistance heat, and investment tax credits to businesses for insulation, solar energy, waste conversion, coal mining, and oil shale development.

- As indicated above, a number of proposals did not succeed in the 94th Congress. Among the reasons cited for such failures were:

-- Widespread opposition to Federal financing aid for large energy companies (particularly oil companies), despite the risky nature of commercializing technologies.

-- Reluctance on the part of market approach advocates to subsidize development of technologies that are or may be uneconomic.

-- The belief that more emphasis should be given to bringing about basic policy changes and regulatory reform, rather than relying on Federal financial assistance.

-- The public perception about the extent of support (in terms of dollars) seemed large during a time when the government is trying to reduce spending and deficits.

-- The assistance programs like synthetic fuels and EIA cover a broad range of projects and may be harder to accept or explain than would be more specific project assistance.

-- If Federal financial assistance results in projects being undertaken which would not have been built otherwise, the demand for capital would be increased, causing interest rates to rise and redirecting capital to less economic investments.

-- Some environmental groups were concerned about supporting projects which may have adverse environmental impacts.

-- Some of these bills, and particularly the synthetic fuels bill, were referred to several Congressional Committees, losing time and interest in the process.

Remaining Problems

- It seems apparent that some needed energy investments may not occur due to market uncertainties, potential risks, or national interests being different from individual company concerns. There are several questions that still must be addressed:

-- Will market forces adequately advance commercialization of the evolving energy technologies and conservation when the prices of conventional energy commodities are controlled?

-- Is there sufficient venture capital available at reasonable rates to permit timely commercialization of evolving technologies in the face of market and government regulatory uncertainties?

-- How can government regulatory and resource development rules be rationalized so that a clear and favorable climate for private action can be established?

-- Can the government bureaucracy manage and plan resource development programs without causing more problems than are solved by its assistance?

-- Is the tax system or other Federal financial measures the "appropriate" mechanism to achieve these energy policy goals?

Possible Initiatives

- Establishment of a Federal government financing authority. Under this approach, a government energy financing authority would be established to implement any existing and new financing programs authorized by the Congress (could include synthetic fuels, inland impact assistance, uranium enrichment, etc.) for energy resource development and conservation activities.

  -- Such a comprehensive mechanism would be advantageous for controlling Federal financial commitments in a coordinated fashion, assessing impacts and distortions upon the capital markets and other segments of the economy, coordinating with other ongoing Federal and State fiscal and monetary actions, and providing appropriate budgetary treatment for these obligations.

- Propose specific financing Authorities. A set of specific financing proposals (with or without a proposal for a government financing authority) could be offered. The possible areas of Federal financial assistance include:

  -- Conservation;

  -- Synthetic fuels;

  -- Coal;

-- Solid waste utilization;

-- Supplemental sources of natural gas;

-- Transportation infrastructure;

-- Inland impact assistance;

-- Nuclear fuel cycle.

- Government Purchase Program. The government can play a major role in fostering the commercialization of evolving energy resources, environmental control devices, and conservation technologies by establishing a market for specific products through initial, high volume government purchases. A government purchase program could be implemented with certain performance and cost criteria, so that subsequent production would be expected to be commercially competitive. The government could consume these products by itself and/or lease or sell them to the private sector. The capital outlays for such a program could be at least several billion dollars and could involve significant administrative costs.

- Pricing Policy. Decisions over pricing and regulatory conditions (particularly with respect to supplemental sources of natural gas) could have a major impact on the need for Federal financial assistance. For example, many firms indicate that incremental pricing of synthetic gas will result in little or no market for the fuel and that "take or pay" contracts may be needed. Others contend that rolled-in pricing generates artificial demand for the product and that "take or pay" contracts force consumers to take all the risk with new projects.

- Tax Policy. The government can also affect investments by modification of Federal tax policy to provide more favorable depreciation schedules, investment tax credits, etc. This alternative is discussed in more detail in Section 2.

Conclusions

- The energy industry will have to make substantial capital investments in the next 10-15 years. Some sectors should have sufficient capital as long as unfavorable regulatory actions are not taken. Sectors, such as electric utilities and synthetic fuels, may need some form of Federal financial assistance. As a central element of our policy, maximum reliance should be placed on private sector financing of energy projects. Many of the barriers to private financing are a result of government regulation. However, Federal financial assistance may be needed for projects which will contribute significantly to energy independence, but would not be undertaken in a timely fashion without such assistance.

-- The new Administration and the Congress should review the entire financing issue, but should assure that those first generation plants that are needed, can be built. The technology, efficiency, economics, and environmental implications of these new facilities should be demonstrated at a commercial level.

SECTION 8

R&D PRIORITIES

Background

- The fuel sources to meet our Nation's energy requirements have changed considerably over the last hundred years. Due to advances in technology, the development of new fuel sources, and economics, coal has replaced wood, and oil and natural gas subsequently replaced coal as our predominant energy sources.

- The impacts of environmental concerns, the oil embargo, higher fuel prices and heightened energy awareness have forced an abrupt re-evaluation of American energy policies.

    -- Environmental groups have raised serious questions about the ability of the environment to withstand continued growth.

    -- The embargo has forced policy-makers to examine the issue of dependence on oil.

    -- Higher energy prices have served as an incentive to conserve and have stimulated the search for technological solutions.

    -- The realization that there are geological limitations to presently used resource supplies - and that we may be pressing these limits, given the long time frames for new technology development and commercialization - has inspired a greater urgency in search for alternatives.

- In the long-run, the Nation must face the question of how the economy will make a transition from reliance on finite oil and gas resources to other, more abundant, resources. In fact, of course, the whole world must begin now to make such a transition as supplies of oil and gas are depleted. The timing for completion of this transition is uncertain, and depends on domestic supply availability, demand, import goals, environmental factors, and technology development. However, the end of this century is likely to be a critical time period.

Proposals Offered

- Reorganization. Prior to the 1973 oil embargo, the responsibility for formulating and executing Federal energy R&D policy was fragmented among a wide variety of Federal agencies. However, the Energy Reorganization Act of 1974 led to the formation of the Energy Research and Development Administration (ERDA). The major objective of this legislation was the creation of a comprehensive, independent energy research and development agency which would play the leading Federal role in the balanced and speedy development of various energy production and efficiency technologies.

    -- Another purpose of the Act was to separate the nuclear research and development functions of the Atomic Energy Commission from the regulatory functions of that agency. (It also established the Nuclear Regulatory Commission.)

- Research and Development Acts. Other major legislative mandates were simultaneously or subsequently given to ERDA in the following additional acts:

    -- The Federal Nonnuclear Research and Development Act of 1974, which provides the major guidance to the ERDA Administrator as to the principles, authorities and duties to be carried out with respect to R&D in energy technologies other than nuclear power.

    -- The Solar Heating and Cooling Demonstration Act of 1974 and the Geothermal Energy Research, Development and Demonstration Act of 1974, which authorize expanded solar and geothermal R&D programs.

    -- The Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976, which authorizes additional funds for R&D in electric cars and requires Federal purchases.

- Expanded Budgets. Federal funding for energy R&D had already begun to increase prior to the embargo (from $382.4 million in FY-70, to $642.3 million in FY-73). In FY-73, 74 percent of the Federal energy R&D budget was devoted to nuclear fission and fusion R&D; 15 percent to coal resource development; 6 percent was expended on environmental control technologies; and the remainder was devoted to a variety of other projects including solar, petroleum and other technologies.

  -- Following the embargo, an even more dramatic increase in Federal R&D expenditures occurred. Budget outlays for total energy R&D rose to $2.9 billion in FY-77 and the emphasis has been changed. Nuclear fission and fusion R&D now amount to 48 percent of the total budget; fossil R&D at 15 percent; environmental research and basic energy sciences at 14 percent; conservation and solar energy at 8 percent; others at 15 percent.

- Research Strategies. As required under its enabling legislation, ERDA prepared annual R&D Plans in 1975 and 1976. The plans have set forth proposed national R&D goals, strategies, and technology priorities. In its most recent plan, ERDA assigned highest national priority to energy conservation technologies, along with direct use of coal, enhanced oil and gas recovery, and nuclear convertor reactor supply technologies.

  -- Greater emphasis was given to commercialization of near-term technologies and to closely coordinating technology development with socioeconomic and environmental factors.

  -- Primary responsibility for developing and commercializing conservation technologies was considered to rest with the private sector, although ERDA funding was also increased in this area.

-- The report argued that national priorities for energy R&D are not the same as priorities for the allocation of Federal funds for energy R&D. In many cases Federal R&D funding may not be justified either because the R&D function can better be performed by the private sector; the objective can better be achieved by some means other than R&D; or the funding required is not sufficiently high in priority compared to other demands for Federal funds.

Remaining Problems

- Despite considerable change in emphasis, there is still criticism of the Federal energy R&D effort. Some claim that ERDA budget levels for energy efficiency (or conservation), near-term, renewable, or non-electric technologies should be higher; that its basic research programs regarding fossil, solar, geothermal, end-use conservation, heat transfer, thermodynamics, and combustion processes should be strengthened; and that alternative R&D budget strategies at different levels of funding should be investigated further.

- In a similar vein, questions are raised as to the need, or desirability of large funding levels for such technologies as the nuclear breeder or fusion reactors.

- There are basic questions remaining with respect to the degree of emphasis on electricity and particularly on nuclear power (convertor reactors as well as breeder) and the appropriate degree of emphasis on energy efficiency and demand reduction as opposed to supply. These questions are at the heart of the Nation's long-term fuels policy (as discussed in Section 2) and at the root of many environmental concerns. There is also dispute over funding full-scale demonstrations of technologies that are not economic at this time.

- With a rapidly growing R&D budget, many difficult choices did not have to be made. As some of the new programs mature from the research phase to development and demonstration, they will require a further increase in the R&D budget relative to the Federal budget or a greater scrutiny of on-going programs. Trade-offs will have to be made on the allocation of funds and careful analysis will be required of on-going R&D efforts. Strategies and priorities should be re-examined continually.

- There are still organizational and activity overlaps in such areas as conservation, environmental and safety R&D, etc.

- It is not yet clear what will happen if the combination of energy policies and R&D fail to bring our longer-term energy situation into a proper balance, but the ERDA long-term analyses suggest that the impacts on U.S. economic viability could be significant.

Possible Initiatives

- Further Definition of Priorities. The most recent ERDA plan pointed out that, although all national energy technology goals (i.e., generic solutions such as expand domestic supply, improve energy efficiency, etc.) must be pursued together, every conceivable technology approach does not have to be pursued with equal vigor or at all. ERDA and the Congress must address the use of limited resources and where priorities ought to lie. They should consider the following questions:

  -- To what degree should the Federal energy R&D program emphasize projects with near-term, mid-term or long-term payoffs?

  -- Should research be spread across many areas to provide greater flexibility and hedges against uncertainties, or concentrated only in a few potentially high payoff areas? Concentration involves evaluating the risks that development strategies may fail, e.g., public rejection of nuclear power; recognition of a catastrophic CO_2 problem; coal production retarded by environmental problems; or technology to guarantee large-scale access to breeders, fusion or solar power ultimately not being achievable. The debate thus becomes whether to expand or limit options.

-- What should be the government's involvement in the following major technologies:

- breeder reactor
- solar electric
- uranium enrichment
- expanded use of coal
- synthetic fuels
- conservation

- Improved Cost-benefit Analysis. There needs to be more analysis of the relationship between Federal expenditure and achievements; the value of increased flexibility; the socio-environmental costs of new technologies; and the national costs of failure to achieve R&D objectives.

Conclusions

- Since energy research and development funding cannot continue to expand at its current rate, it will be necessary to make difficult choices about priorities. The Nation should look most favorably at those technologies that have the greatest likelihood of being able to contribute significantly by the end of the century and of being economic.

SECTION 9

INTERNATIONAL CONSIDERATIONS

ENERGY INDEPENDENCE AND ECONOMIC INTERDEPENDENCE

Background

- U.S. international energy policy pursued in the last three years reflects the fundamental change that has occurred in the international oil system. Key decisions affecting the production and pricing of international oil have shifted from the control and commercial motivations of international oil companies (IOC's) to the less predictable political and economic objectives of the member governments of OPEC.

- The economic and political impacts of the 1973 oil embargo and subsequent four-fold increase in world oil prices increased U.S. concern about the reliability and price of oil imports, focused public attention on energy policy, and gave impetus to first attempts at long-range comprehensive energy planning. Early statements by the Administration announced the goal of energy independence, a concept that was popularly misinterpreted to mean zero imports. Instead, its goal was to reduce imports to levels at which both the likelihood and effects of an embargo would be very small (probably 4-6 MMB/D).

- Initial emphasis was placed on the security of our energy supply. Reliable energy supplies are fundamental to the economic viability of the United States and other consuming countries and to the flexibility in foreign policy necessary to preserve U.S. strategic national security and interests.

  -- In addition to reliability of supply, energy independence was viewed as a means of diminishing the effects of unanticipated substantial increases in world oil prices. Adjustment to such increases imposes severe economic costs on the United States and other consuming nations.

- It is difficult to calculate the costs and benefits of U.S. energy independence. From a domestic perspective, in order to determine benefits, assumptions must be made regarding the likelihood, magnitude, duration, and frequency of embargoes; the ability to influence pricing decisions; the probability of success in reducing imports; the value of added flexibility in foreign policy; the ability to lower costs of new technologies by accelerating implementation; etc. Similarly, the costs of independence must reflect the costs of reducing our imports below that which would result without further Federal intervention, e.g., the economic costs of energy development, conservation programs, environmental and other major economic and social goals.

  -- Alternatives to reducing imports, such as a larger stockpile, diversification of sources or improved bilateral relations should be considered as approaches to reducing vulnerability.

  -- However, analysis done to date indicates that the reduction of imports through cost-effective supply and conservation actions, and the adoption of standby measures, is in the interest of this Nation.

- In an international sense, the goal of energy independence must be pursued within the context of the interdependence among the economies, and related strategic interests of the oil consuming countries, as well as the economic interdependence between consuming and producing nations.

  -- Energy -- especially oil -- is a critical factor in the economic future of most countries.

  -- Differences among oil producers stem largely from variations in the size of oil reserves, populations, and the relative importance of their oil revenues to their economic development programs.

  -- Oil exporters regard the revenues from their oil resources as the principal, if not only, means of transforming their economic base from primary resource suppliers to suppliers of processed and/or finished goods. Such a process requires vast amounts of capital, technology and possibly a longer time frame than the life expectancy of oil reserves in some countries at current production rates. Those nations perceiving a problem may prefer to conserve their oil resources by limiting production and maximizing the revenues derived via high oil prices.

- Reliable supplies of oil at reasonable prices are also necessary for economic growth in importing countries, including those developing countries without significant oil production. The development of alternative energy sources requires large investments, technology development, and long lead times.

- World oil supply and demand projections after the embargo differed in judgments about future consumption, costs and rate of development of alternative energy sources, and the impacts of higher prices. Oil prices have been sustained to date despite the reduction in the rate of growth in energy demand subsequent to 1973. Whether these conditions prevail in the future must await further evidence on a number of factors, including:

    -- Availability, costs and rate of development of oil and gas reserves, and alternatives to oil and gas;

    -- Resolution of institutional factors affecting energy, e.g., the environmental uncertainty over coal and nuclear energy.

- Oil producers could take advantage of continued dependence on imported oil, but run the risk of undermining the viability of the international economic and political system which is crucial to their development plans.

    -- Alternatively, if oil importing nations ignore the dominant role of oil producers and decreasing oil availability, they risk adopting policies resulting in greater oil demand than producers can or elect to produce at reasonable prices.

<u>Approaches Tried</u>

- The Administration proposed a program to reduce substantially U.S. dependence on imported oil by 1985 (thereby reducing its demand for OPEC oil and resulting vulnerability to supply disruptions and abrupt price increases).

    -- The nation's energy dependence can be reduced if a strong domestic energy program is adopted, unless geological projections are greatly inaccurate or institutional factors delay development. Analysis shows that the United States would have imported about 12-13 MMB/D in 1985, if no action had been taken after the 1973 embargo. Legislation passed and signed prior to November 1976 could result in an import level of 7-7.5 MMB/D by 1985, if programs are implemented fully and no negative energy actions are taken.

-- Such measures as natural gas deregulation, insulation tax credit, and accelerated OCS leasing schedules could reduce the 1985 import level to about 4-5 MMB/D. That level, coupled with the impact of stored petroleum reserves and emergency standby measures to offset any future embargo, represents an acceptable level of energy dependence for the U.S.

- Two factors dictate caution in assessing the effectiveness of the U.S. reduced dependency goal:

  -- The ability to sustain acceptable import levels in the post-1985 period may be difficult, unless growth of U.S. consumption is reduced and we increase reliance on coal, nuclear power, and renewable resources.

  -- Even if the U.S. reduces import vulnerability, Japan and most of Western Europe probably will remain heavily dependent on OPEC oil, because their oil resource base cannot meet demand. The strong political and economic ties between the United States and the other industrialized nations will require continued U.S. concern and involvement with the international factors affecting the supply, reliability, and prices of their oil imports.

- <u>Consumer Cooperation</u>. The first step in the U.S. international energy strategy was the establishment of the International Energy Agency (IEA). Its immediate objective was to provide a means for minimizing the risks, costs, and destablizing effects of unexpected supply interruptions. This goal has been accomplished by the International Energy Program, an emergency oil sharing plan.

  -- The IEA evaluations of member nation conservation programs resulted in greater cooperation and publication of <u>Energy Conservation in the International Energy Agency</u>.

  -- Moreover, the IEA has served as a conduit for the exchange of ideas on energy policy and research, at a time when most IEA nations had only formative energy programs.

- The current focus of efforts within the IEA centers around the Long Term Cooperative Program. This program includes:

  -- Extending the basic motivations of the emergency sharing program to the longer term;

  -- Effecting an efficient transition to an energy base that is less dependent on oil, recognizing the constraints to achieving greater reliance on alternate energy sources;

  -- Assessing the implications of the continued reliance on imported sources of energy with uncertain supply and price conditions imposed by producer countries;

  -- Possibly adoption of reduced dependency objectives by IEA nations. This program could reinforce consuming nation commitments to reduce oil imports, and thus strengthen the credibility of national and joint energy goals.

- Emergency Supply Actions. Stockpiling is an effective alternate supply source during interruptions, depending on the level of U.S. imports and the source, likelihood, magnitude and duration of any interruption. The U.S. is committed to a strategic oil storage program. The FEA reserve plan has recommended storage of 500 million barrels for 1982 with the provision that more storage should be considered if U.S. imports were projected to be significantly above 7 MMB/D by 1985.

- Price Actions. The U.S. has argued actively against OPEC Price increases, stating that precipitious price increases generate public fears of inflation and thus can have an adverse effect on Western economies; such effects can be shown to impact negatively the economies of the developing world and OPEC nations; and that there is no economic justification for further price increases.

Future Considerations

- Several key issues concerning our international and related domestic energy strategy and initiatives warrant further consideration:

  -- Measures to further enhance the effectiveness of the IEA in reducing the demand for OPEC oil to a level which minimizes the upward pressure on world oil prices;

  -- The scope and purpose of some form of continuing international energy dialogue between producers and consumers and the manner in which it should proceed;

  -- A thorough review of the relationship between the level of oil prices and the rate at which an energy transition can be made at a pace consistent with other economic goals;

  -- The rate at which alternate fuel development and energy conservation can proceed in order to maximize their impacts on the world energy supply and demand balance;

  -- Measures to encourage adoption of policies to assure the availability of adequate supplies of oil to meet world energy needs through the energy transition.

- The desirability, achievability, and sustainability of energy independence is a dynamic issue and the subject of some disagreement. The process of evaluation and implementation has begun, but the new administration should re-evaluate these issues and consider particularly our non-energy social and economic objectives and the appropriate role of government.

Possible Initiatives

- Consideration should be given both to short-term initiatives which address the immediate problems of the world energy balance and the longer-term transition to a non-fossil fuel base. Actions in the following areas may be feasible:

  -- Congressional Involvement in Reduced Dependency Objectives. The IEA is analyzing the feasibilty of establishing import dependence targets at specific levels for the IEA as a whole and individual nations within the IEA. Consideration should be given as to the extent, timing, and forum for involving the Congress in decisions as to the specific targets and degree of commitment towards achieving those levels.

-- <u>Tariffs or import fees</u>, which are discussed in Section 2 ("Energy Taxes"), could discourage unwanted imports or protect domestic industry, but affect regions inequitably.

-- A <u>quota</u> provision was contained in the House-passed H.R. 6860, but did not survive Senate action. A quota, used in conjunction with allocations to prevent spot shortages and price controls to prevent windfall profits to domestic producers, can provide an upper limit on U.S. import dependency. A quota would signal the intention of the U.S. to move away from dependency on imported oil. However, design and administration of a quota is difficult, it expands U.S. Government intervention and regulation of the marketplace, and it could lead to negative economic impacts, similar to a long-term restriction of supply.

-- <u>New oil production</u> outside of OPEC could increase the amount of oil available to the international market. Since U.S. companies own a large share of necessary oil and gas exploration equipment and technology, the U.S. could explore policies to encourage incremental production.

-- To encourage energy exploration and development in developing countries, the U.S. has proposed establishment of an <u>International Energy Institute</u>. The U.S. also could consider proposals to encourage the flow of capital to enhance energy resource development and to continue to encourage recognition by the existing official international lending institutions of the urgency of the energy investment required, including intrastructure, by such countries. Such assistance might provide the means for developing countries to expand supplies of energy, and might involve adoption of production and pricing policies which reflect the critical contribution of such additional supplies to global energy and economic requirements.

- <u>Reassessment of Energy Goals</u>. Energy goals are not set independently of economic and environmental goals and should be periodically reassessed. Consideration should be given to a national debate on this issue, through public hearings or energy forums.

Conclusions

- Energy will remain a critical factor in world economic and political affairs. The issues of supply security; oil prices; consumer nation cooperation; producer-consumer relations; long-run transition from oil and gas to coal, nuclear, and renewable resources; and the value of and approach to energy independence should be reassessed continually. The following are suggested courses of action:

  -- Continue producer-consumer dialogue;

  -- Involve Congress in setting reduced dependency objectives, perhaps through a Joint Resolution;

  -- Encourage incremental oil and gas production throughout the world and pursue creation of an International Energy Institute;

  -- Initiate a national and regional energy debate.

MULTINATIONAL OIL COMPANIES

Background

- The relationship of the major international oil companies to the U.S. Government and to U.S. energy policy objectives is a matter of obvious public concern. Perceptions about the companies' role in the embargo and price actions of the last three years have generated much discussion, and the structure of these companies has become a domestic political issue in the United States. The public opinion of the major oil companies has affected many energy policy decisions, including the crude oil pricing debate. There are several key issues involving Federal interest that have been raised concerning these companies:

  -- Divestiture

  -- Relationship of oil companies to producing and consuming governments and oversight of oil company negotiations with foreign governments.

  -- Financial reporting requirements

- The international oil market structure is exceedingly complex. The position of the majors vis-a-vis the producer nations has undergone substantial evolution, which is still in process. There are presently four major types of companies within the world market:

  -- The majors. Exxon, Mobil, Texaco, Gulf, Standard Oil of California, British Petroleum and Royal Dutch Shell (Compagnie Francaise des Petroles (CFP) is sometimes included) have historically held large concessions in producing areas. They are fully integrated downstream. Their 1975 liftings were 25 MMB/D worldwide.

  -- The independents. These companies emerged in the 1950's. They are partially or fully integrated and are characteristically seeking foreign crude for domestic refineries.

  -- The consumer national oil companies. These companies developed in France and Italy as governments sought to serve national interest by controlling crude oil supplies to protected domestic markets. Other European national oil companies have emerged as the North Sea has been developed.

-- The producer national oil companies. All OPEC nations, except Gabon, have national oil companies (NOC's) which have entered the production phase through increased participation. They determine production levels, terms of access, and price.

- The control of the world petroleum market has shifted perceptibly in the last three years from the majors to the producer nation governments, through a series of participation agreements, Aramco being the latest. In the Aramco negotiations, the volume of crude which will be allotted to the Aramco members, the amount of their service fee, the compensation paid for assets and other provisions have been subjects for discussion for over a year.

- OPEC governments have also sought to move into downstream markets. They have bought tankers at depressed prices to move into the transportation phase of the industry. However, they currently own only about 3 million deadweight tons (DWT), or enough tonnage to move about 4 percent of government-owned crude oil. OPEC could have a fleet of 20-30 million DWT by 1980 (enough to move 5-8 MMB/D). A tanker capability of this size is thought to be of enough significance to be taken into account in future U.S. contingency planning.

  -- Plans for expanded refinery capacity and petrochemical ventures in OPEC nations have also been announced, but lack of indigenous technical personnel constrains this downstream movement, so that it should not impact the industry markedly in the near- or mid-term.

- Although the petroleum industry is composed of thousands of firms, the economic power wielded by the major companies has been a source of controversy since the early part of this century. The "majors" conduct operations that are truly global in scope and often include diverse activities that have little to do with petroleum or are only tangentially related. These firms (and most of their slightly smaller competitors) share a common characteristic: their corporate structures are vertically integrated; that is, each company operates in more than one of the functional activities necessary to produce, transport, refine and market petroleum products.

-- The actual form of corporate organization used to operate in the various functional areas varies widely: some companies use different intracorporate divisions; others use wholly- or partially-owned subsidiaries; others use joint ventures for particular projects. While the arrangement of a company's internal organizational components may have significant tax or corporate law implications, it has little bearing on the ability of a company to function as a vertically-integrated entity.

-- A second characteristic of many of these firms is that their activities have branched into areas removed from oil and gas. Leaving aside general investments in non-energy sectors of the economy, many of the 18 largest firms control extensive coal and uranium reserves and play a significant role in the development of alternative energy sources. This characteristic, referred to as horizontal integration, is also becoming controversial since it is feared that the inherent possibility for conflicts of interest (favoring or retarding the development of alternate energy resources in relation to oil or gas) may be exercised.

Proposals Offered

- Divestiture legislation. Numerous bills were introduced to require one form or another of vertical or horizontal divestiture. The principal bill on vertical divestiture is S. 2387, which was favorably reported out of the Senate Judiciary Committee in June, but never scheduled for floor action before the 94th Congress ended. S. 2387 requires that petroleum companies meeting certain size criteria (which, in practice, means the largest 18 companies) divest themselves of certain prohibited assets within five years from enactment:

-- Companies engaged in production could not also engage in transportation by pipeline or refining/marketing;

-- Companies in transportation would restrict activities to that field;

-- Marketing or refining operations acquired in the past could continue to function together, but a refiner could not acquire additional marketing assets, nor could a marketing company integrate further into refining;

-- S. 2387 permits companies to design their own divestiture plans, setting forth the method and sequence of divestiture in conformity to Federal Trade Commission guidelines. Final plans would be submitted to the FTC for approval and divestiture would be completed within five years.

- Another vertical divestiture bill was offered during Committee consideration of S. 2387, and may be considered next year. It provides that:

-- Integrated companies would have to treat discrete functional activities separately for accounting purposes (e.g., cost and revenue allocation, pricing, and capital spending);

-- While legal divestiture and accompanying problems would be avoided, companies would be required to conduct each operation as though it were conducted independently, and could not subsidize some operations with the profits made in others or grant discriminatory preferences to affiliated activities;

-- Extensive proprietary data would be gathered by the FTC and SEC and made public.

- The debate on vertical divestiture is well publicized. The companies that would be affected made a concerted effort in the media to stop the legislation, calling it "dismemberment" and pointing to economies inherent in the current system and the fact that such legislation would go far beyond current anti-trust law. Proponents of divestiture presented two major contentions: that divestiture, by increasing competition, would lower prices; and that the oil companies helped support OPEC by prorationing production, a condition which would end if domestic refiners had an independent incentive to seek the lowest priced sources of supply.

- The Energy Resources Council (ERC) interagency subcommittee on divestiture produced a report which showed no evidence that vertical divestiture would achieve its proponents' goals. The ERC raised the following points:

  -- The real question to be considered was whether mass reorganization of the corporate structure of the petroleum industry was likely to contribute to the attainment of national energy policy objectives.

  -- The resulting confusion of the transitional period, whether it might last only five years as proponents claimed or several decades as the industry claimed, would delay the investments necessary to develop domestic resources.

  -- The standard indices of market concentration and competitiveness showed no evidence of excessive concentration.

  -- The Administration indicated that any individual problems of industry corporate structure were better handled by existing anti-trust laws, rather than made the subject of an experiment during a crucial period in our energy future. Further, divestiture could have adverse international implications, and effects on capital markets.

- The principal horizontal divestiture bill was S. 489. While the Congress concentrated last year on vertical divestiture, it is likely that horizontal divestiture will receive greater consideration in the next session. The principal features of S. 489 are indicated below:

  -- Three years after enactment, any petroleum or natural gas firm, irrespective of size, would have to dispose of assets in nuclear, coal, solar or geothermal energy;

-- There is no provision for a direct government role in the divestiture process other than gathering certain types of data.

- With respect to horizontal divestiture, the lack of Congressional attention has been accompanied by a lack of formal position-taking on the question. Proponents of such legislation contend that companies with a direct financial interest in protecting existing investments in oil and gas resources have an incentive to prevent competing energy resources from being developed rapidly. Opponents claim that the U.S. energy situation demands so many new sources of supply that the market for oil would not be largely diminished. Further, opponents also assert that given the magnitude of the financial resources necessary to develop alternate energy supplies, it seems unlikely that they will be developed in the near future if the oil companies are excluded. It is also possible that if all oil companies were forced to dispose of their alternate energy assets simultaneously, the lack of a sufficient number of eligible buyers could further retard the growth of coal, nuclear, and solar energy alternatives.

- Monitoring Oil Company Negotiations. In November 1976, the FEA published a request for comment on increased monitoring of oil company negotiations. The negotiations between producer countries and the IOC's governing lifting and pricing of oil are traditionally a matter of private, commercial concern. The FEA interest in increasing monitoring of these negotiations has come about because of their impact upon supply security; the price level of imported oil; and possible long-term lifting or downstream obligations. Any monitoring should be done cautiously to avoid putting the U.S. Government in the negotiating process and to avoid release of sensitive information.

- Government Oil and Gas Corporation. At various times, the Congress has considered possible legislation establishing a Federal Oil and Gas Corporation. Depending upon the specific proposal, these corporations could develop resources on Federal lands; buy and sell oil and gas; and negotiate directly with foreign governments for purchase. Arguments raised in favor of these proposals include the desirability of better "protecting the public interest" and providing greater credibility to our energy policy. A contrasting viewpoint is that the Federal Government never manages such programs very well (the Post Office and railroads are usually cited), that it is likely to disrupt a smoothly running system, and that it would not accomplish the proponents' objectives.

- Boycott Legislation. There was an intensive effort in the 94th Congress to enact legislation with stringent penalties for participating in a boycott against Israel. Obviously, the oil companies, which have a heavy trade with Arab nations, would be affected by such legislation. The extent of the impact was hotly debated, as well as the desirability of the proposal; and it is likely to surface again in the 95th Congress.

  -- A legislative amendment to the 1976 tax reform bill removes tax advantages from countries complying with the Arab boycott of Israel by disallowing credit for foreign taxes paid to countries boycotting Israel. Because of the complexity of the legislation, the dollar impact on the oil companies is difficult to assess, but due to the volume of business between the IOC's and Arab nations, it could have a major impact. Other observers feel that the compliance provisions of the Act are not defined well enough to be enforceable.

Possible Initiatives

- Oversight of the oil companies. New administrative or legislative options might be considered, for expanded oversight of IOC's in order to provide the data and experience necessary for designing an optimal policy toward the multinationals. This oversight could include authority for reviewing major contract negotiations prior to signing. As indicated above, protection of proprietary information is a major problem area for pre-agreement filing, as well as questions of the desirable role of the government in such negotiations.

- Government purchasing authority. The logistical function of the majors could be supplanted by a

80-533 O - 77 - 11

government entity empowered to negotiate directly with OPEC governments for all U.S. supplies of petroleum products. Such a structure could be used in conjunction with absolute quotas, country quotas, or differential import fees. However, direct government purchases could involve substantial administrative problems (such as matching crude types with refinery needs) and considerable interference with the oil market system. Such authority was vested in the President in the EPCA.

- Divestiture. Continued analysis of the divestiture issue is necessary. The basic argument for or against divestiture should be based on whether there is any evidence suggesting that positive benefits would result and that the possible adverse impacts are outweighed by such benefits.

- Financial Reporting. Under the EPCA, the FEA is required to consult with the SEC to determine the extent to which major changes in accounting practices are contemplated by the SEC.

Conclusions

- The multinational oil companies will remain an important force in domestic and international energy affairs. Rather than act hastily to break up these firms, the Congress should consider carefully the impacts of both vertical and horizontal divestiture. Neither form of divestiture should be supported unless it would increase domestic production, improve the reliability of supply, and reduce prices. With the Nation facing a crucial energy period, this is not the time to disrupt the existing system so dramatically. However, there may be a need for some change in the government/industry relationship and possible alternatives should be explored.

STANDBY MEASURES

Background

- In response to the effects of the 1973 oil embargo, the U. S. government (as well as many other petroleum consuming nations) realized the overwhelming necessity of protecting itself against the potentially serious impacts of a future embargo. The last embargo caused considerable loss in Gross National Product and added about 500,000 people to the unemployment rolls.

- An embargo management strategy has been prepared which outlines the steps the Federal Government will take to mitigate the effects of an embargo. In the event of another supply interruption, the government would act to increase available energy sources, constrain demand and distribute available supplies as equitably as possible.

- Considerable progress was made in providing the basic legislative authorities for a standby program when the EPCA was enacted.

Approaches Taken

- Strategic Petroleum Reserve (SPR). In January 1975, the President asked Congress for authority to build a strategic petroleum reserve of up to a billion barrels. In the Energy Policy and Conservation Act (EPCA) the SPR was authorized, with a requirement that at least 150 million barrels be in storage by the end of 1978. The strategic petroleum reserve will consist mainly of crude oil storage in Gulf Coast salt domes designed to provide drawdown capability of approximately 500 million barrels by 1982 (Congress authorized up to one billion barrels).

  -- Planning for a strategic reserve is necessarily insuring against an unknown event. The sensitivity of the SPR plan to variations in type of embargo, level of existing imports upon commencement of an embargo, and degree of oil sharing required by the IEA must be considered.

-- There continues to be an issue regarding the ultimate size of the SPR. While present plans are to build a 500 million barrel reserve, the issue will be reviewed in the future. Other issues that have come up include the desirability of regional storage, industrial storage, and method of crude oil acquisition.

- <u>International Energy Program (IEP)</u>. By agreement among 19 consumer nations in the International Energy Agency, a program has been established for managing the international allocation of oil during supply interruptions. Under the provisions of the IEP, a member nation experiencing an overall shortfall of 7 to 12 percent of demand can call upon other IEA members to redirect supplies to meet the shortage. Whether a given nation would have a right to additional supply (or an obligation), depends on an allocation formula which factors in magnitude of shortfall, targeted countries, assumed conservation actions, etc.

  -- The IEP allocation system was tested in November 1976. Three scenarios were used in interactive embargo simulations with the IEA secretariat, the Industry Supply Advisory Group (ISAG), and over 30 participating oil companies. The test runs showed that the system works in procedural and mechanical terms.

- <u>Allocation</u>. The program for allocating petroleum products was used during the 1973-74 embargo to distribute available product supplies equitably. This program is currently being phased out; however, standby allocation authority exists until September 30, 1981 (to reimpose allocation controls on those products already decontrolled). Both allocation and price controls probably would be reimposed immediately on all products in the event of another supply interruption.

- <u>Rationing</u>. If the United States is unable to constrain demand and utilize the SPR to reduce sufficiently the impacts of an embargo, it may have to resort to rationing of available supplies. Rationing has been a particularly controversial subject since it is an extremely expensive program (over $2 billion to implement) and administratively burdensome. A rationing plan for both gasoline and diesel fuel, nevertheless, has been designed and will be submitted to Congress.

- Emergency Demand Restraint. After price and allocation controls would be reimposed in an emergency situation, a public awareness and voluntary conservation campaign would be undertaken to stress the severity of the shortage. A wide range of emergency demand restraint measures has been identified, and these could reduce demand by the equivalent of over 1 MMB/D if implemented immediately with full compliance. These measures range in scope from reducing thermostats to shortening the national work week. Should it prove necessary, the President would select for implementation one or more of the mandatory measures (such as commuter parking management and car pooling incentives; heating, cooling and hot water restrictions; weekend gasoline and diesel fuel sales restrictions; restrictions on illuminated advertising; etc.) which would have already been approved by Congress in accordance with the requirements of the EPCA.

- Refinery Output Adjustments. By adjusting the types of products produced from domestic refinery runs, it is possible to increase or decrease the availability of particular products. The ability to do this, however, is constrained by the structure of many refineries. Most are geared to produce given yields with only a narrow range for variation to accommodate fluctuations in seasonal demand.

- Coal Conversion. There is limited potential to further shift oil usage to coal during an embargo situation. It is possible to require emergency drawdown of existing industrial inventories, but such action could result in spot domestic coal shortages. If such a policy were implemented, about 95,000 barrels of oil per day could be redirected in the system temporarily.

Remaining Problems

- The United States has begun to frame, but not yet completed implementation of its standby strategy, mainly because of the absence of real alternatives until the early Strategic Petroleum Reserve becomes operational by 1978. Even then, our reserves would only accommodate a 50 percent loss of imports for about 50-60 days. Despite being able to distribute the shortage better, several important industries would be severely hurt and the disruptions caused during the last embargo (e.g., lines at gas stations, increased unemployment, reductions in disposable income) could recur.

- There are also major problems that would arise in implementing the programs. Under the EPCA, Congress must approve the mandatory conservation plans and the rationing plan before implementation. It is difficult to implement a program before an estimate is made of the total duration of the embargo. As presently conceived, rationing would not even be considered until it was clear that the embargo would last long enough to justify the expense and burden of so complex a program. But there is an element of circularity involved. Those who institute the embargo and can control its duration and magnitude are not likely to announce in advance how long it will last. Rather, they will probably keep the embargo in place until the underlying objectives are accomplished or until the threat of retaliation becomes too great.

  -- Even if U. S. planners knew the intended duration of an embargo, the built-in lead-times required to get Congressional approval and start up a new program mean that there is always a lag between the need for one type of program and the implementation of that program. In effect, programs could become operational only after the situation they were designed to address had deteriorated to the point where a more stringent program was required.

Possible Further Initiatives

- Government-wide Management Strategy. Since it is imperative for the United States to adequately plan for another embargo, it may be worthwhile to require the preparation of such a strategy, fully integrating energy management options with monetary, fiscal and other policies that would be affected by a supply interruption or steep price increase. The government strategy could encompass the problems raised above and consider what to do if an embargo occurs in the near-term.

- Additional Authority. Among the most effective measures to reduce demand during a supply interruption would be the imposition of emergency taxes or fees on petroleum products. Since such authority does not exist now, there could be a request to Congress to amend the EPCA to allow such actions.

Conclusions

- The United States must be prepared to deal with any future interruption of oil supply. We have already made considerable progress in legislating and beginning implementation of a strategic petroleum reserve. In addition to the SPR, we will need standby allocation, demand restraints, and rationing measures. It would be desirable to simplify standby plans and Congress should consider amending the EPCA to allow imposition of fees, tariffs, taxes, etc., during an emergency. Further, the Federal government should prepare a government-wide embargo management strategy, fully integrating energy management options with monetary, fiscal, and other policies.

SECTION 10

FEDERAL ENERGY ORGANIZATION

Background

- Energy organizational issues have been a matter of attention within the Executive Branch and the Congress for some time:

  -- Prior to the 1973 oil embargo, President Nixon had proposed creation of a Department of Energy and Natural Resources (DENR) and division of the Atomic Energy Commission (AEC) into a research agency and a regulatory agency. A small Energy Policy Office had been established in the Executive Office of the President.

  -- In December 1973, during the embargo, the President established the Federal Energy Office (FEO) in the Executive Office of the President. He delegated to it the petroleum price and allocation authorities, vested by law in the President, including those previously exercised by the Cost of Living Council and transferred to FEO some energy functions of other agencies, principally the Interior and Treasury Departments.

  -- In June 1974, the Federal Energy Administration (FEA) was created by law and in October 1974, the Energy Research and Development Administration (ERDA), Nuclear Regulatory Commission (NRC), and policy-coordinating Energy Resources Council (ERC) were established by the Energy Reorganization Act.

  -- The Energy Conservation and Production Act (ECPA), which extended the FEA until December 1977, requires that the President submit to the Congress a reorganization proposal for energy and natural resources by December 31, 1976.

- Among the problems still considered to exist are the following.

-- The existing agencies are a mixture of permanent (e.g., Department of Interior and ERDA) and temporary (e.g., FEA and ERC) entities.

-- Energy functions remain scattered in a number of diverse agencies often leading to overlapping responsibilities and sometimes to gaps in authority.

-- Policy analysis, coordination and evaluation occurs through the ERC, but it is an organization with no staff.

-- Certain independent regulatory functions, such as those carried out by the Federal Power Commission (FPC), should be responsive to overall policy direction, while preserving the independence of specific adjudicatory decisions.

-- Energy is a vital problem, needing a clearly designated spokesman who should perhaps have Cabinet status.

Possible Initiatives

- The President must submit a reorganization proposal to the Congress. Congress as well as the new Administration, has indicated a desire to review the issue. There are a wide variety of alternative approaches that can be considered, including:

  -- Department of Energy and Natural Resources (DENR). This could include such agencies as Interior, FEA, ERDA, possibly FPC, National Oceanic and Atmospheric Administration (NOAA), etc. The DENR would consolidate most energy functions and bring them together with certain natural resource interests. But it would be a very complex organization with such a broad span of control that key areas could be delegated to lower status and there could be a domination of energy over land management decisions. Unless this Department were expanded to include the Forest Service, Soil Conservation Service, Corps of Engineers, etc., it would still fall far short of complete natural resource consolidation. Further, its creation would affect a large number of Congressional Committees.

-- Department of Energy (DOE). This agency could include FEA, ERDA, possibly FPC, the Rural Electrification Administration (REA), and some energy and related functions of Interior, although not its land management and geologic functions. The DOE would be distinctly an energy agency and would guide energy policy; however, it would still require close coordination with DOI and inclusion of some of its possible components would be controversial.

-- Energy Agency. An energy agency would simply combine FEA and ERDA. This would be the easiest organizational change to effect, but would retain many of the current problems cited above.

-- Retain Present System. Under this alternative, the current organizational alignment would be retained, but some changes would be made to improve the system (e.g. strengthening ERC; creating a permanent FEA; etc.)

- A number of key organizational questions remain to be resolved, even within the broad structure of the proposals listed above. These include whether any of the following agencies or functions should be made a part of the new energy organization:

  -- FPC
  -- NRC
  -- REA
  -- ERC
  -- Naval Petroleum Reserves
  -- NOAA
  -- Tennessee Valley Authority (TVA) and other power producing authorities

There are obvious advantages to inclusion of these agencies for the sake of completeness, broad coverage, and policy responsiveness. Disadvantages include domination of the regulatory functions by a policy-making body, dissimilarity of procedures required by current law in various energy agencies, and too great a span of control.

- The energy organizational issue ought to be considered with any other government reorganization questions, including proposals for a Department of Oceans or a cabinet level environment and land management agency.

Conclusions

- There are very good reasons to consider reorganizing the energy functions of the Federal Government. In both the Executive and Legislative Branches, there is a need for consolidation to eliminate fragmented responsibilities. The basic issues that need to be addressed in an Executive Branch reorganization include the degree of separation of natural resources management and economic regulation from broad energy conservation, research, development, and policy functions. However, reorganization only makes the process of government easier; it will not produce more oil and should not be viewed as the answer to our energy problem.

FEDERAL ENERGY ADMINISTRATION,
December 30, 1976.

Hon. PHILIP R. SHARP,
U.S. House of Representatives, Longworth Building,
Washington, D.C.

DEAR CONGRESSMAN SHARP: In my December 16 testimony before the House Interstate and Foreign Commerce Subcommittee on Energy and Power, you requested of me certain papers regarding FEA's progress in implementing conservation programs authorized by the EPCA and the ECPA. I indicated at that time that we had prepared such papers for the Transition Team and I would be pleased to supply these same papers to you.

Enclosed are papers on the following subjects: electric utility rate design proposals, obligation guarantee program, appliance program, industrial reporting program, Federal energy management program, weatherization program, and the State energy conservation program. These documents are the work product of FEA staff, and have yet to be reviewed by members of the Transition Team.

If you have any further questions on these papers, I or my staff will be pleased to discuss them with you further.

Sincerely,

FRANK G. ZARB, *Administrator.*

Enclosures.

ELECTRIC UTILITY RATE DESIGN PROPOSALS

1. *Decision Points.*—Some time after February 14.

2. *Decision Maker.*—FEA Administrator.

3. *Statement of the Issues.*—Title II, section 203 of the Energy Conservation and Production Act requires FEA to prepare and submit to the Congress proposals with supporting analysis on electric utility rates. Because of the complexity of the issue and the short time for the analysis the decision was made that the proposals would be a descriptive analysis of the impacts of alternative electric rate structures and other regulatory policies with no recommendations or value judgments made. After the proposals are completed the issues will be better defined and then the whole issue whether the Federal Government should intercede in utility rate making, traditionally a state prerogative, and if it should how can it be addressed.

4. *Relationship to New Administration Policies.*

5. *Background.*—Title II of the Energy Conservation and Production Act (ECPA) requires FEA to "develop proposals for improvements of electric utility rate design and transmit such proposals to Congress . . . not later than 6 months after the date of enactment of this Act . . ." (by February 14, 1977. See Attachment I). Proposals dealing with rates, ratemaking policies, and other regulatory policies should be studied with respect to:

Cost effective load management;

Marginal cost or time of use pricing;

Efficient use and economical purchase of fuel; and

System and equipment reliability.

These proposals shall also be analyzed as to:

Projected savings of energy resources;

Reduced generating and capital demand; and

Changes in consumer cost.

The resulting analysis will be evaluated as to the adequacy of the data upon which they are based.

TOPICS TO BE EVALUATED

Title II instructs FEA to inform Congress on specific measures which Congress or State or Federal regulatory commissions should consider as effective means to achieve the following objectives:

1. Reduce the cost of electricity to consumers;
2. Reduce capital expenditures;
3. Encourage energy conservation; and
4. Encourage efficient use of existing facilities.

The Title II language calls for evaluation of (a) rate design, (b) ratemaking policy, and (c) other regulatory policies in assessing "effective means." Therefore, the FEA program will look at guidelines that will impact upon demand, supply, planning and financial aspects of electricity regulation.

FEA's submittal to Congress should be viewed as a series of proposals with supporting analyses addressed towards fostering national objectives for electricity. We must also recognize, however, that both the House (Congressman Dingell) and the Senate (Senator Moss) have proposed, and plan to be studied by FEA. It should be recognized, that the Title II study is likely to be used by Congressman Dingell as input to and support for legislatively mandated rate structures.

Initially nine separate topics will be examined by the FEA in detail—

a. Demand management and conservation

1. Rate structures: e.g., declining block; inverted; lifelines rates; time of use; other cost justified rates.
2. Cost effective load management technology.

b. Fuel utilization and fuel purchases

3. Fuel Adjustment clauses.
4. ESECA—coal conversion program.

c. Financing of capital investments

5. Possible electric utility accounting changes including construction work in progress (CWIP) and tax normalization.
6. Comprehensive automatic rate adjustments.

d. Reliability of service

7. Policy actions to achieve better generation plant reliability.

e. Industry structure

8. Co-generation of electricity and industrial steam.
9. Encourage private and commercial applications of solar heating and cooling.

Two additional topics will be addressed if FEA is able to obtain staff assistance from the Federal Power Commission.

10. Interconnection of utility systems (FPC).
11. Analysis of alternative utility system reliability criteria.

Besides the topics above that will be examined in detail, an identification of the issues involved along with a summary of the analyses that have been accomplished in the past will be undertaken for two additional topics.

12. Utility participation in coal and uranium development.
13. Full cost impact of coal quality.

The eventual submittal might not address all of the above listed topics. Some may be rejected as the study progresses due to time constraints or inadequate information.

ANALYTIC APPROACH

Analytic tools beyond those being currently used by FEA will be needed to analyze the potential effects of the topics. Two approaches will be conducted in parallel: individual assessment of each topic, and an overall integrated model to evaluate all parameters simultaneously.

A major thrust of the analyses requested by Congress rests upon determining in a quantitative fashion the effect of alternative rate structures upon a utility's load curve. Good data, sufficient to support a rigorous quantitative analyses of this effect, does not exist nor will it soon exist. With some micro level data we could support preliminary representations of the likely effect of a particular rate structure upon the load duration curve.

Once the key is determined, a number of models exist which attempt to represent how changes in the load curve will affect generating capacity requirements, system reliability, utility fuel requirements, capital requirements and consumer costs. Interconnection of these several models into comprehensive integrated total analysis would allow for ready measurement of the effects of various proposals in the topical areas set forth above. Our plan is not to build a new integrated model, but to enhance to the degree possible within available resources one of the existing integrated models.

However, it is possible that translation of alternative utility rates to changes in expected load demand curves may be less than satisfactory. Further, it is not clear whether existing models treat the factors involved in our prospective proposals in sufficient detail. It may not be feasible to enhance those models to the degree needed or to interconnect their operations in a consistent fashion. For these reasons, the effects of individual proposals in each topical area are being separately investigated in a parallel analytic effort.

In this parallel effort, we plan to carry out both qualitative and quantitative analyses of the principal effects of each individual topic. Second order effects of a specific topic upon electricity demand or upon other utility planning factors would be identified, but would not be analyzed in any quantitative way. Maximum use would be made of support capabilities already under way. We are fortunate in that a number of active FEA contracts have work under way which can provide important input to the analyses which are needed and which, with minor modification, can effectively provide essential support to this program.

SCHEDULE

The ECPA, Title II, schedule—proposals submitted to Congress by February 14, 1977—will be extremely difficult to meet if we are to produce a quality set of proposals, and supporting analyses. We do not believe that a February 14 submittal date is compatible with the type of analysis which some Congressional Committees appear to desire.

An additional 6 months or more would be needed to obtain and make use of the results of the FEA utility rate demonstration projects, and to more accurately represent the effect of various types of rate changes upon demand. We do not consider such a delay to be advisable.

Given the very tight schedule we plan to mount a two-part effort. The first part will be to review, and summarize, for a February 14 submittal to the Congress what is currently known about the topics listed above. The second part of our efforts, which will provide information to the first part, will be an attempt to quantitatively model the impacts of alternative rate structures and load management to the best extent possible given the limited data available and the state-of-the-art of the theory. Because of the complexities of the issues involved, part two cannot be totally completed in time for a February 14 submittal to the Congress. It is our plan, therefore, to develop the best interim report for delivery to the Congress by February 14 and the final proposals with analysis for delivery by May 14, 1977. This schedule modification will, of course, be formally confirmed when the 95th Congress convenes.

EXTERNAL REVIEW PROCESS

Non-governmental sources

It is extremely important that the FEA program receive information from the electric community, i.e., State regulatory authorities, electric utilities, the financial community, and environmental and consumer groups.

To achieve these benefits while not unduly complicating the problem of communication with each of these groups, we are establishing an Ad Hoc Electric Utility Rate Proposal subcommittee of the State Regulatory Advisory Committee to advise and review its rate proposals. Chairmen of the Environmental, Consumer Affairs/Special Impact, Electric Utility, State Regulatory, Energy Finance, Natural Gas Transmission and Distribution and Fuel Oil Marketing Advisory Committees have been asked to appoint a representative to this subcommittee.

Other Federal agencies

The ERC Electricity Task Force will serve as the focal point for interaction between FEA and other Federal agencies. A work group of this ERC task force will be formed to specifically address this topic. Several Federal agencies have great interest in our proposals both in a programmatic sense and as major purchasers of electricity, e.g., GSA, DOD and ERDA. We plan to obtain early review and input to our analysis by these agencies through this subcommittee work group.

Congress

After agreement is reached as to what policies and program efforts should be pursued, C&E and ERD, with Congressional Affairs, will jointly review the FEA's planned program effort with the staffs of Congressman Dingell and Senator Glenn. In addition, the Congressional Research Service will be invited to attend the meetings of and receive all materials sent to members of the advisory committee.

OBLIGATION GUARANTEES PROGRAM

I. *Decision Points.*—Part D, Title IV of the Energy Conservation and Production Act (ECPA) authorizes the Federal Energy Administration (FEA) to implement a two billion dollars energy conservation and renewable-resource obligation guarantees program. Since this authority would expire in September, 1979 and since it would take 6 to 8 months to develop rules and regulations, and to hire and train staff needed to implement such a complex program, it is necessary to make a decision as soon as possible whether or not this program should be implemented immediately.

Currently, OMB has authorized for fiscal year 1977 a study to determine the viability of such a program and pending the outcome of this study, no budget provision for implementing the program in fiscal year 1978 has been included in the President's budget.

II. *Decision Maker.*—Administrator of FEA with the approval of the President.

III. *Statement of the Issues.*—The major issue is whether to implement the Obligation Guarantees Program immediately or to await the outcome of a 6–8 month study which would significantly reduce the time left to implement this program.

IV. *Relationship to New Administration Policies.*

V. *Background.*—ECPA gives the Federal Energy Administration (FEA) authority to administer an energy conservation and renewable-resources obligation guarantees program. Specifically, FEA may guarantee, or make commitments to guarantee, up to $2 billion worth of energy conservation loans and other obligations. The purpose of the program is to stimulate energy conservation by providing a Federal guarantee for the repayment of a loan made to finance up to 90 percent of the cost of the purchase and installation of an energy conservation or renewable-resource measure in existing buildings or industrial plants. Borrowers may include States and local governments, non-profit institutions, small businesses, commercial entities, and owners of residential buildings containing at least three dwelling units. The issuance of guarantees is limited to those loans for which financing on reasonable terms and conditions is not otherwise available, and for which there is a reasonable prospect of repayment. This program expires September 30, 1979.

FEA included in its 1977 supplemental and 1978 budget requests appropriate provisions to implement this program. OMB has, however, included funds in 1977 budget only for conducting a study to establish the need for this program and to estimate program benefits and develop program design. Pending the outcome of the proposed study, no provision has been included in Fiscal 1978 budget to implement this program. At present, this OMB decision stands despite an FEA appeal.

VI. *Decision Options.*

A. Implement the Obligation Guarantees Program (OGP) immediately.

B. Await the outcome of a 6–8 month study before deciding to implement this program.

VII. *Analysis of Options.*

A. *Implement Immediately.*

PROS

Energy prices are artificially low because of externalities and market distortions and because the Federal Government controls oil and natural gas prices below world market levels. Since these controls and distortions will exist for the foreseeable future (oil prices will remain under control through at least March 1979), energy has a relative price advantage. Real petroleum prices have, in fact, declined in the last year. Therefore, the consumption of energy is and will continue to be greater than it would be if oil and gas prices reflected the full value of these fuels.

Although energy usage declined in 1974 and 1975 due mainly to the economic recession and the mild winters, energy demand is on the rise again. In 1976, industrial energy usage is up 4.8 percent over the previous year. Furthermore, since future energy demand will likely resume a growth rate approaching the historical rates.

Although many energy conservation investments have favorable rates of return, few are being made because:

Uncertainties continue to exist about energy prices and conservation technologies.

Many users are still not aware of potential conservation opportunities.

The investor in energy consuming capital does not always pay for the energy used by the plant (e.g., tenants who pay utilities vs. landlord who makes the investment).

Capital investments of any kind are subjected to increasingly competitive internal scrutiny, due in part to the lowered corporate profitability of recent years and the increased requirements for environmental and occupational safety/health investments.

The purpose of the obligation guarantees program is to stimulate energy conservation investments by:

Reducing capital cost to many firms (i.e., lowering interest rates).

Increasing capital availability to potential borrowers, particularly the capital constrained public or quasi-public sector (hospitals, schools, etc.).

Making the leasing of energy conserving equipment more attractive.

FEA analysis indicates that:

The potential market for obligation guarantees ranges from $400 million to over $5.0 billion.

The associated annual energy savings range from 35,000 barrels per day to 480,000 barrels per day.

CONS

See Pros on Option B.

B. Await the study results before deciding to implement OGP.

PROS

The study may provide some additional information about the potential program impacts.

It may provide information which will be useful to improve program design.

CONS

Since the program authorization expires in September 19, 1979, this option leaves effectively only one year for program operation as the study will be finished by December 1977 and it will take 6–8 months to develop regulations, hire and train staff before the program can be implemented.

FEA study which was transmitted to date has already contained analysis suggesting that OGP is likely to be an effective program with significant national benefits in terms of energy savings. Given the lack of basic data and information about the likely behavioral responses of owners of buildings and industrial plants, additional study is unlikely to yield significant new insights into the likely program impact.

Appliance Efficiency Program

I. Publication of test procedure and efficiency improvement target regulations for consumer products as required by EPCA.

II. Under Title III, Part B of the EPCA (P.L. 94–163) FEA was required to publish test procedures and efficiency improvement targets for consumer products outlined in the schedule below:

Appliance	Date of publication: Proposed test procedures	Final test procedures	Final efficiency targets
1. Refrigerators, and refrigerator/freezers	June 30, 1976	June 30, 1976	Nov. 12, 1976
2. Freezers	do	do	Do.
3. Dishwashers	do	do	Do.
4. Clothes dryers	do	do	Do.
5. Water heaters	do	do	Do.
6. Room air-conditioners	do	do	Do.
7. Home heating equipment not including furnaces	Sept. 30, 1976	Dec. 31, 1976	Do.
8. Television sets	June 30, 1976	Sept. 30, 1976	Do.
9. Kitchen ranges and ovens	Sept. 30, 1976	Dec. 31, 1976	Do.
10. Clothes washers	June 30, 1977	Sept. 30, 1977	Do.
11. Humidifiers and dehumidifiers	do	do	Dec. 22, 1976
12. Central air-conditioners	do	do	Do.
13. Furnaces	do	do	Do.

III. The proposed test procedures for room air-conditioners have been published in the Federal Register (41 F.R. 31237, July 27, 1976), and the public comment period for them closed on September 10, 1976. Comments received were evaluated by FEA and submitted to NBS and FTC for their review. The final test procedures for room air-conditioners will be prescribed in the near future. The remaining test procedures are in the process of being developed or are in legal and technical review prior to publication in the Federal Register as proposed test procedures.

On May 14, 1976, FEA published in the Federal Register proposed energy efficiency improvement targets for the 10 covered products. In response to a lawsuit by the Association of Home Appliance Manufacturers, however, the United States District Court for the District of Columbia, on May 21, 1976, ordered that the public hearings be extended through June 9, 1976, and that the period for written comments be extended through June 15, 1976, and noted that further hearings would be held following the issuance of a second proposal. This action made it impossible for FEA to prescribe the final targets by the June 18, 1976, deadline mandated by EPCA. With the enactment of ECPA, NBS was directed to develop the targets, and the deadline for prescribing such targets was extended by that Act.

Subsequent to the court order, FEA requested 1972 baseline data from the appliance manufacturers for use in determining targets. On September 10, 1976, the first 1972 baseline data was received from industry, but most of the data was not received until the week of October 22–29, 1976; and some data is still outstanding. On November 5, 1976, FEA received the single-number targets recommended by NBS for the 10 covered products. However, several of the technical background papers necessary to explain the rationale for the targets have not been delivered. FEA now is in the process of drafting a notice for the Federal Register that will repropose targets for covered products 1 through 10 (section 322(a)(110)).

IV. There are three additional concerns that will require management attention in early 1977.

1. The stringency of the energy efficiency targets, to be established by regulation, for each category of appliances.

2. The Administrator must rule on a petition to preempt the mandatory appliance efficiency standards which the State of California recently promulgated. The petition was received on December 6, 1976.

3. A reporting system to track progress against the energy efficiency targets must be established, and the key issue is whether to require direct company by company reporting or allow aggregate reporting by trade association.

Industrial Reporting Program

I. Issue

Status of Mandatory Industrial Reporting Program.

II. Background

Title III. Part D of the EPCA requires FEA to establish voluntary energy efficiency improvement targets for the 10 most energy-consumptive industries, as well as to promote energy efficiency in all American industries. The identification and ranking of the 10 most energy-intensive industries according to a two-digit SIC classification was published in the Federal Register on March 23, 1976.

Proposed targets for the 10 most energy-intensive industries were published in the Federal Register on November 2, 1976, and the supporting studies have been available for public comment. Ten public hearings were announced in the notice; the first was held on November 22 and the last will be held on December 10, 1976. Final targets will be developed following the public hearings and the termination of the public comment period. These final targets, along with supporting rationale, are required to be published in the Federal Register by December 22, 1976. At this time it is not certain that this requirement will be met for all targets.

Under EPCA, FEA is required to identify those corporations that use 1 trillion or more Btu's per year and are among the 50 most energy-consumptive corporations within each of the 10 most energy-intensive industries. A notice was published in the Federal Register requiring corporations to file information on energy consumption in 1975 by September 30, 1976, which subsequently was extended to November 8, 1976. The notice identifying the 50 most energy-consumptive companies has been sent to the Federal Register.

On January 1, 1977, identified corporations in industries for which energy efficiency improvement targets have been established are required to report their progress toward such targets, unless exempted from such requirement in accordance with EPCA. (The criteria for exemption of a corporation from the reporting requirement were published in the Federal Register on November 24, and FEA is receiving such requests.) The reporting form is in the final stages of review prior to resubmission to the Office of General Counsel. Before the form is approved, however, there must be written and oral comment, and the GAO clearance procedures must be satisfied.

Section 375(c) requires FEA to submit to Congress and the President an annual report on the Industrial Program. It is anticipated that this report will be submitted on schedule.

Federal Energy Management Program

I. *Decision Points.*—FEA, as the coordinator for the Federal Energy Management Program (FEMP), has in the past gathered and reported energy use data from 26 departments and agencies. Only a very limited degree of policy development had preceded the Energy Policy and Conservation Act (EPCA) which, among its provisions, mandated several Federal energy conservation measures. The development of the EPCA mandated the ten-year plan for increasing the energy efficiency of Federal buildings was delegated to FEA and is being done in conjunction with FEMP. While much preliminary work has been done to define implementing actions responsive to EPCA and identify other areas which might be exploited, basic policy decisions concerning the extent of the Federal Government's efforts to manage its own energy use have not yet been made. There is no specific time requirement for making the dicisions, however, the earlier they can be reached, the sooner energy conservation and energy efficiency activities will be strengthened.

II. *Decision Maker.*—The President must provide policy direction and make responsibility assignments. Supporting implementing policy, organizational decisions, and procedures may be recommended or made at lower levels, at the President's option.

III. *Statement of the Issues.*

1. Top management commitment to energy conservation in the Federal Government (both Presidential and heads of departments and agencies).
2. Establishment of a long-range goal for FEMP to provide direction and a gauge to measure progress.
3. Provision of institutional mechanisms to require continuing executive direction, policy development, planning and program implementation activities.
4. Provision for more useful feedback information in progress, including a determination of whether accuracy checks will be made of the basic data, for valuation and updating.
5. Provision for more interagency cooperation and greater transfer of information between agencies.
6. Extent to which the Federal Government should be a "test bed" for demonstration of the products of energy research and development efforts.
7. Extent to which FEMP should transfer its products to other sectors (i.e., State and local governments, business, and consumers).
8. Extent of budget resources allocated to energy conservation and energy efficiency activities, the extent to which these are separately identified in the budget process, and the degree of use of uniform criteria in reviewing resource requests.

IV. *Relationship to New Administration Policies.*—(To be added).

V. *Background.*—Much detailed background can be found in the attached draft report to Congress on implementing actions taken pursuant to EPCA. However, it does not explicitly address problem areas, such as:

(*a*) Several agencies which use energy intensively have taken significant steps to conserve. But FEMP is widely regarded as a "numbers" exercise. It makes sense to use an interagency mechanism to plan, develop, coordinate and evaluate Federal actions to conserve energy and increase efficiency. Both EPCA and the 11/4 Presidential memo tend toward this concept. Question is how far toward the logical conclusion and how forcefully will FEMP be directed by the new administration. Following are several subordinate problems flowing from this first.

(*b*) Available evidence suggests that lack of clear agency-level management commitment is seriously impeding energy conservation efforts. While the Presidential memo and EPCA mandate clearly establish some degree of priority, more is needed. The question is what form, frequency, and force. For example, should there be an Executive Order on energy management in the Federal Government? Or should the new administration take up the issue quarterly at cabinet meetings? Is the President prepared to call agency heads to task for failure to actively manage their energy resources?

(*c*) Closely related is the question of resources to be devoted to energy management because dollars are the tangible expression of management commitment. The "quick-fixes" have been largely exhausted; future gains will require capital investment. The issue here is not budget levels, because that can be regulated. Rather, it is whether or not there should be a requirement for some resources to be devoted to energy activities, highlighting these in the budget process, doing budget analyses across the board in support of program management. There is at this point no consistency of budget treatment.

(*d*) There is at present no formal charter for the FEMP organization, no statement of responsibilities and authorities from the Presidential level for any organization to provide executive direction to the agencies relative to program activity. Such a basis is essential if there is to be a strong, continuing program.

(*e*) There is a credibility problem with the program on two levels. One concerns public perception of how the Federal Government acts as opposed to what it says. The basic issue here is whether or not the Federal Government can reasonably expect citizens to take conservation seriously if it does not itself have a strong, visible, and productive effort in place.

Further, if the Federal Government can show gains in its facilities and operations, it is in a position to lead other segments of the economy to duplicate these measures. The second level concerns the perceptions of Federal managers and employees. We have attempted to take steps leading toward acceptance of the FEMP concept and have had virtually no support outside FEA. Staff level agency personnel accept it but are in no position to respond without a directive from their managers. In short, except for specifically mandated actions, program direction cannot be provided without having at least some vestments of authority and Presidential sanction.

VI. *Decision Options.*—The decision options presented below are necessarily very general because the issue is very fundamental at this point. After the basic policy direction has been established, there will be a whole range of subordinate options to be examined.

(*a*) Continue in present mode, implement EPCA-required actions without special management and funding procedures.

(*b*) Establish management and funding procedures to implement EPCA-required actions.

(*c*) Establish management and funding procedures to implement a broad range of energy conservation and energy efficiency activities.

VII. *Analysis of Options.*

(*a*) Essentially a voluntary approach with all that that implies in terms of fractionated effort and low productivity.

(*b*) A mandatory approach, implying some degree of centralized management direction, which addressed a large portion (about 40%) of Federal energy use. Avoids disadvantages of (a), is not necessarily more expensive, but does require some time and support from top-level managers.

(*c*) A logical extension of (b) to include other areas of Federal energy use, provide for demonstrations of energy R&D products, and transfer to other sectors.

Current Status of the Weatherization Assistance Program

On November 19, 1976, draft regulations were submitted to the Community Service Administration, the Department of Housing and Urban Development, the Department of Health, Education, and Welfare, the Department of Labor, and to ACTION (in accordance with the legislative mandate for interagency coordination) and to each Regional Office and State (through Regional Offices) for pre-publication by the end of this week. Provided that no major revisions are deemed necessary as a result of the comments received, we plan to meet our current schedule date of December 17, 1976, for formal submission of draft regulations to the Office of the General Counsel. With expeditious handling publication in the Federal Register could occur by January 10, 1977. Approximately 2 weeks later a public hearings will be held in each FEA Region and publication of final regulations is anticipated by February 25. Under our current schedule the application package including the regulations, program manual and grant application form will be ready for distribution to the States no later than March 14, 1977.

Budget information concerning this program is contained in the FY 77 supplemental and FY 78 budget submission to OMB and the OMB mark. The President's budget request for this program has not been finally determined.

STATE ENERGY CONSERVATION PROGRAM

The State Energy Conservation Program, as established by Title III, Part C of the Energy Policy and Conservation Act of 1975 (EPCA) (Public Law 94–163), is an outgrowth of the State/Federal Energy Conservation Program developed by FEA in conjunction with the National Governors' Conference and a number of States. The two programs were based on a cooperative effort between the Federal and State governments in the field of energy conservation. Both called for the establishment of energy conservation goals for the reduction of projected State energy consumption by 1980, and both were voluntary.

There are, however, some important differences between the original program and the program established by EPCA. The EPCA authorizes $50 million for each of fiscal years 1976, 1977, and 1978. For 1976, $5 million was appropriated and for 1977, $25 million. States may only receive these funds if they commit themselves to the provisions of the program. Second, the provisions of EPCA required that every State plan include at a minimum five specific energy conservation actions:

(1) Mandatory lighting efficiency standards for non-Federal public buildings.

(2) Programs to promote the availability and use of carpools, vanpools, and public transportation.

(3) Mandatory standards and policies relating to energy efficiency to govern the procurement practices of a State and its political subdivisions.

(4) Mandatory thermal efficiency standards and insulation requirements for new and renovated non-Federal buildings.

(5) A traffic law or regulation which to the maximum extent practicable and consistent with safety, permit motor vehicle to turn right at a red light after stopping.

A State may include any other energy conserving program measure in their plan that will contribute to an overall State goal of five percent reduction in total State energy consumption by 1980.

Plans are to be submitted to FEA by March 28, 1977, and approved plans will then be implemented with the assistance of grants from FEA.

At the end of the first full year of implementation for the EPCA State program, the following activities have been accomplished:

(1) Issuance of final guidelines for feasibility reports (February 20, 1976, Federal Register February 26, 1976).

(2) Receipt of feasibility reports from all 56 eligible States by July 1, 1976, all making positive assessments of the feasibility of achieving 5 percent energy savings by 1980. (Reports due May 20, 1976—three States requested and received one month extensions.)

(3) Issuance of proposed guidelines for State energy conservation plans (June 10, 1976).

(4) Receipt of public comment on proposed guidelines via 11 public hearings, one in each region and one in Washington, D.C. (June 28–July 8, 1976).

(5) Award of $5 million in planning grants to 55 States for use in preparing energy conservation plans—Trust Territory of the Pacific elected to withdraw from the program (September 30, 1976).

(6) Apportionment of $22.5 million to FEA regional offices for implementation grants.

(7) Issuance of final guidelines for State energy conservation plans (October 29, 1976).

(8) Preparation and distribution of program support material, including energy saving methodologies, to FEA regional offices and State Energy Offices (December 1976).

(9) Preparation and distribution to the regional offices of procedures for reviewing and approving State energy conservation plans, including grant management procedures (December 1976).

Title IV, Part B of the Energy Conservation and Production Act (ECPA) (Public Law 94–385), as enacted on August 14, 1976, amends the EPCA by adding a supplemental State Energy Conservation Program. The ECPA provides that FEA shall make grants to the States for supplemental energy conservation plans and authorizes $25 million for fiscal year 1977, $40 million for fiscal year 1978, and $40 million for fiscal year 1979. A State may receive financial assistance for its supplemental plan alone or as part of the EPCA plan.

In order to qualify for financial assistance, each supplemental State energy conservation plan must include procedures for:

(1) Carrying out a continuing public education effort on implementing energy conservation measures.
(2) Insuring effective intergovernmental coordination.
(3) Encouraging and carrying out energy audits for buildings and industrial plants.

ECPA also permits the FEA Administrator to require States to adopt other specified program measures.

Finally, ECPA requires FEA to prescribe guidelines for the supplemental plan by February 14, 1977. FEA will solicit comments from the Governors and will allow at least a 60-day comment period through the Federal Register process before the final guidelines are issued.

At this time, the Office of State Financial Assistance is preparing to issue proposed guidelines for the ECPA supplemental program for public comments.

[Whereupon, at 12:35 p.m., the hearing was adjourned.]

APPENDIX

PROGRESS DURING THE 94TH CONGRESS TOWARD AN INTEGRATED ENERGY POLICY

Energy Strategy: The Road Not Taken?

(By Amory B. Lovins)*

Two roads diverged in a wood, and I—
I took the one less traveled by,
And that has made all the difference.
—Robert Frost

Where are America's formal or de facto energy policies leading us? Where might we choose to go instead? How can we find out?

Addressing these questions can reveal deeper questions—and a few answers—that are easy to grasp, yet rich in insight and in international relevance. This paper will seek to explore such basic concepts in energy paths that the United States might follow over the next 50 years—long enough for the full implications of change to start to emerge. The first path resembles present federal policy and is essentially an extrapolation of the recent past. It relies on rapid expansion of centralized high technologies to increase supplies of energy, especially in the form of electricity. The second path combines a prompt and serious commitment to efficient use of energy, rapid development of renewable energy sources matched in scale and in energy quality to end-use needs, and special transitional fossil-fuel technologies. This path, a whole greater than the sum of its parts, diverges radically from incremental past practices to pursue long-term goals.

Both paths, as will be argued, present difficult—but very different—problems. The first path is convincingly familiar, but the economic and sociopolitical problems lying ahead loom large, and eventually, perhaps, insuperable. The second path, though it represents a shift in direction, offers many social, economic and geopolitical advantages, including virtual elimination of nuclear proliferation from the world. It is important to recognize that the two paths are mutually exclusive. Because commitments to the first may foreclose the second, we must soon choose one or the other—before failure to stop nuclear proliferation has foreclosed both.[1]

II

Most official proposals for future U.S. energy policy embody the twin goals of sustaining growth in energy consumption (assumed to be closely and causally linked to GNP and to social welfare) and of minimizing oil imports. The usual proposed solution is rapid expansion of three sectors: coal (mainly strip-mined, then made into electricity and synthetic fluid fuels); oil and gas (increasingly from Arctic and offshore wells); and nuclear fission (eventually in fast breeder

*Amory B. Lovins, a consultant physicist, is British Representative of Friends of the Earth, Inc. His latest books are *World Energy Strategies: Facts, Issues, and Options* and (with Dr. J. H. Price) *Non-Nuclear Futures: The Case for an Ethical Energy Strategy*.

[1] In this essay the proportions assigned to the components of the two paths are only indicative and illustrative. More exact computations, now being done by several groups in the United States and abroad (notably the interim [autumn 1976] and forthcoming final [1976–1977] reports of the energy study of the Union of Concerned Scientists, Cambridge, Mass.), involve a level of technical detail which, though an essential next step, may deflect attention from fundamental concepts. This article will accordingly seek technical realism without rigorous precision or completeness. Its aim is to try to bring some modest synthesis to the enormous flux and ferment of current energy thinking around the word. Much of the credit (though none of the final responsibility) must go to the many energy strategists whose insight and excitement they have generously shared and whose ideas I have shamelessly recycled without explicit citation. Only the limitations of space keep me from acknowledging by name the 70-odd contributors, in many countries, who come especially to mind.

reactors). All domestic resources, even naval oil reserves, are squeezed hard—in a policy which David Brower calls "Strength Through Exhaustion." Conservation, usually induced by price rather than by policy, is conceded to be necessary but it is given a priority more rhetorical than real. "Unconventional" energy supply is relegated to a minor role, its significant contribution postponed until past 2000. Emphasis is overwhelmingly on the short term. Long-term sustainability is vaguely assumed to be ensured by some eventual combination of fission breeders, fusion breeders, and solar electricity. Meanwhile, aggressive subsidies and regulations are used to hold down energy prices well below economic and prevailing international levels so that growth will not be seriously constrained.

Even over the next ten years (1976–85), the supply enterprise typically proposed in such projections is impressive. Oil and gas extraction shift dramatically to offshore and Alaskan sources, with nearly 900 new oil wells offshore of the contiguous 48 states alone. Some 170 new coal mines open, extracting about 200 million tons per year each from eastern underground and strip mines, plus 120 forty 1,000-megawatt nuclear reactors, 60 conventional and over 100 pumped uranium mines, a new enrichment plant, some 40 fuel fabrication plants, three fuel reprocessing plants. The electrical supply system, more than doubling, draws on some 180 new 800-megawatt coal-fired stations, over one hundred and forty 1,000-megawatt nuclear reactors, 60 conventional and over 100 pumped-storage hydroelectric plants, and over 350 gas turbines. Work begins on new industries to make synthetic fuels from coal and oil shale. At peak, just building (not operating) all these new facilities directly requires nearly 100,000 engineers, over 420,000 craftspeople, and over 140,000 laborers. Total indirect labor requirements are twice as great.[2]

This ten-year spurt is only the beginning. The year 2000 finds us with 450 to 800 reactors (including perhaps 80 fast breeders, each loaded with 2.5 metric tons of plutonium), 500 to 800 huge coal-fired power stations, 1,000 to 1,600 new coal mines and some 15 million electric automobiles. Massive electrification—which, according to one expert, is "the most important attempt to modify the infrastructure of industrial society since the railroad"[3]—is largely responsible for the release of waste heat sufficient to warm the entire freshwater runoff of the contiguous 48 states by 34–44° F.[4] Mining coal and uranium increasingly in the arid West, entails inverting thousands of communities and millions of acres, often with little hope of effective restoration. The commitment to a long-term coal economy many times the scale of today's makes the doubling of atmospheric carbon dioxide concentration early in the next century virtually unavoidable, with the prospect then or soon thereafter of substantial and perhaps irreversible changes in global climate.[5] Only the exact date of such changes is in question.

The main ingredients of such an energy future are roughly sketched in Figure 1. For the period up to 2000, this sketch is a composite of recent projections published by the Energy Research and Development Administration (ERDA), Federal Energy Administration (FEA), Department of the Interior, Exxon, and Edison Electric Institute. Minor and relatively constant sources, such as hydroelectricity, are omitted; the nuclear component represents nuclear heat, which

---

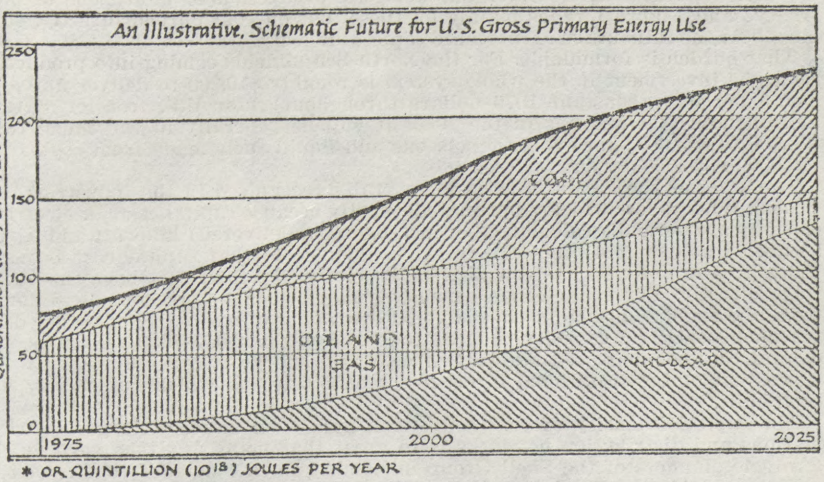
[2] The foregoing data are from M. Carasso *et al.*, *The Energy Supply Planning Model*, PB–245 382 and PB–245 383, National Technical Information Service (Springfield, Va.), Bechtel Corp. report to the National Science Foundation (NSF), August 1975. The figures assume the production goals of the 1975 State of the Union Message. Indirect labor reqirements are calculated by C. W. Bullard and D. A. Pilati, CAC Document 178 (September 1975), Center for Advanced Computation, Univ. of Illinois at Urbana-Champaign.

[3] C. Bupp and R. Treitel, "The Economics of Nuclear Power: De Omnibus Dubitandum," 1976 (available from Professor Bupp, Harvard Business School).

[4] Computation concerning waste heat and projections to 2000 are based on data in the 1975 Energy Research and Development Administration Plan (ERDA–48).

[5] B. Bolin, "Energy and Climate," Secretariat for Future Studies (Fack, S–103 10 Stockholm); S. H. Schneider and R. D. Dennett, *Ambio 4*, 2: 65–74 (1975); S. H. Schneider, *The Genesis Strategy*, New York: Plenum, 1976; W. W. Kellogg and S. H. Schneider, *Science 186:* 1163–72 (1974).

FIGURE 1



is roughly three times the resulting nuclear electric output; fuel imports are aggregated with domestic production. Beyond 2000, the usual cutoff date of present projections, the picture has been extrapolated to the year 2025—exactly how is not important here—in order to show its long-term implications more clearly.[6]

III

The flaws in this type of energy policy have been pointed out by critics in and out of government. For example, despite the intensive electrification—consuming more than half the total fuel input in 2000 and more thereafter—we are still short of gaseous and liquid fuels, acutely so from the 1980s on, because of slow and incomplete substitution of electricity for the two-thirds of fuel use that is now direct. Despite enhanced recovery of resources in the ground, shortages steadily deepen in natural gas—on which plastics and nitrogen fertilizers depend—and, later, in fuel for the transport sector (half our oil now runs cars). Worse, at least half the energy growth never reaches the consumer because it is lost earlier in elaborate conversions in an increasingly inefficient fuel chain dominated by electricity generation (which wastes about two-thirds of the fuel) and coal conversion (which wastes about one-third). Thus in Britain since 1900, primary energy—the input of the fuel chain—has doubled while energy at the point of end use—the car, furnace or machine whose function it fuels—has increased by only a half, or by a third per capita; the other half of the growth went to fuel the fuel industries, which are the largest energy consumers.

Among the most intractable barriers to implementing Figure 1 is its capital cost. In the 1960s, the total investment to increase a consumer's delivered energy supplies by the equivalent of one barrel of oil per day (about 67 kilowatts of heat) was a few thousand of today's dollars—of which, in an oil system, the wellhead investment in the Persian Gulf was and still is only a few hundred dollars. (The rest is transport, refining, marketing and distribution.) The capital

[6] Figure 1 shows only *nonagricultural* energy. Yet the sunlight participating in photosynthesis in our harvested crops is comparable to our total use of nonagricultural energy, while the sunlight falling on all U.S. croplands and grazing lands is about 25 times the nonagricultural energy. By any measure, sunlight is the largest single energy input to the U.S. economy today.

intensity of much new coal supply is still in this range. But such cheaply won resources can no longer stretch our domestic production of fluid fuels or electricity; and Figure 1 relies mainly on these, not on coal burned directly, so it must bear the full burden of increased capital intensity.

That burden is formidable. For the North Sea oilfields coming into production soon, the investment in the whole system is roughly $10,000 to deliver an extra barrel per day (constant 1976 dollars throughout); for U.S. frontier (Arctic and offshore) oil and gas in the 1980s it will be generally in the range from $10,000 to $25,000; for synthetic gaseous and liquid fuels made from coal, from $20,000 to $50,000 per daily barrel.

The scale of these capital costs is generally recognized in the industries concerned. What is less widely appreciated—partly because capital costs of electrical capacity are normally calculated per installed (not delivered) kilowatt and partly because whole-system costs are rarely computed—is that capital cost is many times greater for new systems that make electricity than for those that burn fuels directly. For coal-electric capacity ordered today, a reasonable estimate would be about $150,000 for the delivered equivalent of one barrel of oil per day; for nuclear-electric capacity ordered today, about $200,000–$300,000. Thus, the capital cost per delivered kilowatt of electrical energy emerges as roughly 100 times that of the traditional direct-fuel technologies on which our society has been built.[7]

The capital intensity of coal conversion and, even more, of large electrical stations and distribution networks is so great that many analysts, such as the strategic planners of the Shell Group in London, have concluded that no major country outside the Persian Gulf can afford these centralized high technologies on a truly large scale, large enough to run a country. They are looking, in Monte Canfield's phrase, like future technologies whose time has passed.

Relying heavily on such technologies, President Ford's 1976–85 energy program turns out to cost over $1 trillion (in 1976 dollars) in initial investment, of which 70 to 80 percent would be for new rather than replacement plants.[8] The latter figure corresponds to about three-fourths of cumulative net private domestic investment (NPDI) over the decade (assuming that NPDI remains 7 percent of gross national product and that GNP achieves real growth of 3.5 percent per year despite the adverse effects of the energy program on other investments). In contrast, the energy sector has recently required only one-fourth of NPDI. Diverting to the energy sector not only this hefty share of discretionary investment but also about two-thirds of all the rest would deprive other sectors which have their own cost-escalation problems and their own vocal constituencies. A powerful political response could be expected. And this capital burden is not temporary; further up the curves of Figure 1 it tends to increase, and much of what might have been thought to be increased national wealth must be plowed back into the care and feeding of the energy system. Such long-lead-time, long-payback-time investments might also be highly inflationary.

Of the $1 trillion-plus just cited, three-fourths would be for electrification. About 18 percent of the total investment could be saved just by reducing the assumed average 1976–85 electrical growth rate from 6.5 to 5.5 percent per year.[9] Not surprisingly, the combination of disproportionate and rapidly increasing capital intensity, long lead times, and economic responses is already proving awkward to the electric utility industry, despite the protection of a 20 percent taxpayer subsidy on new power stations.[10] "Probably no industry," observes Bankers Trust Company, "has come closer to the edge of financial disaster." Both here and abroad an effective feedback loop is observable: large capital programs—poor cash flow—higher electricity prices—reduced demand growth—worse cash flow—increased bond flotation—increased debt-to-equity ratio, worse coverage,

---

[7] The capital costs for frontier fluids and for electrical systems can be readily calculated from the data base of the Bechtel model (footnote 2 above). The electrical examples are worked out in my "Scale, Centralization and Electrification in Energy Systems," *Future Strategies of Energy Development* symposium, Oak Ridge Associated Universities, October 20–21, 1976.

[8] The Bechtel model, using 1974 dollars and assuming ordering in early 1974, estimates direct construction costs totaling $559 billion, including work that is in progress but not yet commissioned in 1985. Interest, design and administration—but not land, nor escalation beyond the GNP inflation rate—bring the total to $743 billion. Including the cost of land, and correcting to a 1976 ordering date and 1976 dollars, is estimated by M. Carasso to yield over $1 trillion.

[9] M. Carasso *et al., op. cit.*

[10] E. Kahn *et al.*, "Investment Planning in the Energy Sector," LBL–4479, Lawrence Berkeley Laboratory, Berkeley, Calif., March 1, 1976.

and less attractive bonds—poor bond sales—worse cash flow—higher electricity prices—reduced (even negative) demand growth and political pressure on utility regulators—overcapacity, credit pressure, and higher cost of money—worse cash flow, etc. This "spiral of impossibility," as Mason Willrich has called it, is exacerbated by most utilities' failure to base historic prices on the long-run cost of new supply: thus some must now tell their customers that the current-dollar cost of a kilowatt-hour will treble by 1985, and that two-thirds of that increase will be capital charges for new plants. Moreover, experience abroad suggests that even a national treasury cannot long afford electrification: a New York State-like position is quickly reached, or too little money is left over to finance the energy *uses*, or both.

IV

Summarizing a similar situation in Britain, Walter Patterson concludes: "Official statements identify an anticipated 'energy gap' which can be filled only with nuclear electricity; the data do not support any such conclusion, either as regards the 'gap' or as regards the capability of filling it with nuclear electricity." We have sketched one form of the latter argument; let us now consider the former.

Despite the steeply rising capital intensity of new energy supply, forecasts of energy demand made as recently as 1972 by such bodies as the Federal Power Commission and the Department of the Interior wholly ignored both price elasticity of demand and energy conservation. The Chase Manhattan Bank in 1973, saw virtually no scope for conservation save by minor curtailments; the efficiency with which energy produced economic outputs was assumed to be optimal already. In 1976, some analysts still predict economic calamity if the United States does not continue to consume twice the combined energy total for Africa, the rest of North and South America, and Asia except Japan. But what have more careful studies taught us about the scope for doing better with the energy we have? Since we can't keep the bathtub filled because the hot water keeps running out, do we really (as Malcolm MacEwen asks) need a bigger water heater, or could we do better with a cheap, low-technology plug?

There are two ways, divided by a somewhat fuzzy line, to do more with less energy. First, we can plug leaks and use thriftier technologies to produce exactly the same output of goods and services—and bads and nuisances—as before, substituting other resources (capital, design, management, care, etc.) for some of the energy we formerly used. When measures of this type use today's technologies, are advantageous today by conventional economic criteria, and have no significant effect on life-styles, they are called "technical fixes."

In addition, or instead, we can make and use a smaller quantity or a different mix of the outputs themselves, thus to some degree changing (or reflecting ulterior changes in) our life-styles. We might do this because of changes in personal values, rationing by price or otherwise, mandatory curtailments, or gentler inducements. Such "social changes" include car-pooling, smaller cars, mass transit, bicycles, walking, opening windows, dressing to suit the weather, and extensively recycling materials. Technical fixes, on the other hand, include thermal insulation, heat-pumps (devices like air conditioners which move heat around—often in either direction—rather than making it from scratch), more efficient furnaces and car engines, less overlighting and overventilation in commercial buildings, and recuperators for waste heat in industrial processes. Hundreds of technical and semi-technical analyses of both kinds of conservation have been done; in the last two years especially, much analytic progress has been made.

Theoretical analysis suggests that in the long term, technical fixes *alone* in the United States could probably improve energy efficiency by a factor of at least three or four.[11] A recent review of specific practical measures cogently argues that with only those technical fixes that could be implemented by about the turn of the century, we could nearly double the efficiency with which we use energy.[12] If that is correct, we could have steadily increasing economic activity with approximately constant primary energy use for the next few decades, thus stretching our present energy supplies rather than having to add massively to

---

[11] American Institute of Physics Conference Proceedings No. 25, *Efficient Use of Energy*, New York: AIP, 1975; summarized in *Physics Today*, August 1975.
[12] M. Ross and R. H. Williams, "Assessing the Potential for Fuel Conservation," forthcoming in *Technology Review;* see also L. Schipper, *Annual Review of Energy* 1: 455–518 (1976).

them. One careful comparison shows that *after* correcting for differences of climate, hydroelectric capacity, etc., Americans would still use about a third less energy than they do now if they were as efficient as the Swedes (who see much room for improvement in their own efficiency).[13] U.S. per capita energy intensity, too, is about twice that of West Germany in space heating, four times in transport.[14] Much of the difference is attributable to technical fixes.

Some technical fixes are already under way in the United States. Many factories have cut tens of percent off their fuel cost per unit output, often with practically no capital investment. New 1976 cars average 27 percent better mileage than 1974 models. And there is overwhelming evidence that technical fixes are generally much cheaper than increasing energy supply, quicker, safer, of more lasting benefit. They are also better for secure, broadly based employment using existing skills. Most energy conservation measures and the shifts of consumption which they occasion are relatively labor-intensive. Even making more energy-efficient home appliances is about twice as good for jobs as is building power stations: the latter is practically the least labor-intensive major investment in the whole economy.

The capital savings of conservation are particularly impressive. In the terms used above, the investments needed to *save* the equivalent of an extra barrel of oil per day are often zero to $3,500, generally under $8,000, and at most about $25,000—far less than the amounts needed to increase most kinds of energy supply. Indeed, to use energy efficiently in new buildings, especially commercial ones, the additional capital cost is often *negative*: savings on heating and cooling equipment more than pay for the other modifications.

To take one major area of potential saving, technical fixes in new buildings can save 50 percent or more in office buildings and 80 percent or more in some new houses.[15] A recent American Institute of Architects study concludes that, by 1990, improved design of new buildings and modification of old ones could save a third of our current *total* national energy use—and save money too. The payback time would be only half that of the alternative investment in increased energy supply, so the same capital could be used twice over.

A second major area lies in "cogeneration," or the generating of electricity as a by-product of the process steam normally produced in many industries. A Dow study chaired by Paul McCracken reports that by 1985 U.S. industry could meet approximately half its own electricity needs (compared to about a seventh today) by this means. Such cogeneration would save $20–50 billion in investment, save fuel equivalent to 2–3 million barrels of oil per day, obviate the need for more than 50 large reactors, and (with flattened utility rates) yield at least 20 percent pretax return on marginal investment while reducing the price of electricity to consumers.[16] Another measure of the potential is that cogeneration provides about 4 percent of electricity today in the United States but about 29 percent in West Germany. Cogeneration and more efficient use of electricity could together reduce our use of electricity by a third and our central-station generation by 60 percent.[17] Like district heating (distribution of waste heat as hot water via insulated pipes to heat buildings), U.S. cogeneration is held back only by institutional barriers. Yet these are smaller than those that were overcome when the present utility industry was established.

So great is the scope for technical fixes now that we could spend several hundred billion dollars on them initially plus several hundred million dollars per day—and still save money compared with increasing the supply! And we would still have the fuel (without the environmental and geopolitical problems of getting and using it). The barriers to far more efficient use of energy are not

---

[13] L. Schipper and A. J. Lichtenberg, "Efficient Energy Use and Well-Being: The Swedish Example," LBL–4430 and ERG–76–09, Lawrence Berkeley Laboratory, April 1976.

[14] R. L. Goen and R. K. White, "Comparison of Energy Consumption Between West Germany and the United States," Stanford Research Institute, Menlo Park, Calif., June 1975.

[15] A. D. Little, Inc., "An Impact Assessment of ASHRAE Standard 90–75," report to FEA, C–78309, December 1975; J. E. Snell *et al.* (National Bureau of Standards), "Energy Conservation in Office Buildings: Some United States Examples," International CIB Symposium on Energy Conservation in the Built Environment (Building Research Establishment, Garston, Watford, England), April 1976; Owens-Corning-Fiberglas, "The Arkansas Story," 1975.

[16] P. W. McCracken *et al.*, *Industrial Energy Center Study*, Dow Chemical Co. *et al.*, report to NSF, PB–243 824, National Technical Information Service (Springfield, Va.), June 1975. Extensive cogeneration studies for FEA are in progress at Thermo-Electron Corp., Waltham, Mass. A pathfinding June 1976 study by R. H. Williams (Center for Environmental Studies, Princeton University) for the N.J. Cabinet Energy Committee argues that the Dow report substantially underestimates cogeneration potential.

[17] Ross and Williams, *op. cit.*

technical, nor in any fundamental sense economic. So why do we stand here confronted, as Pogo said, by insurmountable opportunities?

The answer—apart from poor information and ideological antipathy and rigidity—is a wide array of institutional barriers, including more than 3,000 conflicting and often obsolete building codes, an innovation-resistant building industry, lack of mechanisms to ease the transition from kinds of work that we no longer need to kinds we do need, opposition by strong unions to schemes that would transfer jobs from their members to larger numbers of less "skilled" workers, promotional utility rate structures, fee structures giving building engineers a fixed percentage of prices of heating and cooling equipment they install, inappropriate tax and mortgage policies, conflicting signals to consumers, misallocation of conservation's costs and benefits (builders vs. buyers, landlords vs. tenants, etc.), imperfect access to capital markets, fragmentation of government responsibility, etc.

Though economic answers are not always right answers, properly using the markets we have may be the greatest single step we could take toward a sustainable, humane energy future. The sound economic principles we need to apply include flat (even inverted) utility rate structures rather than discounts for large users, pricing energy according to what extra supplies will cost in the long run ("long-run marginal-cost pricing"), removing subsidies, assessing the total costs of energy-using purchases over their whole operating lifetimes ("lifecycle costing"), counting the costs of complete energy systems including all support and distribution systems, properly assessing and charging environmental costs, valuing assets by what it would cost to replace them, discounting appropriately, and encouraging competition through antitrust enforcement (including at least horizontal divestiture of giant energy corporations).

Such practicing of the market principles we preach could go very far to help us use energy efficiency and get it from sustainable sources. But just as clearly, there are things the market cannot do, like reforming building codes or utility practices. And whatever our means, there is room for differences of opinion about how far we can achieve the great theoretical potential for technical fixes. How far might we instead choose, or be driven to, some of the "social changes" mentioned earlier?

There is no definitive answer to this question—though it is arguable that if we are not clever enough to overcome the institutional barriers to implementing technical fixes, we shall certainly not be clever enough to overcome the more familiar but more formidable barriers to increasing energy supplies. My own view of the evidence is, first, that we are adaptable enough to use technical fixes *alone* to double, in the next few decades, the amount of social benefit we wring from each unit of end-use energy; and, second, that value changes which would either replace or supplement those technical changes are also occurring rapidly. If either of these views is right, or if both are partly right, we should be able to double end-use efficiency by the turn of the century or shortly thereafter, with minor or no changes in life-styles or values save increasing comfort for modestly increasing numbers. Then over the period 2010–40, we should be able to shrink per capita primary energy use to perhaps a third or a quarter of today's.[18] (The former would put us at the per capita level of the wasteful, but hardly troglodytic, French.) Even in the case of fourfold shrinkage, the resulting society could be instantly recognizable to a visitor from the 1960s and need in no sense be a pastoralist's utopia—though that option would remain open to those who may desire it.

The long-term mix of technical fixes with structural and value changes in work, leisure, agriculture and industry will require much trial and error. It will take many years to make up our diverse minds about. It will not be easy—merely easier than not doing it. Meanwhile it is easy only to see what not to do.

If one assumes that by resolute technical fixes and modest social innovation we can double our end-use efficiency by shortly after 2000, then we could be twice as affluent as now with today's level of energy use, or as affluent as now while using only half the end-use energy we use today. Or we might be somewhere

---

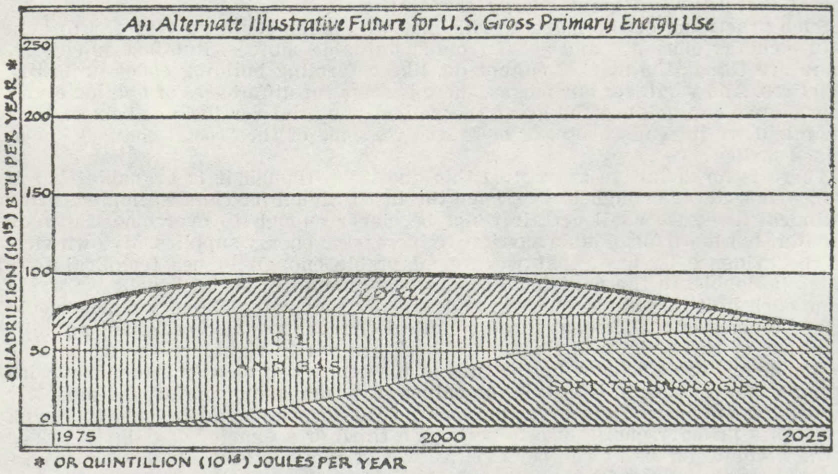
[18] A calculation for Canada supports this view: A. B. Lovins, *Conserver Society Notes* (Science Council of Canada, Ottawa), May/June 1976, pp. 3–16. Technical fixes already approved in principle by the Canadian Cabinet hold approximately constant until 1990 the energy required for the transport, commercial and house-heating sectors; sustaining similar measures to 2025 is estimated to shrink per capita primary energy to about half today's level. Plausible social changes are estimated to yield a further halving. The Canadian and U.S. energy systems have rather similar structures.

in between—significantly more affluent (and equitable) than today but with less end-use energy.

Many analysts now regard modest, zero or negative growth in our rate of energy use as a realistic long-term goal. Present annual U.S. primary energy demand is about 75 quadrillion BTU ("quads"), and most official projections for 2000 envisage growth to 130–170 quads. However, recent work at the Institute for Energy Analysis, Oak Ridge, under the direction of Dr. Alvin Weinberg, suggests that standard projections of energy demand are far too high because they do not take account of changes in demographic and economic trends. In June 1976 the Institute considered that with a conservation program far more modest than that contemplated in this article, the likely range of U.S. primary energy demand in the year 2000 would be about 101–126 quads, with the lower end of the range more probable and end-use energy being about 60–65 quads. And, at the further end of the spectrum, projections for 2000 being considered by the "Demand Panel" of a major U.S. National Research Council study, as of mid-1976, ranged as low as about 54 quads of fuels (plus 16 of solar energy).

As the basis for a coherent alternative to the path shown in Figure 1 earlier, a primary energy demand of about 95 quads for 2000 is sketched in Figure 2. Total energy demand would gradually decline thereafter as inefficient buildings, machines, cars and energy systems are slowly modified or replaced. Let us now explore the other ingredients of such a path—starting with the "soft" supply technologies which, spurned in Figure 1 as insignificant, now assume great importance.

FIGURE 2



V

There exists today a body of energy technologies that have certain specific features in common and that offer great technical, economic and political attractions, yet for which there is no generic term. For lack of a more satisfactory term, I shall call them "soft" technologies: a textural description, intended to mean not vague, mushy, speculative or ephemeral, but rather flexible, resilient, sustainable and benign. Energy paths dependent on soft technologies, illustrated in Figure 2, will be called "soft" energy paths, as the "hard" technologies sketched in Section II constitute a "hard" path (in both senses). The distinction between hard and soft energy paths rests not on how much energy is used, but on the technical and sociopolitical *structure* of the energy system, thus focusing our attention on consequent and crucial political differences.

In Figure 2, then, the social structure is significantly shaped by the rapid deployment of soft technologies. These are defined by five characteristics:

They rely on renewable flows that are always there whether we use them or not, such as sun and wind and vegetation: on energy income, not on depletable energy capital.

They are diverse, so that energy supply is an aggregate of very many individually modest contributions, each designed for maximum effectiveness in particular circumstances.

They are flexible and relatively low-technology—which does not mean unsophisticated, but rather, easy to understand and use without esoteric skills, accessible rather than arcane.

They are matched in *scale* and in geographic distribution to end-use needs, taking advantage of the free distribution of most natural energy flows.

They are matched in *energy quality* to end-use needs: a key feature that deserve immediate exploration.

People do not want electricity or oil, nor such economic abstractions as "residential services," but rather comfortable rooms, light, vehicular motion, food, tables, and other real things. Such end-use needs can be classified by the physical nature of the task to be done. In the United States today, about 58 percent of all energy at the point of end use is required as heat, split roughly equally between temperatures above and below the boiling point of water. (In Western Europe the low-temperature heat alone is often a half of all end-use energy.) Another 38 percent of all U.S. end-use energy provides mechanical motion: 31 percent in vehicles, 3 percent in pipelines, 4 percent in industrial electric motors. The rest, a mere 4 percent of delivered energy, represents *all* lighting, electronics, telecommunications, electrometallurgy, electrochemistry, arc-welding, electric motors in home appliances and in railways, and similar end-uses which now *require* electricity.

Some 8 percent of all our energy end-use, then, requires electricity for purposes other than low-temperature heating and cooling. Yet, since we actually use electricity for many such low-grade purposes, it now meets 13 percent of our end-use needs—and its generation consumes 29 percent of our fossil fuels. A hard energy path would increase this 13 percent figure to 20–40 percent (depending on assumptions) by the year 2000, and far more thereafter. But this is wasteful because the laws of physics require, broadly speaking, that a power station change three units of fuel into two units of almost useless waste heat plus one unit of electricity. This electricity can do more difficult kinds of work than can the original fuel, but unless this extra quality and versatility are used to advantage, the costly process of upgrading the fuel—and losing two-thirds of it—is all for naught.

Plainly we are using premium fuels and electricity for many tasks for which their high energy quality is superfluous, wasteful and expensive, and a hard path would make this inelegant practice even more common. Where we want only to create temperature differences of tens of degrees, we should meet the need with sources whose potential is tens or hundreds of degrees, not with a flame temperature of thousands or a nuclear temperature of millions—like cutting butter with a chainsaw.

For some applications, electricity is appropriate and indispensable: electronics, smelting, subways, most lighting, some kinds of mechanical work, and a few more. But these uses are already oversupplied, and for the other, dominant uses remaining in our energy economy this special form of energy cannot give us our money's worth (in many parts of the United States today it already costs \$50–\$120 per barrel-equivalent). Indeed, in probably no industrial country today can additional supplies of electricity be used to thermodynamic advantage which would justify their high cost in money and fuels.

So limited are the U.S. end-uses that really require electricity that by applying careful technical fixes to them we could reduce their 8 percent total to about 5 percent (mainly by reducing commercial overlighting), whereupon we could probably cover all those needs with present U.S. hydroelectric capacity plus the cogeneration capacity available in the mid-to-late 1980s.[19] Thus an affluent industrial economy could advantageously operate with no central power stations at all! In practice we would not necessarily want to go that far, at least not for a long time; but the possibility illustrates how far we are from supplying energy only in the quality needed for the task at hand.

A feature of soft technologies as essential as their fitting end-use needs (for a different reason) is their appropriate scale, which can achieve important types of economies not available to larger, more centralized systems. This is done in

[19] The scale of potential conservation in this area is given in Ross and Williams, *op. cit.*; the scale of potential cogeneration capacity is from McCracken *et al.*, *op. cit.*

five ways, of which the first is reducing and sharing overheads. Roughly half your electricity bill is fixed distribution costs to pay the overheads of a sprawling energy system: transmission lines, transformers, cables, meters and people to read them, planners, headquarters, billing computers, interoffice memos, advertising agencies. For electrical and some fossil-fuel systems, distribution accounts for more than half of total capital cost, and administration for a significant fraction of total operating cost. Local or domestic energy systems can reduce or even eliminate these infrastructure costs. The resulting savings can far outweigh the extra costs of the dispersed maintenance infrastructure that the small systems require, particularly where that infrastructure already exists or can be shared (e.g., plumbers fixing solar heaters as well as sinks).

Small scale brings further savings by virtually eliminating distribution losses, which are cumulative and pervasive in centralized energy systems (particularly those using high-quality energy). Small systems also avoid direct diseconomies of scale, such as the frequent unreliability of large units and the related need to provide instant "spinning reserve" capacity on electrical grids to replace large stations that suddenly fail. Small systems with short lead times greatly reduce exposure to interest, escalation and mistimed demand forecasts—major indirect diseconomies of large scale.

The fifth type of economy available to small systems arises from mass production. Consider, as Henrik Harboe suggests, the 100-odd million cars in this country. In round numbers, each car probably has an average cost of less than $4,000 and a shaft power over 100 kilowatts (134 horsepower). Presumably a good engineer could build a generator and upgrade an automobile engine to a reliable, 35-percent-efficient diesel at no greater total cost, yielding a mass-produced diesel generator unit costing less than $40 per kw. In contrast, the motive capacity in our central power stations—currently totaling about 1/40 as much as much as in our cars—costs perhaps ten times more per kw, partly because it is not mass-produced. It is not surprising that at least one foreign car maker hopes to go into the wind-machine and heat-pump business. Such a market can be entered incrementally, without the billions of dollars' investment required for, say, liquefying natural gas or gasifying coal. It may require a production philosophy oriented toward technical simplicity, low replacement cost, slow obsolescence, high reliability, high volume and low markup; but these are familiar concepts in mass production. Industrial resistance would presumably melt when—as with pollution-abatement equipment—the scope for profit was perceived.

This is not to say that all energy systems need be at domestic scale. For example, the medium scale of urban neighborhoods and rural villages offers fine prospects for solar collectors—especially for adding collectors to existing buildings of which some (perhaps with large flat roofs) can take excess collector area while others cannot take any. They could be joined via communal heat storage systems, saving on labor cost and on heat losses. The costly craftwork of remodeling existing systems—"backfitting" idiosyncratic houses with individual collectors—could thereby be greatly reduced. Despite these advantages, medium-scale solar technologies are currently receiving little attention apart from a condominium-village project in Vermont sponsored by the Department of Housing and Urban Development and the 100-dwelling-unit Mejannes-le-Clap project in France.

The schemes that dominate ERDA's solar research budget—such as making electricity from huge collectors in the desert, or from temperature differences in the oceans, or from Brooklyn Bridge-like satellites in outer space—do not satisfy our criteria, for they are ingenious high-technology ways to supply energy in a form and at a scale inappropriate to most end-use needs. Not all solar technologies are soft. Nor, for the same reason, is nuclear fusion a soft technology.[20] But many genuine soft technologies are now available and are now economic. What are some of them?

[20] Assuming (which is still not certain) that controlled nuclear fusion works, it will almost certainly be more difficult, complex and costly—though safer and perhaps more permanently fueled—than fast-breeder reactors. See W. D. Mertz, *Science 192:* 1320–23 (1976), *193:* 38–40, 76 (1976), and *193:* 307–309 (1976). But for three reasons we ought not to pursue fusion. First, it generally produces copious fast neutrons that can and probably would be used to make bomb materials. Second, if it turns out to be rather "dirty," as most fusion experts expect, we shall probably use it anyway, whereas if it is clean, we shall so overuse it that the resulting heat release will alter global climate; we should prefer energy sources that give us enough for our needs while denying the excesses of concentrated energy with which we might do mischief to the earth or to each other. Third, fusion is a clever way to do something we don't really want to do, namely to find *yet another* complex, costly, large-scale, centralized, high-technology way to make electricity—all of which goes in the wrong direction.

Solar heating and, imminently, cooling head the list. They are incrementally cheaper than electric heating, and far more inflationproof, practically anywhere in the world.[21] In the United States (with fairly high average sunlight levels), they are cheaper than present electric heating virtually anywhere, cheaper than oil heat in many parts, and cheaper than gas and coal in some. Even in the least favorable parts of the continental United States, far more sunlight falls on a typical building than is required to heat and cool it without supplement; whether this is considered economic depends on how the accounts are done.[22] The difference in solar input between the most and least favorable parts of the lower 49 states is generally less than two-fold, and in cold regions, the long heating season can improve solar economics.

Ingenious ways of backfitting existing urban and rural buildings (even large commercial ones) or their neighborhoods with efficient and exceedingly reliable solar collectors are being rapidly developed in both the private and public sectors. In some recent projects, the lead time from ordering to operation has been only a few months. Good solar hardware, often modular, is going into pilot or full-scale production over the next few years, and will increasingly be integrated into buildings as a multipurpose structural element, thereby sharing costs. Such firms as Philips, Honeywell, Revere, Pittsburgh Plate Glass, and Owens-Illinois, plus many dozens of smaller firms, are applying their talents, with rapid and accelerating effect, to reducing unit costs and improving performance. Some novel types of very simple collectors with far lower costs also show promise in current experiments. Indeed, solar hardware per se is necessary only for backfitting existing buildings. If we build new buildings properly in the first place, they can use "passive" solar collectors—large south windows or glass-covered black south walls—rather than special collectors. If we did this to all new houses in the next 12 years, we would save about as much energy as we expect to recover from the Alaskan North Slope.[23]

Secondly, exciting developments in the conversion of agricultural, forestry and urban wastes to methanol and other liquid and gaseous fuels now offer practical, economically interesting technologies sufficient to run an efficient U.S. transport sector.[24] Some bacterial and enzymatic routes under study look even more promising, but presently proved processes already offer sizable contributions without the inevitable climatic constraints of fossil-fuel combustion. Organic conversion technologies must be sensitively integrated with agriculture and forestry so as not to deplete the soil; most current methods seem suitable in this respect, though they may change the farmer's priorities by making his whole yield of biomass (vegetable matter) salable.

The required scale of organic conversion can be estimated. Each year the U.S. beer and wine industry, for example, microbiologically produces 5 percent as many gallons (not all alcohol, of course) as the U.S. oil industry produces gasoline. Gasoline has 1.5–2 times the fuel value of alcohol per gallon. Thus a conversion industry roughly 10 to 14 times the scale (in gallons of fluid output per year) of our cellars and breweries would produce roughly one-third of the present gasoline requirements of the United States; if one assumes a transport sector with three times today's average efficiency—a reasonable estimate for early in the next century—then the whole of the transport needs could be met by organic conversions. The scale of effort required does not seem unreasonable, since it would replace in function half our refinery capacity.

Additional soft technologies include wind-hydraulic systems (especially those with a vertical axis), which already seem likely in many design studies to compete with nuclear power in much of North America and Western Europe. But wind is not restricted to making electricity it can heat, pump, heat-pump, or compress air. Solar process heat, too, is coming along rapidly as we learn to use the 5,800°C. potential of sunlight (much hotter than a boiler). Finally, high- and low-temperature solar collectors, organic converters, and wind machines can form symbiotic hybrid combinations more attractive than the separate components.

---

[21] Partly or wholly solar heating is attractive and is being demonstrated even in cloudy countries approaching the latitude of Anchorage, such as Denmark and the Netherlands (International CIB Symposium, *op. cit.*) and Britain (*Solar Energy: A U.K. Assessment*, International Solar Energy Society, London, May 1976).

[22] Solar heating cost is traditionally computed microeconomically for a consumer whose alternative fuels are not priced at long-run marginal cost. Another method would be to compare the total cost (capital and life-cycle) of the solar system with the total cost of the other complete systems that would otherwise have to be used in the long run to heat the same space. On that basis, 100 percent solar heating, even with twice the capital cost of two-thirds or three-fourths solar heating, is almost always advantageous.

[23] R. W. Bliss, *Bulletin of the Atomic Scientists*, March 1976, pp. 32–40.

[24] A. D. Poole and R. H. Williams, *Bulletin of the Atomic Scientists*, May 1976, pp. 48–58.

Energy storage is often said to be a major problem of energy-income technologies. But this "problem" is largely an artifact of trying to recentralize, upgrade and redistribute inherently diffuse energy flows. Directly storing sunlight or wind—or, for that matter, electricity from any source—is indeed difficult on a large scale. But it is easy if done on a scale and in an energy quality matched to most end-use needs. Daily, even seasonal, storage of low- and medium-temperature heat at the point of use is straightforward with water tanks, rock beds, or perhaps fusible salts. Neighborhood heat storage is even cheaper. In industry, wind-generated compressed air can easily (and, with due care, safely) be stored to operate machinery the technology is simple, cheap, reliable and highly developed. (Some cities even used to supply compressed air as a standard utility.) Installing pipes to distribute hot water (or compressed air) tends to be considerably cheaper than installing equivalent electric distribution capacity. Hydroelectricity is stored behind dams, and organic conversion yields readily stored liquid and gaseous fuels. On the whole, therefore, energy storage is much less of a problem in a soft energy economy than in a hard one.

Recent research suggests that a largely or wholly solar economy can be constructed in the United States with straightforward soft technologies that are now demonstrated and now economic or nearly economic.[25] Such a conceptual exercise does not require "exotic" methods such as sea-thermal, hot-dry-rock geothermal, cheap (perhaps organic) photovoltaic, or solar-thermal electric systems. If developed, as some probably will be, these technologies could be convenient, but they are in no way essential for an industrial society operating solely on energy income.

Figure 2 shows a plausible and realistic growth pattern, based on several detailed assessments, for soft technologies given aggressive support. The useful output from these technologies would overtake, starting in the 1990s, the output of nuclear electricity shown in even the most sanguine federal estimates. For illustration, Figure 2 shows soft technologies meeting virtually all energy needs in 2025, reflecting a judgment that a completely soft supply mix is practicable in the long run with or without the 2000–25 energy shrinkage shown. Though most technologists who have thought seriously about the matter will concede it conceptually, some may be uneasy about the details. Obviously the sketched curve is not definitive, for although the general direction of the soft path must be shaped soon, the details of the energy economy in 2025 would not be committed in this century. To a large extent, therefore, it is enough to ask yourself whether Figure 1 or 2 seems preferable in the 1975–2000 period.

A simple comparison may help. Roughly half, perhaps more, of the gross primary energy being produced in the hard path in 2025 is lost in conversions. A further appreciable fraction is lost in distribution. Delivered end-use energy is thus not vastly greater than in the soft path, where conversion and distribution losses have been all but eliminated. (What is lost can often be used locally for heating, and is renewable, not depletable.) But the soft path makes each unit of end-use energy perform several times as much social function as it would have done in the hard path; so in a conventional sense, social welfare in the soft path in 2025 is substantially greater than in the hard path at the same date.

VI

To fuse into a coherent strategy the benefits of energy efficiency and of soft technologies, we need one further ingredient: transitional technologies that use fossil fuels briefly and sparingly to build a bridge to the energy-income economy of 2025, conserving those fuels—especially oil and gas—for petrochemicals (ammonia, plastics, etc.) and leaving as much as possible in the ground for emergency use only.

Some transitional technologies have already been mentioned under the heading of conservation—specifically, cogenerating electricity from existing industrial steam and using existing waste heat for district heating. Given such measures, increased end-use efficiency, and the rapid development of biomass alcohol as a portable liquid fuel, the principal short- and medium-term problem becomes, not a shortage of electricity or of portable liquid fuels, but a shortage of clean sources of heat. It is above all the sophisticated use of coal, chiefly at modest scale, that

---

[25] For examples, see the Canadian computations in A. B. Lovins, *Conserver Society Notes*, *op. cit.*; Bent Sørenson's Danish estimates in *Science 189*: 225–60 (1975); and the estimates by the Union of Concerned Scientists, footnote 1 above.

needs development. Technical measures to permit the highly efficient use of this widely available fuel would be the most valuable transitional technologies.

Neglected for so many years, coal technology is now experiencing a virtual revolution. We are developing supercritical gas extraction, flash hydrogenation, flash pyrolysis, panel-bed filters and similar ways to use coal cleanly at essentially any scale and to cream off valuable liquids and gases as premium fuels before burning the rest. These methods largely avoid the costs, complexity, inflexibility, technical risks, long lead times, large scale, and tar formation of the traditional processes that now dominate our research.

Perhaps the most exciting current development is the so-called fluidized-bed system for burning coal (or virtually any other combustible material). Fluidized beds are simple, versatile devices that add the fuel a little at a time to a much larger mass of small, inert, red-hot particles—sand or ceramic pellets—kept suspended as an agitated fluid by a stream of air continuously blown up through it from below.

The efficiency of combustion, of other chemical reactions (such as sulfur removal), and of heat transfer is remarkably high because of the turbulent mixing and large surface area of the particles. Fluidized beds have long been used as chemical reactors and for burning trash, but are now ready to be commercially applied to raising steam and operating turbines. In one system currently available from Stal-Laval Turbin AB of Sweden, eight off-the-shelf 70-megawatt gas turbines powered by fluidized-bed combusters, together with district-heating networks and heat pumps, would heat as many houses as a $1 billion-plus coal gasification plant, but would use only two-fifths as much coal, cost a half to two-thirds as much to build, and burn more cleanly than a normal power station with the best modern scrubbers.[26]

Fluidized-bed boilers and turbines can power giant industrial complexes, especially for cogeneration, and are relatively easy to backfit into old municipal power stations. Scaled down, a fluidized bed can be a tiny household device—clean, strikingly simple and flexible—that can replace an ordinary furnace or grate and can recover combustion heat with an efficiency over 80 percent.[27] At medium scale, such technologies offer versatile boiler backfits and improve heat recovery in flues. With only minor modifications they can burn practically any fuel. It is essential to commercialize all these systems now—not to waste a decade on highly instrumented noncommercial pilot plants constrained to a narrow, even obsolete design philosophy.[28]

Transitional technologies can be built at appropriate scale so that soft technologies can be plugged into the system later. For example, if district heating uses hot water tanks on a neighborhood scale, those tanks can in the long run be heated by neighborhood solar collectors, wind-driven heat pumps, a factory, a pyrolyzer, a geothermal well, or whatever else becomes locally available—offering flexibility that is not possible at today's excessive scale.

Both transitional and soft technologies are worthwhile industrial investments that can recycle moribund capacity and underused skills, stimulate exports, and give engaging problems to innovative technologists. Though neither glamorous nor militarily useful, these technologies are socially effective—especially in poor countries that need such scale, versatility and simplicity even more than we do.

Properly used, coal, conservation, and soft technologies together can squeeze the "oil and gas" wedge in Figure 2 from both sides—so far that most of the frontier extraction and medium-term imports of oil and gas become unnecessary and our conventional resources are greatly stretched. Coal can fill the real gaps in our fuel economy with only a temporary and modest (less than twofold at peak) expansion of mining, not requiring the enormous infrastructure and social impacts implied by the scale of coal use in Figure 1.

---

[26] The system and its conceptual framework are described in several papers by H. Harboe, Managing Director, Stal-Laval (G.B.) Ltd., London: "District Heating and Power Generation," November 14, 1975: "Advances in Coal Combustion and Its Applications," February 20, 1976; "Pressurized Fluidized Bed Combustion with Special Reference to Open Gas Turbine" (with C. W. Maude), May 1976. See also K. D. Kiang *et al.*, "Fluidized-Bed Combustion of Coals," GFERC/IC–75/2 (CONF–750586), ERDA, May 1975.

[27] Small devices were pioneered by the late Professor Douglas Elliott. His associated firm, Fluidfire Development, Ltd. (Netherton, Dudley, W. Midlands, England), has sold many dozens of units for industrial heat treatment or heat recuperation. Field tests of domestic packaged fluidized-bed boilers are in progress in the Netherlands and planned in Montana.

[28] Already Linköping, Sweden, is evaluating bids from several confident vendors for a 15-megawatt fluidized-bed boiler to add to its district heating system. New reviews at the Institute for Energy Analysis and elsewhere confirm fluidized beds' promise of rapid benefits without massive research programs.

In sum, Figure 2 outlines a prompt redirection of effort at the margin that lets us use fossil fuels intelligently to buy the time we need to change over to living on our energy income. The innovations required, both technical and social, compete directly and immediately with the incremental actions that constitute a hard energy path: fluidized beds vs. large coal gasification plants and coal-electric stations, efficient cars vs. offshore oil, roof insulation vs. Arctic gas, cogeneration vs. nuclear power. These two directions of development are mutually exclusive: the pattern of commitments of resources and time required for the hard energy path and the pervasive infrastructure which it accretes gradually make the soft path less and less attainable. That is, our two sets of choices compete not only in what they accomplish, but also in what they allow us to contemplate later. Figure 1 obscures this constriction of options, for it peers myopically forward, one power station at a time, extrapolating trend into destiny by self-fulfilling prophecy with no end clearly in sight. Figure 2, in contrast, works backward from a strategic goal, asks what we must do when in order to get there, and thus reveals the potential for a radically different path that would be invisible to anyone working forward in time by incremental ad-hocracy.

VII

Both the soft and the hard paths bring us, each in its own way and at broadly similar rates, to the era beyond oil and gas. But the rates of internal adaptation meanwhile are different. As we have seen, the soft path relies on smaller, far simpler supply systems entailing vastly shorter development and construction time, and on smaller, less sophisticated management systems. Even converting the urban clusters of a whole country to district heating should take only 30–40 years. Furthermore, the soft path relies mainly on small, standard, easy-to-make components and on technical resources dispersed in many organizations of diverse sizes and habits; thus everyone can get into the act, unimpeded by centralized bureaucracies, and can compete for a market share through ingenuity and local adaptation. Besides having much lower and more stable operating costs than the hard path, the soft path appears to have lower initial cost because of its technical simplicity, small unit size, very low overheads, scope for mass production, virtual elimination of distribution losses and of interfuel conversion losses, low exposure to escalation and interest, and prompt incremental construction (so that new capacity is built only when and where it is needed).[29]

The actual costs of whole systems, however, are not the same as perceived costs; solar investments are borne by the householder, electric investments by a utility that can float low-interest bonds and amortize over 30 years. During the transitional era, we should therefore consider ways to broaden householders' access to capital markets. For example, the utility could finance the solar investment (leaving its execution to the householder's discretion), then be repaid in installments corresponding to the householder's saving. The householder would thus minimize his own—and society's—long-term costs. The utility would have to raise several times less capital than it would without such a scheme—for otherwise it would have to build new electric or synthetic-gas capacity at even higher cost—and would turn over its money at least twice as quickly, thus retaining an attractive rate of return on capital. The utility would also avoid social obsolescence and use its existing infrastructure. Such incentives have already led several U.S. gas utilities to use such a capital-transfer scheme to finance roof insulation.

Next, the two paths differ even more in risks than in costs. The hard path entails serious environmental risks, many of which are poorly understood and

---

[29] Estimates of the total capital cost of "soft" systems are necessarily less well developed than those for the "hard" system. For 100-percent solar space heating, one of the high priority soft technologies, mid-1980's estimates are about $50,000–$60,000 (1976 dollars) of investment per daily oil-barrel-equivalent in the United States, $100,000 in Scandinavia. All marginal capital costs should suffice. For biomass conversion, the 1974 FEA Solar Task Force solar cost estimates, however, depend sensitively on the collector and building design both under rapid development. In most new buildings, passive solar systems with negligible or negative marginal capital costs should suffice. For biomass conversion, the 1974 FEA Solar Task Force estimated capital costs of $10,000–$30,000 per daily barrel equivalent—toward the lower part of this range for most agricultural projects. Currently available wind-electric systems require total-system investment as high as about $200,000 per delivered daily barrel, with much improvement in store. As for transitional technologies, the Stal-Laval fluidized-bed gas-turbine system, complete with district-heating network and heat-pumps (coefficient of performance=2), would cost about $30,000 per delivered daily barrel equivalent. See Lovins, *op. cit.*, footnote 7.

some of which have probably not yet been thought of. Perhaps the most awkward risk is that late in this century, when it is too late to do much about it, we may well find climatic constraints on coal combustion about to become acute in a few more decades: for it now takes us only that long, not centuries or millennia, to approach such outer limits. The soft path, by minimizing all fossil-fuel combustion, hedges our bets. Its environmental impacts are relatively small, tractable and reversible.[30]

The hard path, further, relies on a very few high technologies whose success is by no means assured. The soft path distributes the technical risk among very many diverse low technologies, most of which are already known to work well. They do need sound engineering—a solar collector or heat pump can be worthless if badly designed—but the engineering is of an altogether different and more forgiving order than the hard path requires, and the cost of failure is much lower both in potential consequences and in number of people affected. The soft path also minimizes the economic risks to capital in case of error, accident or sabotage; the hard path effectively maximizes those risks by relying on vulnerable high-technology devices each costing more than the endowment of Harvard University. Finally, the soft path appears generally more flexible—and thus robust. Its technical diversity, adaptability, and geographic dispersion make it resilient and offer a good prospect of stability under a wide range of conditions, foreseen or not. The hard path, however, is brittle; it must fail, with widespread and serious disruption, if any of its exacting technical and social conditions is not satisfied continuously and indefinitely.

VIII

The soft path has novel and important international implications. Just as improvements in end-use efficiency can be used at home (via innovative financing and neighborhood self-help schemes) to lessen first the disproportionate burden of energy waste on the poor, so can soft technologies and reduced pressure on oil markets especially benefit the poor abroad. Soft technologies are ideally suited for rural villagers and urban poor alike, directly helping the more than two billion people who have no electric outlet nor anything to plug into it but who need ways to heat, cook, light and pump. Soft technologies do not carry with them inappropriate cultural patterns or values; they capitalize on poor countries' most abundant resources (including such protein-poor plants as cassava, eminently suited to making fuel alcohols), helping to redress the severe energy imbalance between temperate and tropical regions; they can often be made locally from local materials and do not require a technical elite to maintain them; they resist technological dependence and commercial monopoly; they conform to modern concepts of agriculturally based eco-development from the bottom up, particularly in the rural villages.

Even more crucial, unilateral adoption of a soft energy path by the United States can go a long way to control nuclear proliferation—perhaps to eliminate it entirely. Many nuclear advocates have missed this point: believing that there is no alternative to nuclear power, they say that if the United States does not export nuclear technology, others will, so we might as well get the business and try to use it as a lever to slow the inevitable spread of nuclear weapons to nations and subnational groups in other regions. Yet the genie is not wholly out of the bottle yet—thousands of reactors are planned for a few decades hence, tens of thousands thereafter—and the cork sits unnoticed in our hands.

Perhaps the most important opportunity available to us stems from the fact that for at least the next five or ten years, while nuclear dependence and commitments are still reversible, all countries will continue to rely on the United States for the technical, the economic, and especially the *political* support they need to justify their own nuclear programs. Technical and economic dependence is intricate and pervasive; political dependence is far more important but has been almost ignored, so we do not yet realize the power of the American example in an essentially imitative world where public and private divisions over nuclear policy are already deep and grow deeper daily.

---

[30] See A. B. Lovins, "Long-Term Constraints on Human Activity," *Environmental Conservation 3*, 1: 3–14 (1976) (Geneva); "Some Limits to Energy Conversion," Limits to Growth 1975 Conference (The Woodlands, Texas), October 20, 1975 (to be published in conference papers). The environmental and social impacts of solar technologies are being assessed in a study coordinated by J. W. Benson (ERDA Solar Division), to be completed autumn 1976.

The fact is that in almost all countries the domestic political base to support nuclear power is not solid but shaky. However great their nuclear ambitions, other countries must still borrow that political support from the United States. Few are succeeding. Nuclear expansion is all but halted by grass-roots opposition in Japan and the Netherlands; has been severely impeded in West Germany, France, Switzerland, Italy and Austria; has been slowed and may soon be stopped in Sweden; has been rejected in Norway and (so far) Australia and New Zealand, as well as in two Canadian Provinces; faces an uncertain prospect in Denmark and many American states; has been widely questioned in Britain, Canada, and the U.S.S.R.;[31] and has been opposed in Spain, Brazil, India, Thailand and elsewhere.

Consider the impact of three prompt, clear U.S. statements:

> The United States will phase out its nuclear power program[32] and its support of others' nuclear power programs.
>
> The United States will redirect those resources into the tasks of a soft energy path and will freely help any other interested countries to do the same, seeking to adapt the same broad principles to others' needs and to learn from shared experience.
>
> The United States will start to treat nonproliferation, control of civilian fission technology, and strategic arms reduction as interrelated parts of the same problem with intertwined solutions.

I believe that such a universal, nondiscriminatory package of policies would be politically irresistible to North and South, East and West alike. It would offer perhaps our best chance of transcending the hypocrisy that has stalled arms control: by no longer artificially divorcing civilian from military nuclear technology, we would recognize officially the real driving forces behind proliferation; and we would no longer exhort others not to acquire bombs while claiming that we ourselves feel more secure with bombs than without them.

Nobody can be certain that such a package of policies, going far beyond a mere moratorium, would work. The question has received far too little thought, and political judgments differ. My own, based on the past nine years' residence in the midst of the European nuclear debate, is that nuclear power could not flourish there if the United States did not want it to.[33] In giving up the export market that our own reactor designs have dominated, we would be demonstrating a desire for peace, not profit, thus allaying legitimate European commercial suspicions. Those who believe such a move would be seized upon gleefully by, say, French exporters are seriously misjudging French nuclear politics. Skeptics, too, have yet to present a more promising alternative—a credible set of technical and political measures for meticulously restricting to peaceful purposes extremely large amounts of bomb materials which, once generated, will persist for the foreseeable lifetime of our species.

I am confident that the United States can still turn off the technology that it originated and deployed. By rebottling that genie we could move to energy and foreign policies that our grandchildren can live with. No more important step could be taken toward revitalizing the American dream.

IX

Perhaps the most profound difference between the soft and hard paths is their domestic sociopolitical impact. Both paths, like any 50-year energy path, entail significant social change. But the kinds of social change needed for a hard path are apt to be much less pleasant, less plausible, less compatible with social diversity and personal freedom of choice, and less consistent with traditional values than are the social changes that could make a soft path work.

It is often said that, on the contrary, a soft path must be repressive; and coercive paths to energy conservation and soft technologies can indeed be imagined. But coercion is not necessary and its use would signal a major failure

---

[31] Recent private reports indicate the Soviet scientific community is deeply split over the wisdom of nuclear expansion. See also *Nucleonics Week*, May 13, 1976, pp. 12–13.

[32] Current overcapacity, capacity under construction, and the potential for rapid conservation and cogeneration make this a relatively painless course, whether nuclear generation is merely frozen or phased out altogether. For an illustration (the case of California), see R. Doctor *et al.*, *Sierra Club Bulletin*, May 1976, pp. 4ff. I believe the same is true abroad. See Introduction to *Non-Nuclear Futures* by A. B. Lovins and J. H. Price, Cambridge, Mass.: FOE/Ballinger, 1975.

[33] See *Nucleonics Week*, May 6, 1976, p. 7, and I. C. Bupp and J. C. Derian, "Nuclear Reactor Safety: The Twilight of Probability," December 1975. Bupp, after a detailed study of European nuclear politics, shares this assessment.

of imagination, given the many policy instruments available to achieve a given technical end. Why use penal legislation to encourage roof insulation when tax incentives and education (leading to the sophisticated public understanding now being achieved in Canada and parts of Europe) will do? Policy tools need not harm life-styles or liberties if chosen with reasonable sensitivity.

In contrast to the soft path's dependence on pluralistic consumer choice in deploying a myriad of small devices and refinements, the hard path depends on difficult, large-scale projects requiring a major social commitment under centralized management. We have noted in Section II the extraordinary capital intensity of centralized, electrified high technologies. Their similarly heavy demands on other scarce resources—skills, labor, materials, special sites—likewise cannot be met by market allocation, but require compulsory diversion from whatever priorities are backed by the weakest constituencies. Quasi-warpowers legislation to this end has already been seriously proposed. The hard path, sometimes portrayed as the bastion of free enterprise and free markets, would instead be a world of subsidies, $100-billion bailouts, oligopolies, regulations, nationalization, eminent domain, corporate statism.

Such dirigiste autarchy is the first of many distortions of the political fabric. While soft technologies can match any settlement pattern, their diversity reflecting our own pluralism, centralized energy sources encourage industrial clustering and urbanization. While soft technologies give everyone the costs and benefits of the energy system he chooses, centralized systems allocate benefits to suburbanites and social costs to politically weaker rural agrarians. Siting big energy systems pits central authority against local autonomy in an increasingly divisive and wasteful form of centrifugal politics that is already proving one of the most potent constraints on expansion.

In an electrical world, your lifeline comes not from an understandable neighborhood technology run by people you know who are at your own social level, but rather from an alien, remote, and perhaps humiliatingly uncontrollable technology run by a faraway, bureaucratized, technical elite who have probably never heard of you. Decisions about who shall have how much energy at what price also become centralized—a politically dangerous trend because it divides those who use energy from those who supply and regulate it.

The scale and complexity of centralized grids not only make them politically inaccessible to the poor and weak, but also increase the likelihood and size of malfunctions, mistakes and deliberate disruptions. A small fault or a few discontented people become able to turn off a country. Even a single rifleman can probably black out a typical city instantaneously. Societies may therefore be tempted to discourage disruption through stringent controls akin to a garrison state. In times of social stress, when grids become a likely target for dissidents, the sector may be paramilitarized and further isolated from grass-roots politics.

If the technology used, like nuclear power, is subject to technical surprises and unique psychological handicaps, prudence or public clamor may require generic shutdowns in case of an unexpected type of malfunction: one may have to choose between turning off a country and persisting in potentially unsafe operation. Indeed, though many in the $100-billion quasi-civilian nuclear industry agree that it could be politically destroyed if a major accident occurred soon, few have considered the economic or political implications of putting at risk such a large fraction of societal capital. How far would governments go to protect against a threat—even a purely political threat—a basket full of such delicate, costly and essential eggs? Already in individual nuclear plants, the cost of a shutdown—often many dollars a second—weighs heavily, perhaps too heavily, in operating and safety decisions.

Any demanding high technology tends to develop influential and dedicated constituencies of those who link its commercial success with both the public welfare and their own. Such sincerely held beliefs, peer pressures, and the harsh demands that the work itself places on time and energy all tend to discourage such people from acquiring a similarly thorough knowledge of alternative policies and the need to discuss them. Moreover, the money and talent invested in an electrical program tend to give it disproportionate influence in the counsels of government, often directly through staff-swapping between policy- and mission-oriented agencies. This incestuous position, now well developed in most industrial countries, distorts both social and energy priorities in a lasting way that resists political remedy.

For all these reasons, if nuclear power were clean, safe, economic, assured of ample fuel, and socially benign per se, it would still be unattractive because of the kind of energy economy it would lock us into. But fission technology also has unique sociopolitical side-effects arising from the impact of human fallibility and malice on the persistently toxic and explosive materials in the fuel cycle. For example, discouraging nuclear violence and coercion requires some abrogation of civil liberties;[34] guarding long-lived wastes against geological or social contingencies implies some form of hierarchical social rigidity or homogeneity to insulate the technological priesthood from social turbulence; and making political decisions about nuclear hazards which are compulsory, remote from social experience, disputed, unknown, or unknowable, may tempt governments to bypass democratic decision in favor of elitist technocracy.[35]

Even now, the inability of our political institutions to cope with nuclear hazard is straining both their competence and their perceived legitimacy. There is no scientific basis for calculating the likelihood or the maximum long-term effects of nuclear mishaps, or for guaranteeing that those effects will not exceed a particular level; we know only that all precautions are, for fundamental reasons, inherently imperfect in essentially unknown degree. Reducing that imperfection would require much social engineering whose success would be speculative. Technical success in reducing the hazards would not reduce, and might enhance, the need for such social engineering. The most attractive political feature of soft technologies and conservation—the alternatives that will let us avoid these decisions and their high political costs—may be that, like motherhood, everyone is in favor of them.

X

Civilization in this country, according to some, would be inconceivable if we used only, say, half as much electricity as now. But that is what we did use in 1963, when we were at least half as civilized as now. What would life be like at the per capita levels of primary energy that we had in 1910 (about the present British level) but with doubled efficiency of energy use and with the important but not very energy-intensive amenities we lacked in 1910, such as telecommunications and modern medicine? Could it not be at least as agreeable as life today? Since the energy needed today to produce a unit of GNP varies more than 100-fold depending on what good or service is being produced, and since GNP in turn hardly measures social welfare, why must energy and welfare march forever in lockstep? Such questions today can be neither answered nor ignored.

Underlying energy choices are real but tacit choices of personal values. Those that make a high-energy society work are all too apparent. Those that could sustain life-styles of elegant frugality are not new; they are in the attic and could be dusted off and recycled. Such values as thrift, simplicity, diversity, neighborliness, humility and craftsmanship—perhaps most closely preserved in politically conservative communities—are already, as we see from the ballot box and the census, embodied in a substantial social movement, camouflaged by its very pervasiveness. Offered the choice freely and equitably, many people would choose, as Herman Daly puts it, "growth in things that really count rather than in things that are merely countable": choose not to transform, in Duane Elgin's phrase, "a rational concern for material well-being into an obsessive concern for unconscionable levels of material consumption."

Indeed, we are learning that many of the things we had taken to be the benefits of affluence are really remedial costs, incurred in the pursuit of benefits that might be obtainable in other ways without those costs. Thus much of our prized personal mobility is really involuntary traffic made necessary by the settlement patterns which cars create. Is that traffic a cost or a benefit?

Pricked by such doubts, our inflated craving for consumer ephemerals is giving way to a search for both personal and public purpose, to reexamination of the legitimacy of the industrial ethic. In the new age of scarcity, our ingenious strivings to substitute abstract (therefore limitless) wants for concrete (therefore reasonably bounded) needs no longer seem so virtuous. But where we used to accept unquestioningly the facile (and often self-serving) argument that traditional economic growth and distributional equity are inseparable, new moral and humane stirrings now are nudging us. We can now ask whether we are not already so wealthy that further growth, far from being essential to addressing our equity problems, is instead an excuse not to mobilize the compassion and commitment that could solve the same problems with or without the growth.

---

[34] R. Ayres, *10 Harvard Civil Rights-Civil Liberties, Law Review*, Spring 1975, pp. 369–443; J. H. Barton, "Intensified Nuclear Safeguards and Civil Liberties," report to USNRC, Stanford Law School, October 21, 1975.

[35] H. P. Green, *43 George Washington Law Review*, March 1975, pp. 791–807.

Finally, as national purpose and trust in institutions diminish, governments, striving to halt the drift, seek ever more outward control. We are becoming more uneasily aware of the nascent risk of what a Stanford Research Institute group has called ". . . 'friendly fascism'—a managed society which rules by a faceless and widely dispersed complex of warfare-welfare-industrial-communications-police bureaucracies with a technocratic ideology." In the sphere of politics as of personal values, could many strands of observable social change be converging on a profound cultural transformation whose implications we can only vaguely sense: one in which energy policy, as an integrating principle, could be catalytic?[36]

It is not my purpose here to resolve such questions—only to stress their relevance. Though fuzzy and unscientific, they are the beginning and end of any energy policy. Making values explicit is essential to preserving a society in which diversity of values can flourish.

Some people suppose that a soft energy path entails mainly social problems, a hard path mainly technical problems, so that since in the past we have been better at solving the technical problems, that is the kind we should prefer to incur now. But the hard path, too, involves difficult social problems. We can no longer escape them; we must choose which kinds of social problems we want. The most important, difficult, and neglected questions of energy strategy are not mainly technical or economic but rather social and ethical. They will pose a supreme challenge to the adaptability of democratic institutions and to the vitality of our spiritual life.

XI

These choices may seem abstract, but they are sharp, imminent and practical. We stand at a crossroads: without decisive action our options will slip away. Delay in energy conservation lets wasteful use run on so far that the logistical problems of catching up become insuperable. Delay in widely deploying diverse soft technologies pushes them so far into the future that there is no longer a credible fossil-fuel bridge to them: they must be well under way before the worst part of the oil-and-gas decline. Delay in building the fossil-fuel bridge makes it too tenuous: what the sophisticated coal technologies can give us, in particular, will no longer mesh with our pattern of transitional needs as oil and gas dwindle.

Yet these kinds of delay are exactly what we can expect if we continue to devote so much money, time, skill, fuel and political will to the hard technologies that are so demanding of them. Enterprises like nuclear power are not only unnecessary but a positive encumbrance for they prevent us, through logistical competition and cultural incompatibility, from pursuing the tasks of a soft path at a high enough priority to make them work together properly. A hard path can make the attainment of a soft path prohibitively difficult, both by starving its components into garbled and incoherent fragments and by changing social structures and values in a way that makes the innovations of a soft path more painful to envisage and to achieve. As a nation, therefore, we must choose one path before they diverge much further. Indeed, one of the infinite variations on a soft path seems inevitable, either smoothly by choice now or disruptively by necessity later; and I fear that if we do not soon make the choice, growing tensions between rich and poor countries may destroy the conditions that now make smooth attainment of a soft path possible.

These conditions will not be repeated. Some people think we can use oil and gas to bridge to a coal and fission economy, then use that later, if we wish, to bridge to similarly costly technologies in the hazy future. But what if the bridge we are now on is the last one? Our past major transitions in energy supply were smooth because we subsidized them with cheap fossil fuels. Now our new energy supplies are ten or a hundred times more capital-intensive and will stay that way. If our future capital is generated by economic activity fueled by synthetic gas at $25 a barrel-equivalent, nuclear electricity at $60—120 a barrel-equivalent, and the like, and if the energy sector itself requires much of that capital just to maintain itself, will capital still be as cheap and plentiful as it is now, or will we have fallen into a "capital trap"? Wherever we make our present transition to, once we arrive we may be stuck there for a long time. Thus if neither the soft nor the hard path were preferable on cost or other grounds, we would still be wise to use our remaining cheap fossil fuels—sparingly—to finance a transition as nearly as possible straight to our ultimate energy-income sources. We shall not have another chance to get there.

---

[36] W. W. Harman, *An Incomplete Guide to the Future,* Stanford Alumni Association, 1976.

[Reprinted from Bulletin of the Atomic Scientists, vol. 31, December 1975]

ENERGY AND PROSPERITY—SOME ELEMENTS OF A GLOBAL PERSPECTIVE

(By John P. Holdren*)

Civilization is not running out of energy; but it is running out of cheap energy, out of environmental tolerance for disruptive energy technologies, and out of time in which to do something about it.

The global dilemma that is emerging from this situation has three main elements.

1. Energy is an indispensible (necessary but not sufficient) ingredient of prosperity. The prospects for prosperity of nations presently poor, and of the poorer segments of rich nations, are threatened as the price of this indispensible commodity rises.

2. The technologies of energy supply, conversion, and application are dominant ingredients of civilization's disruption of the global environment. Thus, while the fruitful application of energy fosters prosperity, the environmental side-effects of the same energy flows undermine prosperity by means of direct damage to health, property, and human values, and by disrupting public-service functions of natural systems (for example, nutrient cycling, climate regulation, pest control, water management, and ocean fish production).[1] Inevitably, a point must be reached where the incremental gains in well-being from applying more energy do not compensate for the incremental losses due to the environmental impact of making that energy available.

3. High rates of growth of energy use in the rich countries, where total use is already very high, compound the foregoing problems. Rapid growth on top of an already large base becomes increasingly troublesome economically as the base gets ever larger:

Supplies of capital for building new facilities are strained, so capital itself becomes more expensive.

Such cheap energy resources as remain do not suffice, so more expensive ones are tapped.

The world market price of even the cheaply extractable resources rises to equal that of the expensive supplements, so poor countries can no longer afford to pay even for their present pathetic share of the world energy supply, and rich countries experience serious problems of inflation and balance of payments.

In desperate attempts to sustain rapid growth and increase self-sufficiency, firms and nations gamble ever larger stakes on unproven energy technologies, some likely to fail expensively. The same hasty technological gambles, forced by a high growth rate on a large base, greatly increase the chance and probable magnitude of serious environmental mistakes.

No policy or combination of policies can deal successfully with these problems unless it incorporates as a central element a sharply reduced rate of growth of global energy use. Overconsumption in the richest countries, and the legitimate needs of the poor countries, dictate that this reduction be accomplished by the very sharp slowdown in growth of energy use in the rich countries, where most of the world's total annual use now takes place.

Table 1 shows the situation in 1972, in round numbers, with the world divided for simplicity into two groups: 2.5 billion people living in countries with per capita gross national product less than about $650 1972 U.S. dollars, here denoted

---

*John P. Holdren, physicist, is assistant professor, Energy and Resources Program, at the University of California, Berkeley. He presented the report to the 1974 Pugwash Conference on Science and World Affairs at Baden, Austria.

[1] For more detailed discussion and an extensive bibliography, see John P. Holdren and Paul R. Ehrlich, "Human Population and the Global Environment," *American Scientist*, 62: 3 (May–June 1974), 282–92.

poor, and the remaining 1.2 billion people, here denoted rich.[2] Energy consumption is given as the equivalent continuous rate, in thermal kilowatts (kwt), and excludes food energy, energy content of dung used for fuel, and some wood used for fuel. (One kwt amounts to 1,038 kilograms of coal equivalent per year; a human metabolic energy use rate of 2,500 kilocalories per day corresponds to 0.12 kwt.)

TABLE 1.—GLOBAL DISTRIBUTION OF ENERGY USE IN 1972 AND RECENT RATES OF CHANGE

	United States	Other rich countries	Poor countries
Population (in billions)	0.2	1.0	2.5
Per capita energy use (in kwt)	12.0	3.7	.5
Total energy use (in billions kwt)	2.4	3.7	1.3
Percent of total energy use	33.0	50.0	17.0
Recent annual growth (percent):			
Population	.7	1.0	2.5
Total energy use	5.0	5.0	5.5
Per capita energy use	4.3	4.0	3.0

Source: U.N. Statistical Yearbook, and U.S. Department of Commerce, Statistical Abstract of the United States.

In the lower half of Table 1, recent annual growth rates in population and energy use are given. Some hint of the problems implied by continuation of these trends may be obtained by extending a 5 percent annual rate of growth in total energy use through, say, 2020, accompanied by population growth rates of 1 percent per year in the rich countries and 2.5 percent per year in the poor ones. The (absurd) result is 8.3 billion people in poor countries at an average energy use rate of 1.66 kwt per capita and 1.9 billion people in rich countries at an average per capita use rate of 34.3 kwt. The total rate of energy use would be 80 billion kwt, more than 10 times the 1972 figure.

Now it is easily shown that a dramatic slowdown in the growth of energy use in the rich countries would permit, in principle, an *acceleration* of the growth of per capita energy use in the poor countries within a context of declining global growth. In this way the wide rich-poor gap in energy use, which roughly parallels the ethically indefensible and politically unstable rich-poor gap in well-being, could begin to be narrowed. (Much attention must also be given to the other aspects of socioeconomic development, without which energy alone cannot produce prosperity.) The slower rate of growth in total global energy use, and the much slower growth in the rich countries where certain environmental impacts of energy technology are now most severe, would significantly reduce the grave environmental risks that accompany continuation of past trends.

The success of such a scheme depends heavily on the success of programs to limit the growth of populations. Only at lowered population growth rates can the high growth in per capita energy use needed and desired in the poor countries be achieved within an economically and environmentally sustainable rate of total growth. In the rich countries, the effect of multiplying even small population increments by the very high per capita energy use already prevailing there makes it essential to approach a zero rate of population growth as soon as possible.

SCENARIO FOR REDISTRIBUTION

A specific scenario that illustrates the potential of diverting the bulk of growth in energy use from rich to poor countries, while slowing population growth, is presented in Table 2. The period between 1972 and 2020 is divided into four subintervals, within which postulated average annual rates of growth of population and per capita energy use are indicated.

The rates are optimistic but not physically impossible. In the period 1972–80, the growth of per capita energy use in both rich countries and poor ones represents a moderate reduction from the recent historical trends, reflecting the 1973–74 worldwide petroleum squeeze; the average rates of population growth in this period are unchanged from the recent values. The steady decline of rich-country

[2] An interesting analysis of the historical data of the widening rich-poor gap in the 1950s and 1960s, grouping countries as rich, poor and intermediate, is given by Harrison Brown, "Population Growth and Affluence: The Fissioning of Human Society," *Quarterly Review of Economics,* Spring 1975 (forthcoming).

population growth to zero over the subsequent two decades seems not entirely implausible, in view of declining fertility rates already experienced in the United States, Europe, and elsewhere. The reductions shown in population growth in the poor countries between 1980 and 2020 will require consensus and enormous effort, but the experience of the People's Republic of China suggests it is possible.[3]

That growth rates in per capita energy use as large as those shown for the poor countries in 1990–2020 are possible in individual countries for limited spans of time is not in doubt, but achieving these *averages* in all the poor countries for 30 years would be a formidable task. It would require an unprecedented transfer of technical resources and capital from the rich countries to the poor ones, of the magnitude envisioned by Academician Sakharov in his famous essay of 1968.[4]

The mechanism for such a transfer is yet to be determined. Yet Table 2 shows that the results, if it could be done, would be remarkable. The total rate of energy use by a population of 6.7 billion people in 2020 would be about 28 billion kwt, or 4 times the 1972 rate instead of more than 10 times. Average per capita use among the 5.3 billion poor would roughly equal the 1972 rate for Japan or Austria, and the average per capita use of the 1.4 billion rich would be that of the United States in the early 1960s.

TABLE 2.—A SCENARIO FOR REDISTRIBUTION OF GROWTH ENERGY USE

	Rich countries		Poor countries	
	Population	Per capita use	Population	Per capita use
Postulated average growth rates in specified periods (percent):				
1972–1980 [1]	1.0	3.0	2.5	2.5
1980–1990	.7	1.0	2.0	3.5
1990–2000	.3	.5	1.5	4.5
2000–2020	0	.2	1.0	4.5
Values at specified times (population in billions, per capita energy use in kwt):				
Mid-1972	1.20	5.25	2.50	.50
Mid-1980	1.30	6.65	3.05	.61
Mid-1990	1.39	7.35	3.72	.86
Mid-2000	1.44	7.72	4.31	1.33
Mid-2020	1.44	8.03	5.26	3.20

[1] Measured from midyear to midyear.

Note: Total energy use in 2020: 28,400,000,000 kwt. Total population in 2020: 6,700,000,000. Average annual rate of growth in total energy use, 1972–2020: 2.8 percent.

It is far from certain that 4 times the 1972 rate of energy use can be managed in 2020 without grave environmental problems, just as it is not clear that 6.7 billion people can be fed and provided with other raw materials for a decent existence without undermining essential environmental services.[5] Nevertheless, there is perhaps a chance, particularly with the degree of international cooperation that could emerge from a substantial narrowing of the rich-poor gap. There is *no* chance in the continuation of past trends.

Success will require, in addition to the sort of drastic reallocation of growth just described, great emphasis on promoting those technologies of energy and materials supply that generate the least environmental disruption, and on phasing out those posing the greatest threats of irreversible ecological or social harm. Solar energy has great promise in the first category; nuclear fission deserves careful scrutiny as to whether it belongs in the second.

A final essential ingredient of the approach advocated here is a major, coordinated worldwide campaign of research, development, and implementation aimed at increasing the amount of prosperity derived from each unit of energy (and, indeed, from each unit of other raw materials). The link between energy and well-being, while genuine, is not inflexible. This fact is illustrated by studies of alternative modes of producing goods and services within individual coun-

[3] Pi-Chao Chen, "China: Population Program at the Grass Roots," in *Population: Perspective 1973*, ed. H. Brown, J. Holdren, A. Sweezy, B. West (San Francisco: Freeman-Cooper), 1974.

[4] Andrei D. Sakharov, *Progress, Coexistence, and Intellectual Freedom* (New York: W. W. Norton), 1968.

[5] Paul R. Ehrlich and Anne H. Ehrlich, *Population, Resources, Environment* (San Francisco: W. H. Freeman) 2nd Ed., 1972.

tries[6] (for example, different steel production processes in use in the United States differ in energy intensiveness by almost a factor of four), and by comparison between countries (for example, per capita energy use in North America is about twice that in Sweden but few would argue that North Americans are twice as well off as Swedes).

Tailoring technologies of energy supply and application to specific regional conditions can avoid in the developing countries much of the needless energy waste that now prevails in the rich ones. These considerations mean that prosperity in the poor countries can be increased at a rate faster than the rate of growth of energy use itself, and that, even in rich countries where a drastic slowing of growth in energy use is called for, ingenuity can reduce the impact on the economy and on the prospects for increase in actual wellbeing. Such transitions will of course pose some economic problems, but a powerful reason for accepting these is that they are likely to be much less severe and more temporary than the growing economic problems of the status quo.

One is always reading that the sorts of drastic changes proposed here are infeasible, impractical, and unrealistic, particularly in the economic and political sense. I believe that the alternative of proceeding along our present course is *physically* impractical as well as socially unacceptable. Can our political and economic scientists devise ways to bring the world's institutions into line with physical reality in time?

Energy in the United States—How Much, How Soon?

(Statement of John P. Holdren, Ph. D.*, at Hearings Before the Subcommittee to Review the National Breeder Reactor Program, Joint Committee on Atomic Energy, U.S. Congress, June 10, 1975.)

The main questions that energy policy must confront can be concisely summarized:

(1) How much energy should be supplied?
(2) With what technologies should it be supplied?
(3) Who should pay the associated costs?

At issue under the first question are the costs and benefits to society of various levels of energy consumption and various rates of change in these levels (growth or decline). The second question—which I view not as a search for the ideal energy source but as a search for the least undesirable mixture of sources—is important regardless of the answer to the first; a stabilized or even a reduced level of energy use would not absolve us from making difficult choices about how best to supply that level. Similarly, the third question—involving how we use prices, taxes, and regulation to distribute the direct and indirect costs of energy use—is crucial no matter how the first two questions are answered.

Still, the three questions are far from independent. If the answer to the question "How much?" is very high, the range of choice under "What technology?" diminishes; we may have to choose all the options at once, at great expense. And the higher the costs, the trickier is the question "Who pays?" I am pleased, therefore, to see the basic question of "How much energy?" at last beginning to receive some of the critical scrutiny it deserves, and especially pleased to see it taken up at the outset of these important hearings, where it belongs.

My own view on this question is that the United States is threatened far more by the hazards of too much energy, too soon, than by the hazards of too little, too late. That the contrary view is so widely held is the result, I believe, of two factors:

(A) The economic, environmental, and social costs of today's level of energy use, and of rapid growth of this level, have been seriously underestimated by most observers.

(B) The economic and social costs of slower growth have been just as seriously overestimated.

Let me elaborate by stating and expanding upon some specific propositions relevant to this issue.

---

[6] For the case of the United States, see, for example, Office of Emergency Preparedness, *The Potential for Energy Conservation* (Washington, D.C.: Government Printing Office), 1972.

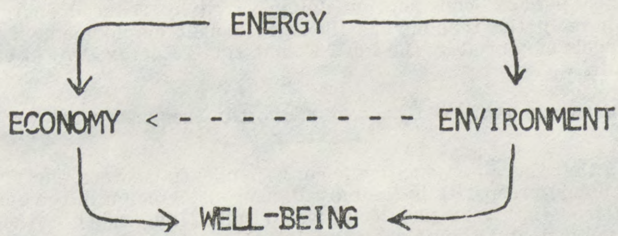
*Assistant Professor of Energy and Resources, University of California, Berkeley, CA. 94720. The opinions herein are the author's.

RAPID GROWTH IN ENERGY USE FOSTERS EXPENSIVE MISTAKES

Especially where the existing level of energy use is already high, rapid growth forces exploitation of high-cost energy sources as well as low-cost ones, strains available supplies of investment capital, and encourages gambles on inadequately tested technologies. The pressure of growth favors "streamlining" of assessment and licensing processes, further enlarging the probability that some of these gambles will fail—at great economic, environmental, or social cost.

EVEN AT SLOWER GROWTH RATES, INCREASES IN ENERGY USE MAY DO MORE HARM THAN GOOD

While the productive application of energy fosters prosperity through the operation of the economic system, the environmental and social effects of these same energy flows undermine prosperity by means of direct damage to health, property and human values, and by disrupting "public-service" functions of natural systems (e.g., climate regulation, waste disposal, pest control, ocean fish production). It is useful to visualize the main relationships in the terms shown in the sketch.



The essence of the matter is that human well-being is not and cannot be provided by the productive machinery of the economy, working in isolation. Well-being requires, in addition, a physical environment conducive to health, and the functioning of the economy itself depends on a variety of services performed by the physical environment—services we could not afford economically to replace by technology on the necessary scale even if we knew how to do it. Clearly, the benefits to well-being obtained through the economic side of the relationship by means of increased energy use could in some circumstances be completely cancelled by the associated damage to well-being through the environmental side. Not only has this outcome probably already occurred for certain energy sources in certain locations, but under continued growth it is eventually inevitable overall, irrespective of the energy sources chosen.

CONSERVATION OF ENERGY MEANS DOING BETTER, NOT DOING WITHOUT

Fortunately, the slowing of energy growth and even the eventual reduction of the total level of energy use need not mean a life of economic privation for the American public.

The essence of conservation is the art of extracting more well-being out of each gallon of fuel and each kilowatt-hour of electricity. Much progress in this direction can be made through changes that increase efficiency in industrial processes and electricity generation, and energy consuming devices in homes, commerce, and transportation. (The Energy Policy Project of the Ford Foundation concluded that a combination of such measures, embodied in their "Technical Fix" scenario, could reduce U.S. energy consumption in the year 2000 to 124 quadrillion BTUs, compared to 187 quadrillion under "Historical Growth". There is good reason to believe that the sustained application of ingenuity could yield even bigger gains.) Of course, some kinds of energy conservation will require changes in the behavior of individuals, and critics of conservation are quick to suggest that what is implied here is a return to primitive existence. In a society that uses its 5,000-pound automobiles for half-mile round trips to the market to fetch a six-pack of beer, consumes this in underinsulated buildings that are overcooled in summer and overheated in winter, and then throws the aluminum cans away at an energy loss equivalent to a third of a gallon of gasoline per six-pack, this "primitive existence" argument strikes me as the most offensive kind of nonsense.

SAVING A BARREL OF OIL IS GENERALLY CHEAPER THAN PRODUCING A BARREL

Slowing the growth of energy consumption by means of rational conservation measures can actually save a great deal of money. For although technological improvements to increase energy efficiency often require some additional capital investment over conventional practice, this investment is usually less than the investment that would be needed to product from new sources (offshore oil, nuclear fission, geothermal development) an amount of energy equal to that saved. In this sense, conservation is the cheapest new energy source. (The Energy Policy Project's "Technical Fix" scenario reduces energy-related capital investment—for supply and conservation—by 285 billion 1970 dollars over the time period 1975–2000, compared to the "Historical Growth" scenario.) The money saved by conservation, of course, would in principle be available for some of this country's many other pressing needs.

LESS ENERGY CAN MEAN MORE EMPLOYMENT

The energy-producing industries comprise the most capital-intensive and least labor-intensive major sector of the U.S. economy. Accordingly, each dollar of investment capital taken out of energy production and invested in something else, and each personal-consumption dollar saved by reduced energy use and spent elsewhere in the economy, is likely to benefit employment. The detailed economic models employed by the Ford Foundation's Energy Project confirm this general result.

THE LINK BETWEEN ENERGY USE AND ECONOMIC PROSPERITY IS NOT FIRM BUT FLEXIBLE

The notion that there is a one-to-one correspondence between energy consumption and economic prosperity is the most dangerous delusion in the energy-policy arena. It is true that very poor countries (India, Indonesia) use only a little energy per person, and that rich countries (U.S., Japan) use much more, but within a given "prosperity bracket" there is enormous variation in energy used per dollar of GNP. In 1974, three Western European countries—Sweden, Denmark, and Switzerland—had per capita GNP's higher than that of the United States, despite energy use per person in these countries around half that in the U.S. or less. How do these countries produce so much more GNP per unit of energy used than the U.S.? The answer is complex, of course, and has partly to do with the fact that these European countries have a somewhat larger fraction of their economic activity in services (e.g., health care, education), which are less energy intensive per dollar and per job than manufacturing, than does the U.S. It is clear from such international comparisons between countries, as well as from comparisons of different sectors within the U.S. economy, that the U.S could change the pattern of its economic growth in ways that would lead to greatly reduced growth in energy consumption without a corresponding cost in prosperity.

I conclude from all of this that the high rates of growth of energy use and electricity generation traditionally anticipated for the time period 1975–2000 are neither desirable nor necessary. They are not desirable because the economic, environmental, and social costs of such growth are likely to be severe; they are not necessary because the application of a modicum of technological and economic ingenuity can produce continued and indeed growing prosperity without them.

Of the formal projections of U.S. energy and electricity use that have been published, I believe the most sensible is the "Zero Energy Growth" scenario of the Ford Foundation's Energy Policy Project. Combining the effects of improvements in efficiency, shifts in the composition of economic output toward greater emphasis on services, and modest changes in behavior, this scenario leads to a levelling off of annual U.S. energy use at 100 quadrillion BTUs in the year 2000. Of this amount, 31 quadrillion BTUs are used for the generation of electricity. These figures represent an increase compared to 1974 of about 33 percent in total energy use and 50 percent in electricity generation. If our goal is to maximize human well-being, accounting both for the benefits of energy use and the likely costs, we should not aim at more energy growth than this, and I believe it possible that we should even aim at less.

BIBLIOGRAPHIC NOTES

Some international implications of energy trends in the U.S. are treated in John P. Holdren, "Energy and Prosperity: Some Elements of a Global Perspective", *Bulletin of the Atomic Scientists*, January 1975, pp. 26–28 (submitted here as an addendum for the record).

The scenarios and underlying assumptions developed by the Energy Policy Project of the Ford Foundation are summarized in *A Time to Choose: America's Energy Future*, Ballinger Publishing Co., Cambridge, Mass. 1974.

An analysis demonstrating that the present technical efficiency of energy end-use in the U.S. is, for many applications, less than 10 percent of what is possible is given in *Efficiency Use of Energy: A Physics Perspective*, 1974 Summer Study of the American Physical Society (available from Professor R. Socolow, Princeton University, Princeton, N.J. 08540).

The ratios of BTUs per job and BTUs per dollar of GNP in different sectors of the U.S. economy, illustrating the potential for economic growth and high employment without corresponding energy growth, are tabulated in B. Hannon, "Options for Energy Conservation", *Technology Review*, February 1974.

80 533 - 77 —— 14

[From the Bulletin of the Atomic Scientists, March 1976]

The Nuclear Controversy and the Limitations of Decisionmaking by Experts

POLICYMAKERS MUST STOP WAITING FOR TECHNICAL CONSENSUS WHERE NONE IS POSSIBLE, AND CONCENTRATE INSTEAD ON HOW TO MINIMIZE THE SOCIAL COSTS OF UNCERTAINTY; THE CALIFORNIA INITIATIVE PRESENTS SUCH AN OPPORTUNITY

(By John P. Holdren*)

Anyone who has been paying close attention to the nuclear controversy probably is prepared by now to concede that an old saying about experts applies with special force to experts in the nuclear field: If you laid them all end to end, they'd never reach a conclusion.

The fact is that the experts—individuals with appropriate specialized training who have devoted a significant amount of time to aspects of the nuclear issue—do not agree about the answers to many of the important questions. They do not agree, for example, about just how toxic plutonium is, nor about the probability of certain kinds of reactor accidents, nor about how much damage a large accident would do, nor about the adequacy of various proposals for the management of radioactive wastes.

Where quantitative statements are possible at all, the actual magnitudes of the differences in expert opinion are often very large—factors of tens to thousands and more. The difficulty is if anything even more acute where the character of the uncertainty does not lend itself readily to quantification, as is the case for some of the most crucial aspects of the nuclear issue: power-plant security and safeguards for special nuclear materials.

How likely are attempts to sabotage nuclear reactors or fuel-cycle facilities? What is the probability of success of such an attempt? By what margin can a given countermeasure reduce this probability? How likely is successful theft of nuclear materials by stealth or force? How difficult is it to manufacture an effective nuclear bomb once the materials are in hand? What infringements of traditional American civil liberties are likely to accompany measures intended to deter nuclear theft or to recover stolen material?

I do not believe the inability of experts to agree on these issues is a temporary situation, at least not temporary in terms of the time scale on which major decisions about nuclear power must be made. Let me first explain why I think this is so, and then what it means for the formation of nuclear policy in general and the California nuclear initiative in particular.

Limits of expert opinion

To understand the nature of expert disagreement and its likely duration, one must examine the specific controversies.

In the case of plutonium toxicity, responsible difference of opinion continues to exist both because the experimental data are scanty and because the data that do exist are susceptible to alternative interpretations. The accumulation of enough additional experimental data to resolve the uncertainty to a convincing degree is not likely to take less than 10 to 15 years and might take much more.

In the case of reactor accidents that might be caused by equipment malfunctions and human error, the expert community is divided about the conceivable realism of probability estimates in the range of one in ten thousand to one in one billion per reactor year. I am among those who believe it to be impossible *in principle* to support numbers as small as these with convincing theoretical arguments (that is, in the absence of operating experience in the range of 10,000 reactor-years or more), even ignoring the crucial possibility of malevolence. The reason

---

*John P. Holdren, physicist, is associate professor of Energy and Resources at the University of California, Berkeley. This article is based in part on the author's testimony on the California Nuclear Safeguards Initiative presented last November to the state of California Assembly Committee on Energy and Diminishing Materials.

I hold this view is straightforward: nuclear power systems are so complex that the probability the safety analysis contains serious errors (for example, that it omits failure modes more important than those included) is so big as to render meaningless the tiny computed probability of accident.

Let me illustrate the idea here with a greatly simplified example. Suppose an analyst says the probability of a certain outcome is one in a billion per year. If there is a 90 percent chance he is right, and a 10 percent chance he has made a mistake which, if discovered and corrected, would make the probability of the outcome one in a hundred thousand per year, then *your* best estimate of the probability of the outcome becomes $0.90 \times 10^{-9} + 0.10 \times 10^{-5} = 1.0009 \times 10^{-6}$, about 1,000 times higher than the analyst's figure.

The sorry history of attempts to compute absolute probabilities for the failure of complex systems—power grids, spacecraft, weapons systems—reinforces my skeptical view of such numbers.

Even these sorts of uncertainties, however, are rendered largely academic by the possibility of willful production of disastrous events at reactors—and possibly other fuel-cycle facilities—by saboteurs or terrorists. The most elaborate safety systems can be circumvented by sufficiently sophisticated intervention, and the most formidable barriers against access to nuclear facilities can be breached by sufficiently determined use of force. On this much I suspect experts can agree. They probably can agree, further, that physical security at most existing facilities is clearly inadequate to deal either with clever "inside" jobs or with substantial use of force, and that may steps *could* be taken to reduce significantly the vulnerability of nuclear facilities to deliberate disruption. I believe no agreement will be possible, however, on any *quantitative* statement of the residual chance of successful sabotage, regardless of the protective measures that might be taken. The inherently unpredictable human element simply plays too large a role at too many steps to permit a meaningful and convincing assessment. How many disgruntled and alienated people will there be in our society 10 or 20 years hence? What fraction of these will choose nuclear terrorism or sabotage as a vehicle for venting their frustration or achieving their goals? What fraction of this fraction, in turn, will be clever enough and determined enough to succeed? Policy and technology can influence the answers to these questions, upwards or downwards, but cannot pin down the magnitudes.

Waiting for consensus

My own—unprovable—suspicion on this point is that the probability of a deliberate nuclear-power disaster is and will remain higher by at least a factor of 10 than the probability of an accidental one. If it should actually happen to be true that the chance of a large nuclear accident is as low as one in a million per reactor per year, then the margin by which deliberate intervention is more important than accidents would be even larger. Again, this is according to *my* evaluation of human frailty and of the vulnerability of complex systems. I would not expect consensus. But this is the point: policy-makers must stop waiting for consensus where none is possible and concentrate instead on how to minimize the social costs of uncertainty.

The problem of the misuse of nuclear materials is similar in character. Theft of these materials for use in making nuclear explosives or radiological terror weapons is certainly possible; it could certainly be made more difficult. Concerning *how* easy it would be to steal the materials, how easy it would be to make a bomb once the materials were in hand, and how much more difficult these steps could be made, there is no consensus. And there is not likely to be any. Theodore Taylor, who knows exactly how to make nuclear explosives, has argued forcefully that it is not really very hard; others, who also know how, have argued in essence that Taylor greatly overestimates the number of people who are nearly as clever as he is. I believe this disagreement is not likely to be resolved by further argument although it might be resolved by the real-world "experiment" that is now in progress.

Even less susceptible to theoretical arguments is the civil-liberties aspect of the nuclear-materials problem. The threat here, in my view, is not so much the special police forces and employee-screening procedures that might be set up to protect nuclear materials from theft; but rather the extraordinary abridgements of civil liberties that the authorities would probably deem justified to recover stolen nuclear materials before these could be used to make and explode a bomb. Some people seem to find this sort of scenario unrealistic, but I have seen no convincing case for such complacency—and I do not think one can be made.

If, as I am suggesting here, the disagreement of experts on major aspects of nuclear power is not a temporary condition but, for practical purposes, at least a semipermanent one, then how is society to proceed? Others have said that nuclear power is too technical an issue to be handled by the public or even by legislators. I believe almost exactly the opposite: the problem is too *nontechnical* to be handled by the technical experts.

I am myself a technologist by training—my background is in engineering and plasma physics—but I have been preoccupied for a substantial part of the past several years with some of the liabilities and shortcomings of technology. One of the biggest of these is our tendency to perceive certain issues as mainly technological, when in fact the fraction of the problem that actually can be illuminated by technical insights is small; the result is to reserve for the judgment of experts decisions where their expertise is of very limited relevance.

The nuclear controversy is clearly such a case. The toughest questions cannot be resolved by technical expertise. Experts can and should clarify the technical aspects of options and the range of technical uncertainty as best they can. But the public-policy question in the nuclear controversy—how to deal with a situation characterized by uncertainties of these kinds and in these degrees—is not a technical issue. It is a social one. What kinds of risks should be accepted in exchange for what kinds of benefits? With how much uncertainty of specific kinds does the public care to live? How does one weigh the high routine impact of some technologies (for example, burning coal) against the small chance of a big disaster associated with others (for example, nuclear reactors)? The answers to these kinds of questions should be sought in a way that embodies the fullest possible participation of the affected public, and that places the major decisions in the hands of those most directly accountable to the public through the political process.

[Preprinted from "Costs of Energy as Potential Limits to Growth", in the Sustainable Society: Social and Political Implications, Dennis Pirages, ed., Praeger (New York), Spring 1977 (in press).]

COSTS OF ENERGY AS POTENTIAL LIMITS TO GROWTH

[By John P. Holdren*]

The basic material ingredients of existence and prosperity are air, water, food, fiber, energy, physical space, and nonfuel minerals. The most obvious question concerning natural limits to growth of human populations and economies is whether the supply of these basic ingredients is adequate. The question is uninstructive, however, if posed strictly in terms of how much material exists (in the case of air, water, space and minerals) or in terms of how much could theoretically be produced (in the case of food and energy) if economic and social costs could be ignored. In these terms, adequacy invariably seems assured for any population and level of material goods per person that can reasonably be envisioned for the next 50 to 100 years. This is true both for the United States and for the world.

There are, however, meaningful questions involving possible limits to growth on the more easily visualized time scale of a few decades. These questions concern not absolute potential supply but rather economic costs, achievable rates of deployment of new or existing technologies, and social costs. With respect to economic costs, for example: Can potential resources be converted into available supplies at economic costs society can pay? (The oil shales provide an example of a vast resource the existence of which is assured, but for which the economics of exploitation is uncertain.) With respect to rates: Will constraints of logistics, economics, and social and technological inertia permit the rate of mobilization of resources to keep pace with the anticipated rate of growth of needs? To mention examples, limitations on capital for new power plants or shipyards for tankers could constrain the rate of growth of U.S. energy supply without placing a fundamental constraint on the ultimate level of consumption. With respect to social costs: What will be the direct effects on human health of pollution associated with high levels of resource use or high rates of increase, and what could be the effects on human well-being of disruption of social systems and of geophysical processes that influence food production, recycle wastes, and otherwise maintain a hospitable environment for humans?

As an indispensable ingredient of prosperity and a major source of social costs, energy is a particularly fitting focus for the study of such questions. Let us therefore look more closely at the technological choices for energy supply, and at the questions that must be asked concerning their economic and social costs. (Many answers are missing, but trying to ask the right questions in a systematic way seems a useful beginning.)

TECHNOLOGICAL OPTIONS FOR ENERGY SUPPLY

Listed in Table 1 are the principal choices for energy supply during the next several decades, together with my personal estimates of the earliest date at which each one could contribute energy equal to a 10 percent share of the total annual energy use of the United States in 1975. These estimates are "optimistic" in the sense that they assume in each case that a major national commitment is made to develop and deploy the source in question as rapidly as possible. It is most unlikely, of course, that the country would make such a commitment for all the sources at once.[1]

Oil and gas (domestic plus imported) were contributing almost 75 percent of U.S. energy supply in 1975, but most experts agree that the contribution of

---

*Associate Professor of Energy and Resources, University of California, Berkeley.

[1] A more complete discussion of the status of various energy technologies than can be given here is to be found in Paul R. Ehrlich, Anne H. Ehrlich, and John P. Holdren, *Ecoscience: population, resources, environment,* W. H. Freeman, San Francisco, 1977, Chapter 8.

domestic resources of oil and gas will continue the decline entered in the early 1970s owing to diminishing discoveries.[2] Imported oil was 17 percent of U.S. energy supply in 1975 and could be increased, at least temporarily, if the country cared to pay the economic and social costs. Imported gas in 1975 was just over 1 percent of U.S. energy supply and probably could not reach 10 percent before 1985 (owing to the need to construct off-loading, conversion, and storage facilities for the liquefied natural gas to be imported.)

Use of coal in conventional facilities—electric-utility boilers and steelmaking, for example—was 19 percent of U.S. energy in 1975. The greatest potential for expansion is thought to be in advanced applications such as liquefaction and gasification and combined-cycle power plants. These technologies require further development to make them commercially attractive. Even if the commitment is made, which at this time is uncertain, the large and expensive facilities involved could not be built rapidly enough to reach my 10-percent criterion before the mid-1990s.

More uncertain still is whether oil shale will be developed on a large scale. The technology is less developed than that for advanced coal conversion, and industry seems at the moment to lack enthusiasm for pushing ahead. Possibly oil shale and tar sands combined (the latter deposits mostly in Canada) could achieve the 10-percent figure in 2000 if incentives materialize.

The rather late dates given in Table 1 for fission become understandable when one recognizes that nuclear reactors at present contribute only to the electrical portion of the energy budget, and electricity as a whole makes up only 25 percent of our annual drain on primary energy sources. Fission reactors in 1975 were generating about 8 percent of the nation's electricity, hence accounting for 2 percent of total energy supply. These reactors are all of the "converter" type—relatively inefficient users of uranium. The pace of construction has fallen far below the enthusiastic nuclear-industry estimates of a few years ago, and it seems unlikely that this energy source could quintuple its 1975 contribution before 1990, if then. The more efficient but even more controversial breeder reactors cannot be developed, tested, and deployed quickly enough to meet my 10-percent criterion before 2000, despite massive federal investments in this enterprise.

Controlled fusion may achieve a laboratory demonstration of scientific feasibility by 1980 or so, but the obstacles between laboratory and commercial power plant should not be underestimated. The engineering problems of fusion are so severe that the first commercial plant can hardly be expected before the year 2000, and many experts find that estimate (which is the U.S. Energy Research and Development Administration's target) overoptimistic. If the target is met and the plant works beautifully, it would still be difficult to build by 2015 the hundred or so large plants needed to meet my 10-percent criterion. This is probably true for laser fusion as well as for magnetic confinement, although less is known today about the newer and still partly classified laser approach.

Fusion-fission hybrid reactors—a fusion core surrounded by a blanket where fusion neutrons either induce fission or produce fissile fuel for fusion reactors located elsewhere—conceivably could prove feasible before pure fusion does. Whether such devices would be attractive enough economically to justify a major program is in doubt, but even if they do they are at least ten years behind the fission breeder reactor.

The speed with which solar energy could make a major contribution if a national commitment were made has been widely under-rated. Among "direct" approaches to harnessing the sun's energy, the easiest to implement quickly is collection of the energy as heat on flat-plate or focusing collectors. (The main applications are heating and cooling of buildings, industrial process heat, and thermal generation if electrictiy.) These thermal approaches in combination could meet the 10-percent figure by 2010, possibly sooner. Photovoltaic cells have a chance of making the 10-percent level by 2015 to 2020 if progress in lowering their production costs continues. Production of fuel by photosynthesis, chemical mimics of photosynthesis, and catalytic dissociation of sea water could probably meet the 10-percent criterion between 2015 and 2025, depending on degree of success with the more esoteric approaches.

---

[2] Statistics on U.S. production and use of energy are from U.S. Department of Commerce, *Statistical Abstract of the United States*, Government Printing Office, Washington, D.C. 1976.

Sunlight is already harnessed indirectly for electricity generation in the form of hydropower (the hydrologic cycle is driven by the sun). It provides 15 percent of U.S. electricity in 1975, but there probably are not enough suitable dam sites for its contribution ever to reach 10 percent of total 1975 energy use. Wind power might be able to reach the 10 percent level by 2030 to 2040, depending on technological developments now very hard to predict. Ocean waves and thermal gradients together perhaps belong on the same timetable. Of the non-solar "geophysical" energy sources, probably only hot dry rock has the potential to reach the 10-percent criterion at all. With great effort and good luck, this might be achieved by 2015.

The most rapidly accessible "new" energy technology is the technology of energy conservation. (By conservation I mean more efficient use of energy. Strictly speaking, energy is always conserved—so says the first Law of Thermodynamics—but the term "energy conservation" is useful shorthand for getting more well-being per unit of energy used.) Most people may be unaccustomed to thinking of increased efficiency as an energy "source," but a barrel of oil saved by better insulation is every bit as real a contribution to national energy supply as a barrel of oil imported or pumped from a domestic field. (Like other energy technologies, raising efficiency has economic and social costs, but there is reason to believe these are often smaller than those of alternative technologies.) And there is so much "fat" in the U.S. energy budget—energy use that can be trimmed by the most modest and innocuous conservation measures—that there need be no difficulty in making a 10-percent contribution to energy supply this way by 1980. The contribution by the year 2000 could easily be 35 percent of the total U.S. energy use in 1975.[3]

A TAXONOMY OF ECONOMIC AND SOCIAL COSTS

One of the greatest pitfalls in cost-benefit comparisons of all kinds is leaving something important out of the accounting. A useful precaution is to develop a logical framework for ordering the subject—a taxonomy, as it were—to help assure at least that the right questions are asked. I concentrate here on the costs, inasmuch as the benefits of energy supply have been amply and enthusiastically described elsewhere. It is useful in this connection to distinguish among:

1. The origins of the costs, namely the specific activities that generate them. For a given energy technology, what is important here is not to leave out of the accounting any of the steps undertaken in the discovery and delivery of the energy, or any of the phases associated with each step (see Table 2).

2. The character of the impacts produced by these activities, meaning what is taken from, added to, or done to the economic, social, and physical environments (Table 3, column 1).

3. The costs themselves, meaning the nature of the damage to human well-being produced by the impacts (Table 3, column 2).

In Table 4, the list of impacts from Table 3/column 1 is made more concrete with examples from the major energy technologies. (The list is illustrative, not comprehensive.) One theme that begins to emerge from Table 4 is that few categories of impact are unique (in a qualitative sense) to a single energy option. Equity effects and military ramifications attend both fossil fuels and nuclear power, for example. In the same vein, the possibility of devastating accidents accompanies not only nuclear reactors but also hydro dams upstream from population centers and Liquefied Natural Gas (LNG) tankers in big-city ports; long half-life radioactive effluents come from geothermal power and coal-burning facilities as well as from the nuclear fuel cycle; and mutagens, manifesting themselves as genetic diseases and deaths in future generations, come from virtually all combustion as well as in the form of ionizing radiation. This is not to suggest that choices as to "better" and "worse" among the various energy options cannot be made, but only that the criteria are not quite so clear-cut as sometimes is assumed.

EVALUATING SEVERITY OF IMPACTS AND COSTS

To proceed beyond a mere listing of the impacts and costs of various energy options, three tasks must be undertaken: (1) identifying the most appropriate criteria by which to evaluate the severity of the impacts and/or costs; (2) acquiring the information needed to quantify the performance of various energy

[3] Lee Schipper, Raising the productivity of energy utilization, in J. Hollander (ed.) Annual Review of Energy, vol. 1, Annual Reviews, Inc., Palo Alto, Ca., 1976.

options against these criteria, where quantification is possible; (3) comparing the results from different energy options in a way that can enlighten decision making.[4] (The tasks are listed here in increasing order of difficulty.)

These considerations suggest the classification of criteria for evaluating severity into three broad categories: (a) criteria that are quantifiable (at least in principle) and amenable to comparisons among different technologies; (b) those that are quantifiable but difficult or impossible to compare from one technology to another; and (c) those that are difficult or impossible to quantify even for a single technology. Table 5 provides a listing of some of the most important criteria, arranged according to this scheme.

Comparability is greatest, of course, for direct economic costs. Some capital costs for various energy facilities as of about 1974, in 1974 dollars, appear in Table 6.[5] It is important to note that costs of energy technology have been escalating considerably faster than the rate of inflation for the economy as a whole. A company planning to construct any of the facilities listed in Table 6 starting in 1976 might expect to pay, in current dollars, between 50 percent and 100 percent more than the figure given. What is most significant about the numbers in Table 6, then, is not so much the absolute values but the relative values among the various technologies; the clear message is that the trends in energy development—toward more remote deposits of oil, toward more abundant but lower grade resources such as coal and oil shale, toward sophisticated technologies of fission and fusion, toward the inexhaustible but dilute solar resource—are all trends toward more expensive energy. The era of cheap energy is over.

Beyond this broad assertion, drawing detailed conclusions from numbers such as those in Table 6 can be dangerous. Information on economic costs is quantitative, but that is not to say it is always accurate. Costs of present technologies may be distorted by subsidies of various kinds and by other imperfections in the market, and are further clouded by inconsistent use of accounting schemes by different estimators.[6] Costs of future technologies are uncertain because no one knows what a highly complex facility will cost to build until it has been done. (It can be argued, in fact, that one doesn't really know the cost accurately until not one but dozens of examples have been built.)

The uncertainties inherent in comparisons of dollar costs are illustrated by the results of a study conducted by the author and two colleagues in 1975.[7] Total electricity generating costs for 1990 in mid-1974 mills per kilowatt-hour were estimated for eight fossil-fuel and nuclear generation alternatives, letting capital costs, fuel costs, load factors, and plant efficiencies vary over the range of recent estimates for these parameters by competent analysts. The results are summarized in Table 7. The clear conclusion is that the uncertainties are far bigger than the inter-source differences in the "base-case" or "best" estimates.

Like direct economic costs, consumption of resources such as land, water, and energy can be quantified and readily compared among alternative energy options. Some economists ergue that there is no need for such separate tabulation and comparison, since the dollar cost of the resources used is already included in the overall dollar costs of the various options. A major weakness in this position is the distortion introduced by subsidies and other market imperfections, as noted above. Since land or water may well be subsidized or underpriced for one energy option and not for another, it is instructive to disaggregate from deceptive dollar totals the physical quantities used, in hectares, liters, joules, and so on.

Still, there are ambiguities in quantifying resource use. Does one distinguish between water that is evaporated and water that is polluted but returned to the surface? In fuel cycles for electricity generation, evaporative cooling towers (if used) invariably dominate the water use, whether water polluted and returned is counted or not (Table 8).[8] Concerning land use, accounting problems arise in

---

[4] Some of the discussion in this section is condensed from a more comprehensive treatment in Robert J. Budnitz and John P. Holdren, Social and environmental costs of energy systems, in Hollander (ed.), *Annual Review of Energy*.

[5] The principal source of these cost figures is Carl J. Anderson and others, "An Assessment of U.S. Energy Options for Project Independence," University of California Lawrence Livermore Laboratory Report UCRL–51638, September 1974. Estimates for fusion and central-station solar are the author's.

[6] An excellent discussion of these problems is I. C. Bupp and others, the economics of power, Technology Review, vol. 77, no. 4 (February 1975), pp. 14–25.

[7] Kirk Smith, John Weyant, and John P. Holdren. "Evaluation of Conventional Power Systems." University of California (Berkeley) Energy and Resources Group Report ERG 75–5. July 1975.

[8] Tables 8 through 12 appeared previously in Budnitz and Holdren (Note 4) and are based on the compilation by Smith, Weyant, and Holdren (Note 7). The extensive primary literature from which these data were collected is referenced there.

discriminating between temporary and permanent commitments of land. It is probably useful to distinguish inventory commitments (km^2 per MWe installed, committed for the duration of the facility's operation, e.g. the land on which the plant sits), temporary commitments (km^2-years per MWe-years of delivered electricity, e.g. km^2 strip-mined per MWe-yr, multiplied by the mean number of years required to restore the land to other uses), and permanent commitments (km^2-years per MWe-yr, e.g. repositories for radioactive wastes). Very few land-use data are available disaggregated in this detail. Some figures are collected in Table 9. Another question related to resource use is how far one traces these impacts. In net-energy accounting, for example, one would usually ascribe to the energy costs of coal-fired electricity generation the fuel burned by trains hauling the coal. Should one also count the energy used to manufacture the trains? Or the gasoline used by workers commuting to work to manufacture the trains?

Difficulties in comparability between different technologies arise even with easily quantified impacts such as use of non-fuel minerals. If construction of a solar power plant were to require 100 kg of aluminum per electrical kilowatt, for example, and a nuclear power plant required 10 kg of stainless steel per electrical kilowatt, how would one decide which is the more serious impact (aside from price, which as noted above may not accurately reflect the real costs)? Measurement of the material demands against known reserves, annual consumption for other purposes, and estimates of eventually recoverable resources provides indices that are a step toward comparability, but are still imperfect. (Resource estimates are flawed, and consumption for other purposes may change.)

The same problem arises with respect to material effluents. A kilogram of carbon monoxide is not equivalent in social costs to a kilogram of sulfur dioxide. A curie of tritium is not equivalent to a curie of plutonium. An increasingly popular index that supplies some measure of comparability in these instances is the number (in units of volume) obtained by dividing the quantity of the material by the maximum concentration permitted by applicable regulations. In this way, the impact of discharges is represented in terms of the volume of air or water needed to dilute the effluent to the permissible concentration. Thus a kilogram of SO_2, divided by the primary federal (US) standard of 80 μg per cubic meter of air, corresponds to a "dilution volume" of 12.5 million cubic meters of air. A curie of tritium (about a tenth of a milligram), for which the Recommended Concentration Guideline (RCG, formerly Maximum Permissible Concentration, or MPC) for public exposure is 0.2 μCi per cubic meter of air, has a "dilution volume" of 5 million cubic meters of air. Dilution volumes for several fuel cycles are shown in Table 10. This approach has the defects that standards for different effluents do not contain equal margins of safety (or non-margins) with respect to the level at which adverse effects on health appear, and that the different physical properties of different effluents lead to vastly different *rates* of dilution and/or detoxification.

When one is concerned with ecological disruptions, it is generally useful to compare the scale of the technological disturbance against the yardstick of the relevant natural process. For example one can compare additions of CO_2 to the atmosphere with the "natural" concentration of CO_2 or with natural flows into and out of the atmosphere, one can compare technological energy flows in a specified area with the natural energy flows that govern climate, and so one. Some comparisons of this kind are presented in Table 11. It is sometimes hard to know, however, which of several candidate natural yardsticks is most meaningful, and the comparison between completely different kinds of impacts is not straightforward in any case.[9]

Counting deaths and injuries is straightforward only for occupational accidents (Table 12) or dramatic disasters such as dam failures. Deaths and illnesses due to pollution are obscured by multiple causative factors (some energy-related and some not) and by other epidemiological difficulties: synergistic effects, data inadequate because of small sample size or short time period of observation, pre-existing conditions, lack of a good control group. Estimating death and disease that might result from eventual accidents involving technologies with which we have little experience to date (such as nuclear fission) is even more difficult because no reliable estimates of the probability of such events are available. Some of the uncertainties are reflected in Table 13, which shows the ranges

---

[9] The view that disruption of natural biogeochemical systems on a large scale may represent a greater threat to human well-being than the direct toxic effects of civilization's effluents on people is developed in detail in John P. Holdren and Paul R. Ehrlich, Human population and the global environment, *American Scientist*, vol. 62, No. 3 (May–June 1974), pp. 282–292, and in Ehrlich, Ehrlich, and Holdren, (Note 1), Chapter 11.

of competent opinion concerning impact on public health of the routine operation of some alternative electricity-generating schemes.[10]

For rough comparison, the range of conceivable values of the contribution of major fission-reactor accidents to public risk (computed as 6,000 person-days lost per death, including delayed cancers by ignoring non-fatal illnesses and genetic effects) spans not less than 5 orders of magnitude—from 0.0005 person-days lost per megawatt-year to 50 person-days lost per megawatt year—even if the potential contribution of sabotage to the probability of disaster is not considered.

It is important, of course, to specify the way in which social and environmental costs are distributed in space and in time. One distinguishes among local, regional, and global effects, and among effects that are borne essentially at the time of the causative event (e.g. accidental deaths), later in the life of the exposed person (e.g. cancer), or in future generations (e.g. genetic disease). In practice, people seem more impressed by costs that are concentrated in space and time (and society is usually willing to pay more to avoid them). As an ethical problem, however, perhaps more attention should be given to those cases in which the bearers of the costs are far removed in space and time from those who reap the benefits of the activity in question. How assessments that compare different technologies should weigh differences in the spatial and temporal distribution of impact is not at all clear.

The boundary between quantifiable and nonquantifiable criteria is a fuzzy one, as the foregoing paragraph illustrates. Areas and times affected can be specified quantitatively, at least in principle, but the associated issues of the degree of voluntarism in imposed risks and the degree of coincidence of risks and benefits lend themselves to no tidy index.

Two other criteria that are clearly important but, at the same time, quite resistant to quantification are degree of irreversibility of harm and quality of evidence of potential harm. These aspects are not unrelated. The greater the degree of irreversibility potentially associated with a particular course of action, the heavier should be the burden of proof upon those advocating this action to show that the irreversible harm will not in fact materialize—or, in other words, the less conclusive the evidence against proceeding should have to be in order to stop the action. Some semblance of a quantitative index for irreversibility can in principle be supplied in the form of the time required to repair the damage, but this is enormously uncertain in many cases of greatest interest (e.g. nuclear war or climatic change). Quality of evidence can be characterized (e.g. as speculation, hypothesis based on limited data, theory with extensive empirical support, etc.), but hardly quantified.

CONCLUDING OBSERVATIONS

The foregoing observations on the uses and liabilities of various approaches to evaluating the economic and social costs of energy technologies have been intended to be illustrative of the sorts of problems encountered in technology assessment in the energy field, certainly not comprehensive. The interested reader should consult the references for more detail.

While acknowledging that space has not permitted developing many of the points that are relevant to this very broad topic (and that lack of knowledge would in any case preclude developing others!), I will venture some broad observations on the connection of energy costs and limits to growth.

First, in the short term, the main problems will arise from dynamics of growth more than from absolute limits on scale of operations. Attempts to maintain a high growth rate on an already large base, and to increase national self-sufficiency rapidly, will lead to economic gambles on untried technologies that will fail expensively; strains on investment capital; and bigger social costs than would be incurred if there were time to weigh alternatives carefully (particularly troublesome is high risk of irreversible environmental errors).

Second, the data needed to evaluate with confidence the magnitude of the social costs of present energy technologies (to say nothing about future ones) are in many cases not available, and much further research is needed. Nevertheless, the information that is available suggests the possibility in the next few decades of significant interference in critical environmental processes and of a significantly increased chance of the aggressive use of nuclear weapons, to name two important problem areas. That we have come to the point where such disruptions are plausible, without having developed the capability to understand—let alone

---

[10] Table 13 and the fission reactor accident estimates in this paragraph are based on Smith, Weyant, and Holdren.

control—the possibilities in detail, gives reason to slow greatly the growth of energy consumption while more knowledge of the threats, and more benign technologies, are sought.

Third, energy technologies for the longer term are not likely to be cheap, even excluding social costs. For solar energy, hot-rock geothermal, controlled fusion, and fission breeder reactors, raw fuel is free or nearly so, but capital costs are likely to be more than high enough to erase these savings. These capital costs include heavy requirements for nonfuel raw materials, possibly exotic ones.

Fourth, there is no energy technology presently known or imagined (solar energy not excepted) with negligible environmental impact. Among the most fundamental problems are environmental damages associated with materials requirements of energy technologies, and potential disruption of climate by perturbing regional and global energy flow patterns. (The principal climatic threat is not global warming and melting of ice caps, which is slow and far away, but altering circulation and rainfall patterns with disastrous consequences for agriculture, which may be happening already.[11])

Fifth, technological therapy for social costs of existing and future energy technologies is often worthwhile, indeed essential, but laced with pitfalls: logistic constraints on achievable rate of implementation; high economic costs; limitations on level of impact reduction, with diminishing returns to investment at high levels of reduction; and the difficulty that many fixes only *shift* the impact, creating new problems to replace old ones.[12]

In the end, then, there will remain a deep-rooted dilemma in energy's two-sided role in human affairs—its contributions to well-being through material prosperity, on the one hand, and its undermining of well-being through environmental and other social costs on the other. It is inevitable that a point will be reached where the incremental gains in well-being from applying more energy do not compensate for the incremental losses due to the social costs of making more energy available. This point represents a "rational" limit to growth, although a physical limit enforced by unmistakable disaster might be some distance beyond it. There is some reason to suppose that the United States (although not the world as a whole) is already near or beyond this "rational" limit to energy growth.

TABLE 1. *Options for energy supply*[1]

Fossil fuels:	
Petroleum/gas:	
Domestic	(2)
Imported	(2)
Coal:	
Conventional	(2)
Advanced (gasification, liquefaction, combined cycle)	1995
Oil shales/tar sands	2000
Nuclear:	
Fission:	
LWR's, HTGR's HWR's	1990
Breeders	2000
Fusion:	
Magnetic confinement	2015
Laser	2015
Hybrids	2010
Solar:	
Direct:	
Thermal collectors	2010
Photovoltaics	2015
Direct fuel production	2015
Indirect:	
Wind	2030
Hydrological cycle	(3)
Waves/ocean thermal gradients	2030

1 Dates are estimates for earliest contribution of an amount of energy equal to 10 percent of total energy use in the United States.
2 Now.

11 See Holdren and Ehrlich (Note 9) and S. Schneider and L. Mesirow, "The Genesis Strategy," Plenum, New York, 1976.
12 These points are developed at length in John P. Holdren, Technology, environment, and well-being: some critical choices, in Chester L. Cooper (ed.), "Growth in America," Greenwood Press, Westport, Conn., 1976.

Geophysical:	
Geothermal steam	(3)
Hot rock	2015
Tides	(3)
Technologies of conservation:	
Transportation	1980
Industrial processes	1980
Residential/commercial	1980

[3] Never.

TABLE 2.—*Origins of costs of energy supply*

STEPS IN ENERGY'S PATH THROUGH SOCIETY	PHASES ASSOCIATED WITH EACH STEP[1]
Exploration.	Research.
Harvesting.	Commercial construction.
Concentration.	Commercial operation.
Refining.	Eventual dismantling.
Transportation.[2]	Management of any long-lived wastes.
Conversion.[2]	Regulation and monitoring.[3]
Storages.[2]	
Marketing.	
End-use.	

[1] Not every phase is associated with every step.
[2] May occur more than once.
[3] Occurs in parallel with all other phases.

TABLE 3.—*Impacts and costs of energy supply*

IMPACTS	COSTS
Initial investment.	Opportunity costs (goods and services foregone because the money to pay for them was spent on energy instead, or because other resources needed to produce them were used to produce energy instead).
Operating expenses (wages, taxes, insurance, fuel costs, maintenance).	Death and disease (among energy workers, members of the public now living, future generations).
Resource consumption (land, water, energy,[1] other raw materials).	Damage to economic goods and services (property, tourism).
Material effluents[2] (solid, liquid, gaseous, including radioactive materials).	Damage to environmental goods and services (climate, nutrient cycles).
Electromagnetic radiation[2] (ionizing, microwave, and other).	Esthetic loss and nuisance (impaired visibility, ugly structures, loss of environmental diversity).
Heat.[2]	Uneasiness and other psychological distress (among persons displaced by energy technology, or fearful of other costs before they materialize).
Noise.[2]	Undesirable social or political change (loss of civil liberties as a part of government's response to technology-induced vulnerability).
Physical transformation of environment[2] (structures, land-forms, vegetation, fluid dynamics).	
Aggravation of inequity.	
Redistribution of population.	
Facilitation of military developments.	
Other altered vulnerabilities (of the energy sector or society as a whole, to geophysical, biological, or sociotechnical disruptions).	

[1] Investing energy to get energy does not seem such a remarkable phenomenon, but a field of investigation called net-energy analysis has emerged to deal with its ramifications.
[2] These may occur as a foreseen consequence of routine operations or as results of accidents, malicious intervention (sabotage, terrorism), or natural disasters.

TABLE 4. *Examples of impacts of energy technologies*

Resource consumption

Solar: land, metals for collectors, energy for fabrication.
Oil shale: water for extraction and processing.

Fission : water for evaporative cooling, energy for fuel enrichment.
Hydropower : evaporative water losses from reservoir.

Material effluents

Fossil fuels : SO_x, NO_x, CO_x particles (including heavy metals).
Fission : tailings from uranium mills, tritium and krypton–85 from reprocessing.
Geothermal : hydrogen sulfide, mineral salts.
Conservation : asbestos from manufacture and installation of insulation.

Electromagnetic radiation

Fission : neutrons in reactors, gamma rays from spent fuel in shipment.
Fusion : neutrons, stray magnetic fields.

Heat

All energy conversion : discharge, as heat, of part of energy handled.
Electric transmission : stray fields near lines.
All energy end-use : conversion of all energy used to heat, mostly immediately and at point of use.

Physical transformation of environment

Geothermal : subsidence.
Imported oil : dredging and filling for port facilities.
Strip-mining coal : altering landforms and vegetation.
Ocean geothermal : altering local circulation pattern.
Windmills : bird traps.
Oil/gas pipelines : barriers to wildlife migration.

Aggravation of inequity

Fossil fuels : create worst air pollution in central cities where poor cannot escape.
Fission : steers rich-country research and development into channels unlikely to benefit most poor countries.
Conservation : energy-saving investments in insulation, better appliances, etc., out of reach of poor.
End-use : energy-intensive mechanization and automation may eliminate unskilled jobs.

Redistribution of population

Hydropower : displacement of valley residents.
Offshore oil : coastal urbanization around support facilities.
Western coal : development on the High Plains.
Solar : development in the Southwest desert.

Facilitation of military developments

Fission : international proliferation of nuclear weapons.
Imported oil : oil revenues fund armaments for exporting nations.
Laser fusion : possible links to military lasers and design of fusion bombs.

Other altered vulnerabilities

Hydropower : dam failure from earthquake or sabotage.
Fission : reactor failure from earthquake, terrorist A-bombs.
Imported oil : political blackmail.
All-electric economy : regional blackout from central-system accident or sabotage, dependence on central authority.

TABLE 5. *Indices and criteria for evaluating impacts and costs: some examples*

CRITERIA QUANTIFIABLE IN PRINCIPLE AND AMENABLE TO COMPARISON AMONG ENERGY OPTIONS

Initial investment : dollars per unit of deliverable energy flow (per kilowatt or per barrel per day, must be adjusted in comparisons to account for different load factors and equipment lifetimes).

Operating costs : dollars per unit of energy (per kilowatt-hour or per barrel or per million BTU, initial investment may be factored in to give total dollar cost per unit of energy).

Resource consumption : joules of energy, cubic meters of water, square kilometers of land.

Material effluents : kilograms of the same substance emitted by different options (sulfur dioxide from coal and oil).

Deaths: number, or number of days of life lost.

Disease: number of cases, or number of days of activity lost.

Damage to economic goods and services: dollars.

Damage to environmental goods and services: dollar cost of replacing services with technological equivalents (quantification very difficult in practice).

CRITERIA QUANTIFIABLE IN PRINCIPLE BUT DIFFICULT TO COMPARE

Risk to environmental goods and services: magnitude of intervention in a natural process as a fraction of characteristic scale of that process (cumulative human CO_2 input to atmosphere: nature inventory=0.10).

Resource consumption: kilograms of different materials (niobium for fusion versus cadmium for solar photovoltaics).

Material effluents: kilograms of different substances, curies of radioactive ones.

Spatial and temporal distribution of harm: quantitative distribution functions in space and time.

CRITERIA DIFFICULT OR IMPOSSIBLE TO QUANTIFY

Degree of irreversibility of harm.

Degree of voluntarism in risk (occupational versus public risk).

Degree of coincidence of risks and benefits (are benefits widespread and risks concentrated or vice versa?).

Extent of socio-political implications (not only almost impossible to quantify but usually controversial even qualitatively).

Quality of evidence of harm (speculation, theory, extensive experimental evidence).

TABLE 6.—*Capital costs for energy technologies (1974 dollars)*

Fuel and heat (dollars per thermal kilowatt of flow (24-hour average)):	
Oil well, Persian Gulf	4
Oil well, U.S. onshore	100
Oil well, U.S. offshore	200
Oil pipeline (1,500 km)	12
Tanker from Persian Gulf	20
Oil refinery	30
Coal strip mine	20
Coal underground mine	40
Coal train (1,500 km)	4
Coal slurry pipeline (1,500 km)	25
Coal liquefaction or gasification	180
Oil shale extraction and processing	200
Solar home heating	600
Electricity (dollars per electrical kilowatt):	
Geothermal dry-steam plant	200
Hydro dam and powerplant	300
Coal-fired plant	450
Fission reactor (light-water coded)	600
Uranium mining and milling [1]	3
Uranium enrichment [1]	23
Solar thermal electric plant [2] (approximate)	1,200
Fusion reactor (approximate)	1,200
Transmission and distribution of electricity	200

[1] Cost normalized to peak electrical kilowatts of reactor capacity.

[2] Cost not based on peak power but on yearly production in kWh divided by 6,100 hours. This puts capital cost on a comparable basis with nuclear or fossil-fueled plant with annual load factor of 70 percent.

TABLE 7.—ELECTRICITY GENERATION COSTS IN 1990—RESULT OF A SENSITIVITY ANALYSIS

[In millions of electrical kilowatts; 1974 dollars]

Generating system	Low estimate	Base case	High estimate
Coal with stack-gas scrubber	27	32	62
Coal, fluidized bed boiler	22	27	52
Gasified coal, combined cycle	26	31	61
Imported residual fuel oil	32	43	57
Light-water reactor, no plutonium recycle	19	23	69
Light-water reactor, plutonium recycle	18	21	67
Liquid metal fast breeder reactor	18	22	71
High temperature gas reactor	18	21	66

TABLE 8.—USE OF WATER IN FUEL CYCLES FOR ELECTRICITY GENERATION ($10^6 m^3$/plant-year)

Fuel	Evaporated in wet towers at powerplant	Blowdown water in plant cooling towers[a]	Fuel-processing water use[b]	Waste management water use[b]
Standard coal[c]	11.0	6.6	0.3	1.7
Coal gasification/combined cycle[d]	6.6	4.0	.5	
Oil	10.0	6.0	1.5	
Uranium (LWR)	17.0	10.0	.5	.01

[a]Returned to surface polluted.
[b]Some evaporated, some returned.
[c]Wet-lime scrubbing for SO_2 removal.
[d]Combined-cycle powerplant efficiency equals 47 percent; fuel-cycle thermal efficiency 37 percent.

TABLE 9.—LAND USE IN FUEL CYCLES FOR ELECTRICITY GENERATION

	Inventory (km^2 per plant)[a]	Temporary commitment (km^2-year per plant-year)[b]	Permanent commitment (km^2 per year)[c]
Deep-mined coal	12–15	10–29	
Surface-mined coal	12–15	20–240	
Oil	3–14		
Surface-mined uranium for LWR	1	1–2	0.001
Solar-thermal	56		

[a] Includes facilities for processing and transportation, but not transmission.
[b] A 10-yr mean time for restoration to other use.
[c] Plant capable of delivering 1,000 MWe-year per year at 100 percent load factor (18 MWe average per km^2).

TABLE 10.—DILUTION VOLUMES IN AIR FOR ROUTINE EFFLUENTS OF FUEL CYCLES FOR ELECTRICITY GENERATION ($10^3 km^3$ PER PLANT-YEAR)

Fuel and effluents	Dilution volume (powerplant only)[a]	Dilution volume (all other steps)
Coal with lime scrubbing:		
NO_2, SO_2, HC	200–550	7–8
Particles, heavy metals	23–48	[b]29–370
Coal-gas/combined cycle:		
NO_2, SO_2, HC	8–77	7–8
Particles, heavy metals	5–48	[b]29–370
Oil (RFO):		
NO_2, SO_2, HC	66–450	21–58
Particles, heavy metals	12–120	1–4
Uranium:		
^3H, ^{85}Kr, ^{222}Rn	0.0003–0.027	0.013–1.9
Trans-U		0.5–1.6

[a]Standards used, per m^3: NO_2=100 g, SO_2=80 g, HC=160 g, particles=75 g, heavy metal=1.5 g, ^3H=0.2 Ci, ^{85}kr=0.3 Ci, ^{222}Rn=0.003 Ci, transuranium nuclides=5×10^{-8} Ci.
[b]High figure includes coal losses in transport, probably not comparable to other particulate emissions.

TABLE 11.—ENVIRONMENTAL INPUTS FROM ENERGY CYCLES AS FRACTIONS[a] OF NATURAL YARDSTICKS

Energy-related input	Natural yardstick	Input/ yardstick
Petroleum in oceans	Natural seepage	6–20
CO_2 in atmosphere	Atmospheric CO_3 reservoir	[b]0.1
Particles in atmosphere	Volcanoes, sea salt, dust	0.05–0.5
Sulfur in atmosphere	Sea salt, biological processes	.05
Nitrogen fixation ($N-NO_x$)	Biological processes, lightning	0.7
Heat dissipation at surface	Sunlight absorbed at surface	[c]0.0001
		[d]0.01

[a]Ratio of annual flows on a global basis, unless otherwise noted.
[b]Cumulative perturbation in inventory.
[c]Global.
[d]Large urban regions.

TABLES 12.—OCCUPATIONAL ACCIDENTAL DEATHS AND INJURIES IN FUEL CYCLES FOR ELECTRICITY GENERATION (1 SIGNIFICANT FIGURE)

Fuel	Deaths per plant-year	Injuries per plant-year	10^3 man-days lost per plant-year[a]
Deep-mined coal	2–6.0	30–100	10–40
Surface-mined coal	1–4.0	10–60	7–30
Oil	0.1–0.2	4–10	1–2
Uranium (LWR)[b]	.1–0.3	5–10	1–2

[a]Evaluated at 6,000 man-days per death and 50 to 100 man-days per injury, depending on fuel cycle and stage.
[b]Range encompasses surface and underground uranium mines.

TABLE 13.—PUBLIC HEALTH IMPACTS OF ROUTINE OPERATIONS OF ALTERNATIVE ELECTRICITY GENERATION SCHEMES

[Person-days lost per megawatt-year. Person-days lost computed at 6,000 per death, 50 per illness other than cancer, 100 per cancer.]

	Low estimate	High estimate
Coal plant with stack-gas scrubber	5	1,500.0
Coal plant, fluidized bed combustion	4	800.0
Coal gasification plus combined cycle	0.3	200.0
Residual fuel oil	2	1,500.0
Fission reactor (light-water cooled)	.01	.1

ARTICLES FROM SECRETARIAT FOR FUTURE STUDIES

A Progress Report From the Future Study "Energy and Society," February 19, 1976

1. INTRODUCTION

The Secretariat for Future Studies in Sweden has commissioned four future studies, one of which is the project "Energy and Society". Further information about the Secretariat is available, see (1).

The study "Energy and Society" was decided upon in the spring of 1974. Planning started late fall 1974, the staff was recruited and some subcontracts were made during the spring of 1975. The project group, which altogether consists of 5 persons, started working September 1, 1975. Since then numerous contracts have been taken and a series of more limited reviews and special studies commissioned. Some reports have already been published. The study is scheduled to be completed at the end of 1977. We think that it is now appropriate for a progress report.

The Swedish debate on energy policy has been very intense during 1974 and 1975. The Parliament has decided to adopt a conservation program with the aim that the annual increase in energy demand shall be reduced to an average of 2% during the years 1975–85. The government has also decided to study the possibilities of implementing "zero growth" in energy from 1990 and onwards. Another review of energy policy will take place in 1978.

A series of projects and studies have been commissioned by the government for this next round of energy policy. This future study is one of these projects. For further information on Swedish Energy Policy, see (2) and (3).

The outline and perceptional framework of this future study is discussed in (4), where some of the other activities on Swedish Energy Policy are mentioned. This study has been planned by the project group. The plans have also been discussed in an advisory group for the different departments of the Swedish Government, the chairman of which is the energy policy adviser to the Prime Minister.

2. MODE OF WORK

As is elaborated in (4), the main work of the project group is not towards research per se, but in organizing research already been done into what we hope will be a coherent framework for analyzing the long term energy policy options of a small, well-to-do country. Long term policy is to no small degree a matter of perception and we will later dwell somewhat on how we today perceive of the problems.

The professional backgrounds of the project staff include operations research, systems analysis, public administration, econometric model building and basic physics.

At the same time we are subcontracting a fairly large amount of state-of-the-art-papers on different subjects, mainly to researchers in different universities.

3. PROGRAM OF WORK

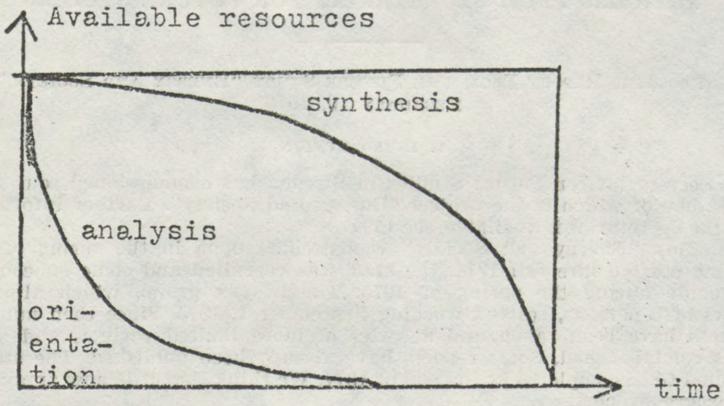
We have somewhat arbitrarily divided our work into five blocks—or areas—and three phases. The five blocks are:

1. Interaction between energy policy and other policy areas.
2. Energy demand.
3. Energy supply.
4. Institutional aspects of energy policy.
5. Methods of integrating supply and demand.

The three phases are:

1. A phase of orientation (how do we perceive of the energy policy problems).
2. A phase of (deeper) analysis.
3. A phase of synthesis.

We have started working on all five blocks simultaneously. The resources allocated over the project's life time in the three phases are suggested in the figure below.



Right now we are about 4/5 through the orientation phase. Although most work has been done on block 1, all blocks have been started upon.

Results so far will be discussed somewhat below. We are right now in the process of putting priorities on what to concentrate upon in the second phase.

Below follows a very brief presentation of results achieved so far together with hypotheses on important areas for future work. This progress report contains a number of preliminary findings and hypotheses. We have deliberately been rather explicit, with the sincere hope that readers who have access to studies that confirm or reject our results and main ideas will contact us. This presentation starts with the work being done in the five blocks (section 4–8 below) and is concluded by a description of what we now think will be the main outline of the synthesis.

4. SHORT DISCUSSION ON BLOCK 1—INTERACTION BETWEEN ENERGY POLICY AND OTHER POLICY AREAS

This block is subdivided into five subblocks on economic, social, environmental, structural and foreign policy.

4.1 Energy and economic policy

We have completed a rather thorough study of the energy use since 1950 in the Swedish economy. Draft reports (in Swedish) are completed. This analysis shows that per unit of GNP Sweden's economy has become more energy intensive over the years. Energy use divided into the usual different sectors—industrial, commercial, transportation and residential—give some more detail.

Industry has increased its use of energy, but kWh/unit output has decreased over the years. The same goes, of course, for labour. Labour productivity has increased faster than energy productivity, why energy per job has increased over the years.

All other sectors have had a slight decrease in energy efficiency (energy demand per unit output has increased) over the years. This holds for agriculture, forestry, transportation, commercial. Energy demand per job has increased rapidly in all sectors.

We have also studied energy use per unit of final demand in the economy. Table is for 1970, primary demand for energy.

	TWh	Percent	Per unit (kwh/SCr)	Labor intensity L/SCr. 1,000
Private	191	44	3.06	26.1
State	19	4	1.70	44.1
Municipal	23	5	1.24	51.1
Investment	58	13	2.16	47.0
Export	135	31	4.70	41.0
Inventory change	14	3		
GNP total	439	100	2.60	

These figures have been studied over time as well. We have not yet corrected Swedish energy use for energy content in imports. We have also studied the influences on energy use of changes in composition over time in final demand.

This study showed that these changes in composition have had a very large influence. Especially the private consumption has become more energy intensive, and at the same time the direct use of energy relative to total energy has increased. This simply reflects changes such as more cars, bigger housing, more energy intensive leisure time etc. We are now in the process of disaggregating the final demand for energy into different end uses (food, housing, medical care, education etc).

These retrospective studies have together with research being done in other places given us some fairly strong hints of future conflicts between different goals. Right now we believe that it will be difficult to simultaneously achieve low growth in energy demand, full employment, increase in real income and reduced distribution of wealth. The main reason is that an increase in real income demands an increase in the overall labour productivity in the economy, which in turn demands a certain size of the goods producing sector, where labor and capital to a greater extent is interchangable than in the service sector. This coupled with employment goals and the energy intensiveness of private consumption make us believe that it will in the long run be difficult to decouple energy demand and economic growth—*unless* we conceive of rather drastic changes in the composition of private consumption. Since the energy intensive part of this is related to housing, transportation, food delivery and (possibly) leisure time we feel that such changes will not take place easily.

However, we feel that the present way of analyzing e.g. the conflicts between energy and employment is not sufficient for the long-term perspective. Economic models by definition only consider the monetary economy and are not usable for analyzing interfaces and interdependencies between e.g. monetary economy and nonmonetary ways of distributing productive resources in e.g. households, between households etc. Prime examples of such interfaces are the service sectors, for example, taking care of children and old people which only to a small extent is registered in the monetary economy. Most services are distributed outside the economy. In other words, long-term discussions on energy and economy need a foundation in a theory of how jobs are created which extends beyond the inherently short and medium term concepts of the present economic theory where creation of jobs are by definition linked to the size of the monetary economy.

Parallel to this is a feeling of ours that the question of economic growth (and real income) per se and its relationship to energy supply is a somewhat misleading question. Obviously the content of growth, that is, the composition of production and thus consumption is a more interesting aspect. How this could be analyzed is, however, another question, but we feel that more effort should be directed towards this area.

We will publish two reports on energy and economic growth and energy and employment during spring 1976.

4.2 Energy and social policy

We have also started some studies on the interface between energy and social policy. The first study aims at getting a better description on energy use by the

Swedish consumer. We are looking at household expenditure in different categories of goods and services and the resulting direct and indirect use of energy. Here we also want to describe how different Swedish households use energy—the type of houses, cars, appliances they use etc.

Saturation levels are quite clear in many appliances, but there is no reason to believe that there automatically will be any saturation in over all use (direct and indirect) of energy.

Future energy demand from households seem to be highly dependent on how people choose to spend their free time. There are some very energy intensive ways of spending free time, and it is not inconceivable that these patterns will grow quickly. Policy on the shortening of the working time is therefore important, and it seems that the general agreement by all political parties to aim for reducing number of working hours per day rather than the number of working days per week will have important impact on free time patterns of living.

If possible we will extend this study on household expenditure to deeper studies on life styles. The report on the household and use of energy is due in spring 1976.

We have also done some preliminary thinking on the relationship between the level of participation of the individual—that is, the degree of control he has over his own situation—and use of energy. This seems to be particularly important in the housing sector—it is rather evident that persons living in single family dwellings have a much greater control over their use of energy than people living in apartments. This is also related to the type of contracts the tenants have, whether they simply rent or whether they are co-owners. Here organizational and technical components interconnect. It would be interesting to study how the degree of control has changed over time for different groups of individuals, and how these changes have related to the relative weighing of performance and efficiency as opposed to self reliance.

We do not yet know how much material we can find on these topics, but we have started to collect data on energy use in space heating as a function of type of ownership and the degree of control. More information on this topic should be available during spring 1976.

4.3 Energy and environmental aspects

We have just about completed two survey studies on the amount of energy needed for pollution control and control of hazards in work life. The results indicate that the amount of energy needed for these activities are comparatively small and are likely to remain so in the future. The study on working hazards concludes that the greatest part of energy demand in this sector is from ventilation in places with toxic particles, gases etc. in the air. This ventilation increases greatly the amount of air that has to be heated, and different heat recuperation components can significantly reduce the total amount of energy needed. In other working places it is the heat flux itself that is hazardous, and therefore energy conservation measures automatically decreases the hazards involved. These reports are being completed during winter 1976.

We have also commissioned a state-of-the-art paper on the relationship between energy and climate (5), written by Swedish meteorologist Bert Bohlin. He concludes that the green house effect of carbon dioxide is the most important of the diverse effects on the climate from energy use that has been discussed. The total amount of fossil fuels (coal, oil, gas) already identified on earth vastly exceeds the amount that from climatological reasons can be safely used. In other words, it seems as the use of fossil fuels is limited not by the total amount available but by the green house effect on the climate. This report is available in English.

We have also commissioned a survey on the relationship between energy production and environment. This study will survey what is known about the impact on health, etc. The study will be completed late summer 1976.

4.4 Energy and social structure

Swedish debate has to a none-too small extent centered around the structural consequence of different choices of energy technology. Those consequences have an organizational and a geographical dimension.

We have commissioned a study to review the literature on technology and social structure, with special emphasis on energy technology. The results so far have been rather limited, but some interesting observations have been made. A preliminary report will be presented at a seminar this March. The work will continue in block 4, institutional aspects of energy policy.

The geographical dimension of social structure is possibly somewhat easier to discuss. As is suggested in (4), there seems to be a rather close relationship between the way we organize our society spatially and the amount of energy we use. The spatial organization not only conditions the amount of transportation necessary, it also conditions the total amount of buildings, etc., necessary in a society. One way to study these topics is through so called time-budgets. We have not yet started working on this. So far we have commissioned a survey on what is known in geographical sciences about the role of energy.

4.5 Energy and foreign policy

We have commissioned a survey on the situation of developing countries and the future world energy market. This study, which will be completed during spring, shows clearly that the present conditions on the world oil market—comparatively low prices, with energy (inspite of the OPEC oil price raise) only playing a limited part in the total budget of the rich countries—is dependent on the fact that the great majority of population of the world does *not* demand the same amount of energy as does the developed world. In other words, to the extent that our wealth is dependent on cheap oil, it seems that our wealth and their poverty are interdependent. This indicates, to put it mildly, a highly unstable situation.

We have also been thinking about the types of dependencies that energy policy make up between developed countries. There are many interesting examples here, but we have not yet started serious work. The question of international relations will be touched upon later in block 3, in relations to the supply situation.

5. ENERGY DEMAND—A SHORT DESCRIPTION OF BLOCK 2

Energy demand is usually discussed in terms of output from different activities in the economy and their respective use of energy per unit output. See (6) for an illustrative example.

In more complex studies econometric models are frequently used. This will be the case here, and the model is described in (7). It will enable us to study the relationship between different growth rates in terms of final demand in the economy and the corresponding impact on the use of energy.

Conservation measures will have to be included in this work.

A report on energy conservation in the Swedish housing sector has already been completed by one of the members of the project staff (8). This study, which is based on a linear programming model, gives a detailed breakdown of what conservation measure should be implemented and how the corresponding energy supply sector should be organized. The results indicate that it is economically sound at present oil and electricity prices to invest roughly 1,000 MSCr per year during 10 years in conservation measures. This would lower the energy demand for space-heating with roughly 20 percent. The calculations also indicate that district heating ought to be extensively promoted, combined with electricity generation.

We are right now completing surveys on conservation measures in a Swedish industry and the transportation sector. A large number of studies of separate industries will be published during the spring, and we expect to have a much better grasp of these matters at the end of spring. If possible these results will be run through the econometric model.

Such studies as described above are fairly straight forward. A number of them exist nowadays. However, it seems to us that they have to be complemented on two aspects. First, they give very poor indications on what the situations look like as seen from the consumer. Secondly the basic idea of dividing the economy into "producers and consumers" obscures some important aspects, however convenient the division is in other aspects.

To look at energy demand from the consumer's side in the economy is very much related to what was discussed in 4.2 above. We have therefore done a survey of energy analyses with the explicit purpose to look at life cycle energy costs. What cars cost in energy terms in production and use, what do houses, food, appliances cost etc. The findings indicate that nearly all of the major household energy consuming devices require more energy in their use than their production. At the same time, the possibilities of the consumer to influence the use of energy is rather limited once the device is bought. This indicates the necessity to go further into life-cycle energy costs and the key-role of the design of devices. This design influences not only energy cost of using, but also energy and economic cost of material recycling. This report is published (9) in Swedish.

Energy use in any type of activity is intimately related to technology, which in turn is intimately related to organizational and institutional aspects. A number of studies of the food-delivery-system in different countries (UK, U.S., Sweden) have shown that the amount of energy needed to feed the population has increased quickly during the last decade. This of course reflects technological change in agriculture, food industry, distribution systems, retailers, et cetera.

We think it would be very illuminating to study how these food delivery systems (from farm to kitchen) have changed technically and organizationally over the years. The same type of studies ought to be done on other functionally defined delivery systems, such as housing, clothing, health, education, etc. We think that such studies would add important knowledge to the role energy has played in technical and organizational change. It is, however, not likely that we ourselves will have time to do such studies.

We mentioned above that it was necessary to use other approaches than looking at the economy from the producer's or the consumer's point of view. In (4) we have elaborated somewhat on this, and found that the use of energy in Sweden to a large extent seems to be explainable in terms of the flow of material in society and the (with the material-flow interdependent) spatial organization. The latter topic was mentioned under point 4.4 above, and will not be further covered.

The flow of materials through society is obviously important, since the material processing industry plays such a large role in the energy budget of the country. Possibly also since energy supply takes an increasing share of this material flow. We have therefore started a survey with the aim to collect what studies we can find on end use of different materials in Sweden and other developed countries. We do not yet know what the results will be, but we expect to have a much clearer understanding of the interactions between energy flows and material flows.

6. ENERGY SUPPLY—A SHORT DESCRIPTION OF BLOCK 3

We have started our orientation phase in the supply area with once more analyzing energy demand. But this time from a physical point of view. In (4) we have explained why end-use analysis in terms of physical energy quality is important. We have therefore started a review of concepts of energy quality with the aim to describe Swedish energy demand in qualitative terms. This study will later be extended into comparing supply and demand in qualitative terms, in the sense of the matrix below.

		Energy demand High quality	Energy demand Low quality
Energy supply	High quality		
Energy supply	Low quality		

Today the demand side is roughly equally divided between high and low quality energy use (the latter being mostly space-heating), while almost all of the commercially supplied energy is high quality.

Studies of these kinds will make it possible to study the potential of alternative energy sources. Not only in the all-too-frequent discussion whether the alternative sources can compete with e.g. nuclear energy on the latter's terms but in the terms of the type of energy quality demanded in end-use.

This, we feel, will open up some new ideas on how to discuss different supply options. It should be stressed already here that such studies have to include possible changes in energy consumer's technology. Today electricity supply in Sweden is 50 p/s AC, reflecting the historical fact of centralized power production. Quite a few alternative options are not AC but DC-based, as e.g. photovoltaic cells, storage systems such as fuel cells, batteries, etc. This suggests that one of the interesting ways to make these alternative options economically feasible is to make electrical equipment more adaptable to alternative supply systems. We will return to this question in the next section.

We have also started collecting the studies being made on energy resources, notably fossil fuel and uranium. Here we have taken an interest in the interactions between the light water reactor fuel cycle and the penetration of the breeder reactor.

It seems that the quantitative relationship between various variables such as the size of the light water reactor programme, capacity of processing plants and the doubling time of the breeder reactors imply important conclusions to the political economy of the uranium world market already in the 1990's. We are working on a short review on the quantitative aspects of the above mentioned quantitative relationships and are very much interested in the political aspects.

Obviously the political economy of the world petroleum market in say the 1990's is also interesting. We have not found any attempt to figure out what this market might look like once when world production has peaked. It is frequently assumed that reactions to increasing shortage will be smooth adjustments through the market mechanisms, but we suspect that the market will be highly unstable and unpredictable. It seems to us that the key role in this will be played by the U.S., and the relationship between U.S. energy policy and foreign policy therefore seem to have important implications for among other countries Sweden.

We have also discussed a number of other studies in this block, but this will not be elaborated upon here.

7. INSTITUTIONAL ASPECTS OF ENERGY POLICY—BLOCK 4

The aim of this block is to understand what the institutional requirements are if the Swedish society wants certain energy technologies implemented—whether they are supply or on the conservation side of the equation. In (4) we have discussed at some length what we believe are the essential differences between an energy policy that is basically supply oriented and one that is basically aimed at controlling both supply and demand.

We have therefore devoted considerable resources to this area, and have commissioned a series of studies. One of these is a study of Swedish energy policy since the end of the last century. This study, which will be completed during spring this year shows quite clearly the interactions between technical and organizational (at the corporate level) and institutional (intercorporate level) change. Energy policy as reflected in official documents are moreover almost solely electricity policy, despite the fact that fossil fuel has had a much greater importance during the century. This "bias" of the official documents simply reflects the different institutional implications of fossil fuel in Sweden and electricity. The latter penetrated into Swedish society at the end of the 19th century and demanded roughly 20 years of intense adaptation of the legal system in order to be viable. Fossil fuel, by contract, needed almost no such change. The electricity supply system was very early split into two groups—producers and distributors. The latter were quite frequently municipal authorities, and this has been very important during the fights over combined power generation (electricity and district heating) that has raged since the 1960's. The electricity producers are very much against combined systems for a variety of reasons, but it seems that one of the main reasons is a question of role and domination. If the local authorities themselves produce a large part of the electricity that they distribute the electricity producers will have a totally different market situation than otherwise. This by now 15 year old fight seems to be intimately tied up with the nuclear power policy question as well.

Another study that recently has been commissioned is a review of the regulatory system of the power industry. There seems to be a built in "force-of-expansion" in the system of rules governing rates, depreciation rules, accessibility to the capital market etc. A specially interesting part of this system of rules is the to a large extent self-imposed rules of quality of services (as the variability of periodicity, voltage etc). Such rules tend to have large implications for capital costs and represent interesting and by no means unquestionable divisions of responsibility between the electricity producers and the producers of electrical equipment for industry, households etc. The higher quality standards for e.g. voltage, the higher the cost for the electricity producer and thus electricity and the lower the cost to the consumer of buying the appliances.

These rules have not been changed since the 1930's, and seem never to have been studied on a cost-effectiveness basis. Rough estimates also show that the quality offered probably exceed the quality needed to a large extent.

All these aspects are important since rules of this kind often have profound influence on the technical and organizational build-up of the system. The question of who should stabilize the voltage—the appliance itself, the individual household, the landlord, the electricity distributor or the producer—do not only have implications on costs but also on the role that so-called alternative energy supply options can play (see section 5 above).

This is just an example of several that are discussed somewhat more extensively in another study, which goes into more detailed discussion on the relationship between technical and organizational change in a number of Swedish cases. These cases include the struggle for domination over the national power grid, attempts to use waste heat from industries for district heating etc. All examples show that technical components that bridge technologies belonging to different organizations and different professional schools are subject to fierce struggle and frequently rejection.

The implications by the work so far done are very clear. There are some very steep stumbling blocks in the way of different alternative energy sources, such as wind, solar etc. or even cogeneration based on e.g. diesel engines. These blocks do not depend on the complexity or the novelty of the technology involved but on the mess larger scale introduction of new technologies usually do to the social systems built around existing technologies. It should be stressed, that while the utilities never had any serious problems in accepting the highly complex nuclear power, they have been much more negative to the essentially much simpler systems based on cogeneration. The latter is a threat, while the former is (or was) a promise.

A series of studies will be discussed at a seminar in March of this year. After that it will be discussed how publications will be made. There is no doubt but that this area is virgin territory, but it also seems to be very fertile for further studies.

8. NOTE ON THE SYNTHESIS

The different studies mentioned above are, as can be seen, so far rather fragmented parts of the orientation phase, together with certain deeper analyses.

We have also started some discussions on how to intergrate all these fragments into a somewhat more holistic perspective. While we are by no means certain how this is to be done, we do have certain ideas.

The main principle of long term energy policy for a small country, as we see it, is to ensure a certain degree of freedom. We do not want to become "prisoners of the energy system", i.e. we want to be able to *choose* our energy future. This in itself calls for alternatives. These choices, however, should not only be between different energy supply systems, they should be choices between different energy goals and different social goals since these goals never can be separated. It follows that long term energy policy should be directed more towards avoiding the bad and dangerous situations rather than towards the one and only "best" solution. Usually coupled to this problem is the problem of how to avoid premature decisions, and the problem of estimating the cost of waiting. After all, the best energy policy is a policy that does not create any problems.

An idea of avoiding the bad rather than going for the best makes a certain influence in perception of the problem.

We feel today that the long term Swedish energy policy problems have the following facets:

Transformation.—The time horizon of the present oil and (quickly coming) uranium based burner reactors (LWR etc.) is limited. This time horizon seems to be of the same order of magnitude as the time horizon for making distinct changes in the demand pattern. Not perhaps in the time horizon of conservation measures, but in measures aiming at the growth of particularly energy intensive activities.

It is not inconceivable that we will have serious and structural disturbances in the world oil and uranium market during the 1990's. This could hit a small country like Sweden seriously. It seems that one of the main factors deciding how smooth this transformation from present energy resource bases to future bases will be the policy of the U.S.

Future alternatives.—Beyond oil and burner reactors stand a number of alternatives (and combinations thereof). The main ones are:

The breeder technology.
The solar technology.
The coal technology.
Fusion, possibly.

All these have different advantages and disadvantages and represent different stages of technical and economical feasibility. Shale-oil are hardly possibilities in Sweden.

The main differences are of course in quantitative and qualitative potential. The breeder (assuming it is acceptable for other reasons) seem to have a limitation in rate of introduction (depending on size of burner reactors, doubling times etc.), while solar mainly is limited in annual amount (and intensity). This calls for a slightly revised way of analyzing energy demand. This has been discussed in section 6 above.

Energy demand is usually analyzed as if the supply is fossil fuel, i.e. in terms of primary BTU's. The above mentioned long term alternatives call for different ways of analysis, making explicit allowance towards the differences in energy quality of the different sources. This will be done through a slightly revised econometric model, where energy demand is expressed in qualitative terms (process heat, low temperature heat, nonsubstitutable electric, transportation etc.). This has been discussed in section 6 above.

Energy use and social goals.—The rather extensive studies mentioned in section 4 above already give some ideas on how serious the conflicts are between a policy for reduced energy growth and other social goals.

Some of the major long term conflict areas seem to be:

Real income, due to the high (higher than GNP) energy intensity of private consumption. At the same time, one wonders what the significance of such a concept as real income is in a longer time perspective. Possibly we should stop worrying about real income and start thinking more about content of growth, consumption patterns etc.

Distribution of income, since it seems unlikely that we can afford average Swedes to live on the same energy budget as today's well-to-do without drastically increasing energy demand. In other words—limitations of a growth of energy demand will also sharpen conflicts over distribution.

Climatological consequencies of increased use of fossil fuels.

Institutional consequences of different choices of supply technologies. Breeder, fusion and possibly larger scale use of coal will almost surely call for a decision making network capable of very high level coordination, and thus centralization. Wide-spread use of solar power could be made to fit into such a structure, but need not have one. On the other hand, the institutional consequences of more decentralized systems are not necessarily altogether positive.

Foreign policy, especially national independence. It seems that the different sources have very different consequences as regards our independence and self-reliance. The relation between rich and poor countries, enters this area of conflicts as well.

This list does not mean that other conflicts may not arise. But it means that we think that it is possible to have e.g. high employment and reduced growth of energy demand. The same goes, possibly, for environmental aspects of energy (other than climate). That these conflicts could be solved does not mean that they will be solved (of course).

Freedom of action.—This has already been mentioned as the backbone of the future study. To keep options open has a cost, especially to those who feel they already know what the best (or worst) solution is, and therefore have to bear the cost of postponing decisions.

Strategies for keeping Swedish options open.—Certain decisions have to be taken now in order to increase the number of options. One such option-increasing strategy is conservation. There are others, e.g. in the institutional field.

9. CONCLUDING REMARKS

It should once again be stressed that this paper is a progress report. It contains findings that we today think are important. Since our work has just begun, we cannot promise that we will not change opinions and priorities during future work. We therefore welcome comments and studies that confirm or reject the hypotheses we have made here.

BIBLIOGRAPHY

1. Programme for Future Studies in Sweden. Secretariat for Future Studies, P.O. Box, S–103 10 Stockholm.

2. The Prime Minister. Address to the meeting of the Executive Committee of the Social Democratic Labour Party, Sundsvall, February 1975. Prime Minister's Office, Fack, S–103 10 Stockholm.

3. Energy Planning in Sweden. A presentation of the resolution on energy policy adopted by the Spring Session of the 1975 Riksdag. The Ministry of Industry, Fack, S–103 10 Stockholm.

4. Energy and Society, Conceptual outline introducing a future study. "Energy and Society", Fack, S–103 10 Stockholm.

5. Bert Bolin. Energy and Climate. Secretariat for Future Studies, Fack, S–103 10 Stockholm.

6. Energy for Sweden. Forecasts and R&D Programme. October 1974. Ministry of Industry, Fack, S–103 10 Stockholm.

7. Bergman-Bergström-Björklund: An Energy Forecasting Model for Sweden. 1976. Economic Research Institute, Stockholm School of Economics, Box 6501, S–11383 Stockholm.

8. An Energy Demand Model for the Swedish Residential Heating Sector. Working Paper 6048. January 1976. Ekonmiska forskningsinstitutet vid handelshögskolan i Stockholm, Box 6501. S–113 83 Stockholm.

9. Energianalyser—en introduktion samt försök till strukturering. Thomas B. Johansson and Måns Lönnroth. A report from the Future Study "Energy and Society", Fack, S–103 10 Stockohlm. December 1975.

OCTOBER 26, 1976.

The Future Study: Energy and Society

SWEDISH ENERGY POLICY—TECHNOLOGY IN THE POLITICAL PROCESS

Introduction

This paper aims at discussing technology as an issue in the political process. The main emphasis is on energy policy, and the paper is very much an open-ended one. More questions are asked than being answered.

The paper is based on the work in the project "Energy and Society,"[1] one of the projects of the Secretariat for future studies in Sweden.[2]

The paper consists of two interrelated but somewhat separate parts. In the first part (sections 1, 2, 3) we will discuss the decision on energy policy taken by the Swedish Parliament in May 1975. A decision that was seen by many as marking an end of one era and a beginning of another. In the second part (sections 4, 5) we will discuss the driving forces behind the Swedish electricity supply systems. Forces that here are explaining in terms of the interrelations between technical and organizational change.

The two parts will be tied together in the end by some notes on possible future long term energy policies, the introduction of new technical alternatives and their relationships to recent and possible organizational structures. The main theme will be that it does not seem likely that we will have very much choice when it comes to supply technologies unless we change the division of responsibility in the energy supply system.

The paper is concluded with an epilogue, where the situation of nuclear power after the parliamentary election in September 1976 is discussed.

1. The situation in 1975

1.1 The decision of the Parliament in May 1975

The Swedish Parliament took a decision on future Swedish energy policy in May 1975. The main contents of this decision were:

An outspoken intent to decrease the historical growth rate of final energy demand to 2 percent on the average between the years 1975 and 1985, together with a commitment to try to achieve zero growth in final demand from 1990 onwards.

To realize this goal a series of measures were taken. These include a higher tax on energy, grants for retrofitting in spaceheating, grants for increased use of waste-heat from industrial plants, etc., together with a large R. & D. program. The latter is divided roughly equally between supply and demand.

A series of measures on the supply side. Notably a continued expansion of nuclear power.

A new decision on energy policy to be taken in 1978.

More details will be given later in the paper. For a comprehensive summary, see the speech of the Prime Minister[3] and material from the department of industry.[4]

This decision has been marked as the end of one era and the beginning of another.

The outgoing era was an era when energy policy by and large was handled on the administrative level in the government. Only rarely were fragments of energy policy discussed in the Parliament or by the Government. The policy up to 1975 can be summarized as a supply-oriented policy, with the main emphasis on electricity supply. The oil supply was by and large left to the market forces.

---

[1] Energy and Society. Conceptual outline introducing a future study. Secretariat for Future Studies. Sweden. December 15, 1975.

[2] Programme for Future Studies in Sweden. Secretariat for Future Studies. Sweden. November 1975.

[3] The Prime Minister. Address to the meeting of the Executive Committee of the Social Democratic Labour Party, Sundsvall, Sweden, February 1, 1975.

[4] Energy Planning in Sweden. The Ministry of Industry. Sweden. 1975.

Thus it can be said that with some minor exceptions energy had not been a political issue since, roughly, the beginning of this century. We will return to this later, and only note that at that time energy was an issue because of the intense legislative work necessary to implement hydropower into an economy whose legal system reflected the then essentially agrarian character of the country.

The new era is characterized as **a policy of active balancing of supply and** demand. With a deliberate weighing of measures to increase supply with measures to decrease demand. This means a qualitative change in policy which already has meant some rather marked changes in the division of responsibility not only between the private and the public sector, but also within different parts of the public sector.

This change occurred gradually, but two events were significant. The first one was the change in the outlook on nuclear power that took place in 1973 and the second was the oil embargo.

1.2 Nuclear power in Sweden

Nuclear power has since long been seen as the next stage in energy supply. This goes back to the 1950's, when there was some worry about the rapidly increasing imports of oil. Nuclear power was then seen as a method for generating space heating. More seriously it also goes back to the discussion during the 1950's and 1960's on conservation of the remaining rivers in the north—during these years nuclear power was seen as the next method to generate electricity and thus gave the possibility to preserve parts of the wilderness.

Nuclear power was also a part of the industrial policy of the country—the wish to be on the technological frontier covered not only nuclear power but also e.g. computers etc. Sweden was anxious to establish a nuclear industry of its own, and heavy commitments were made in different forms. In 1972 the CDL[5] published a forecast of electricity demand which required a plan for building 24 nuclear reactors up to the year 1990. This would make Sweden the largest nuclear power in terms of electricity generated per capita. Political agreement was unanimous.

The first nuclear plant was built by a private consortium, and the 24 plants were to be built by both private and public utilities.

According to the law on nuclear energy a utility that wants to build a nuclear plant has to ask the Government for permission. The Government's decision is taken after a series of court hearings etc., has been made. If the plants are constructed by the State Power Board the Parliament as well has to decide upon the financing.

By 1973 decisions had been taken to build a total of 11 plants—some private, some by the State Power Board.

By now a growing uneasiness was felt, and individual members in the Parliament started asking questions on among other topics the nuclear fuel cycle. A leading person in this change of mood was Nobel laureate Hannes Alfvén, who questioned among other things reactor safety, proliferation, waste handling etc.

A bill was presented to the Parliament by one of its members calling to a halt the further expansion of nuclear power if certain requirements could not be met. The bill was rejected by the Parliament, whcih instead stated that "no decisions should be made on expanding nuclear power until a comprehensive material is available to the Parliament".

All that existed up to 1973 was thus a forecast made by CDL, which requested 24 plants up to the year 1990. The program was a program for generating electricity, and there was no equivalent program for handling the total fuel cycle.

The result of the debate in the Parliament was thus what has been called a moratorium. A series of royal commissions dealing with energy forecasts, nuclear matters etc. were supposed to be finished during 1974, and it was concluded that a new decision should be postponed until 1975.

But the resolution of the Parliament also in effect meant a change in the balance of power between the executive branch—the Government—and the Parliament. Without any formal legal changes the Parliament made itself the final decisionmaker on the number as well as the location of nuclear plants.

1.3 The oil embargo

Import of oil expanded rapidly since 1945. Every now and then worried remarks were heard on the growing dependence on foreign energy sources, but by and

---

[5] CDL (Central Operating Management). Electricity Supply in Sweden 1975–1990. 1972 Study.

large this dependence was accepted. Since the expansion almost entirely was managed by the private sector—the early attempt by the Social Democratic Government to socialize the oil industry around 1946 was never carried out—the expansion also by and large went unnoticed in the official documents. The intervention of the public sector was limited to requiring certain stockpiling of reserves. The short interruption of supply during 1956–7 was followed by a period of steadily falling oil prices and was by and large ignored.

The embargo of 1973–74 changed all this. Not only did it show the vulnerability of Sweden to external pressure. It was to many also an ominous sign of structural difficulties within the industrial societies. And of course between the rich and the poor world. To some the oil crisis was taken as a reason for trying to awake the public to the fact that more fundamental changes in the capitalist economy were necessary. To some extent this also included parts of the Government.

1.4 The public debate on energy policy

Thus the review of nuclear power decided upon by the Parliament coincided in time with the oil embargo.

These two events thus triggered a debate with two major aspects. What should the energy supply look like, and how much energy did we really need.

The government responded to this new situation and in January 1974 mounted a campaign of study groups throughout Swedish Society. These study groups were organized under the aegis of the voluntary adult education associations which in turn have strong links to different popular movements such as the political parties, churches, temperance movements, etc.

Special grants were given and the educational associations were offered background material of different types. Most of the associations decided to write their own booklets.

The groups started their discussions in the fall of 1974, and altogether some 8,000 study groups were set up with altogether 80,000 participants. About half of these were organized by ABF (the Swedish WEA—Workers' Educational Association) which has close ties with the Social Democratic Party and the trade unions. The other participants were divided between liberal- and center party, the conservatives, churches, environmental groups etc. Thus the study groups were only partly oriented to political parties.

During this fall there was also an intense discussion in the press, together with public meetings, hearings of experts, et cetera.

No doubt the debate centered a lot around different aspects of nuclear power. But it also developed into a debate on how much energy that was needed, what the relations were between energy supply and different social goals such as high employment, welfare, environmental questions etc. The debate rapidly evolved into a debate based on fundamental political views on society.

At the same time none of the different political parties had any clear cut views of the future energy policy.

There were of course differences—the center party taking a strong stand against nuclear power at an early stage—but by and large the programs of the political parties evolved as a result of the debate.

The bill of the Government and the subsequent decision of the Parliament has to be seen in this light. On the most sensitive topic, nuclear power, it was decided to increase the number of nuclear plants from 11 to 13. This would secure the supply of electricity up to the year 1985.

Thus, we can say that in the short run the plans of the electric power industry of 1972 were by and large upheld, although the forecasts were reduced. The inertia of the factors deciding the demand was regarded as too large, they were not possible to break too quickly. In the short run the viewpoints of the established organizations of energy supply was by and large accepted. In the longer run they were not.

And there is no doubt that the Government and the Parliament strained somewhat the interpretation of the study groups conclusions on how much nuclear power that was acceptable. The opinion polls continue to show a strong uneasiness about nuclear power, which cuts through all political parties.

Although all the political parties have declared their views on nuclear power, it is obvious that the feelings of the public do not neatly follow the party lines. The split is much more within than between parties. In all parties very large groups are against nuclear power, and it is much too early to declare nuclear power a non-issue.

This issue apparently stirs up moods within the public of much greater intensity and depth than generally was imagined.

One can thus see the decision making process on energy policy between 1973 and 1976 as a process where an issue which up to then had been handled by highly competent and thus specialized technocracy had been taken out of its hands and put squarely into the range of issues that are handled by the political level. Whether this change is temporary or not remains of course to be seen. No doubt the expertise that hitherto had handled energy policy was severely shocked by the intensity of the debate. The established analogies, frameworks of reference and paradigms were rejected. It remains to be seen what the new paradigms will look like and to whom the power to decide will be allocated.

In other words—the political debate on energy policy was very much a debate on legitimacy. The legitimacy of the established decision-making process was questioned and to some extent openly rejected. Whether it is possible or not to change the decision-making process in such a way that its outcomes are more acceptable to the public remains to be seen.

In the following we shall dwell somewhat on these topics.

2. Swedish energy supply and demand

The Swedish demand for energy was 1973 roughly (in TWh [1]) :

Industry	154
Transportation	73
Residential and commercial	146
Total final demand	373

[1] 1 TWh equals 1,000,000 MWh.

Today oil accounts for over 70 percent of primary energy, hydropower 15 percent, spent liquor, firewood and waste 8 percent, coal 4 percent and nuclear 1–2 percent of the energy supply.

The Swedish energy/GNP-ratio is 60 percent of the U.S. ratio. Schipper [6] has done a detailed breakdown of the statistics and shown that this difference by and large is explained by the fact that the Swedish transportation pattern is much less energy consuming than the American one, and that Swedish industry sector by sector is more energy efficient. The Swedish climate is on the average colder, but the buildings are better insulated. For detailed information, see Schipper.[6]

Historically, however, the Swedish situation is not as flattering. Swedish energy demand has increased with 4.5 percent annually since the early 1950's. This is considerably faster than GNP, and the energy/GNP-ratio has thus increased. The Swedish economy has thus become less and less energy efficient.

A more detailed analysis shows that the Swedish industry has become more and more efficient in its use of energy, that is, less and less energy is required per unit of output of the total industry. All the other sectors—transportation, agriculture, commercial and residential etc.—have become less energy efficient. The rise in Sweden's energy to GNP-ratio is to no small degree explained by the rapid increase in energy use primarily in the final consumpiton in the households. Larger and warmer homes, more cars, more appliances etc. The share of energy that is supplied directly to the household has also increased over the years. It is now about two-thirds of the total household energy consumption. In the latter is included not only the energy needed for heating homes nad driving cars but also for building homes, producing goods, et cetera.

Roughly speaking the Swedish economy has become more and more energy efficient in producing goods and less energy efficient in using the same goods.

[6] L. Schipper, A. J. Lichtenberg. Efficient Energy Use and Well Being. The Swedish Example. LBL–4430. ERG–76–09. University of California, Room 100, Building T–4, Berkeley, California 94720.

This means that Swedish energy demand to a larger and larger extent is determined by what the households do, that is lifestyle patterns, et cetera.

But how does one analyze energy demand? The established way of describing energy use is in terms of industry, transportation, commercial and residential sectors. Nearly all studies from different countries are made in these terms, and the latest official Swedish forecast [7] was no exception. At the same time it was obvious that the political debate very much centered around questions like the relationship between energy and employment, standard of living, income distribution, work environment, et cetera.

Questions and topics that simply were not possible to address through the established ways of describing energy use.

To put the case more explicitly—the established way is the way of the energy supply establishment. The breakdown into industrial, transportation, residential and commercial use is necessary and more or less sufficient for making crude forecasts (crude since these forecasts also invariably are made without reference to the price of energy). It is a way of describing energy use which is a direct consequence of an attitude that demand shall not be influenced. Thus it is not necessary to understand energy demand. Or the relationship between energy use and the economy.

In order to at least approach the politically relevant questions other types of breakdowns of the statistics are necessary. One such example is the following table in which the intensity of the use of primary energy for different end-uses in the economy is given in terms of kWh/SCr.[7a]

	1960	1965	1970
Private consumption	2.13	2.62	3.06
State consumption	1.86	1.29	1.70
Municipal consumption	1.07	1.27	1.24
Investment	1.94	1.85	2.16
Export	3.58	3.53	4.70

The most obvious development is that private consumption has become increasingly more energy intensive. This is referred to above as being the result of larger homes, bigger cars, more appliances, et cetera.

It is also possible to relate the amount of employment—in terms of numbers of working hours—that the different end-uses generate per unit. This is shown in the table below (number of man hours/1000 Scr).

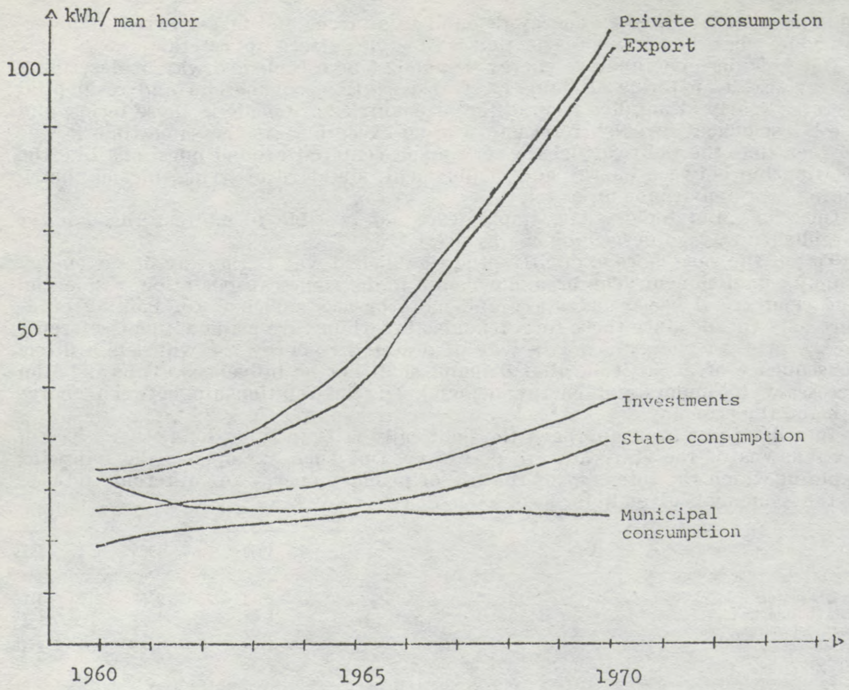
	1960	1965	1970
Private consumption	62.0	46.7	26.0
State consumption	57.6	49.0	43.7
Municipal consumption	56.8	51.4	51.2
Investment	73.8	58.1	46.8
Export	75.8	56.5	41.1

The Swedish labor force has become increasingly more efficient. And the fastest increase goes for private consumption and export, which both are very goods-oriented. Where it is relatively easy to substitute men for capital.

These two tables can now be combined, and we can compute the amount of energy that is needed per unit of work for different end-uses. This is shown in the figure below.

---

[7] Energi 1985–2000. SOU 1974 : 64, 1974 : 65. Allmänna Förlaget, Stockholm. 1974.
[7a] Scr equals Swedish Crowns.



The most striking point is that the difference between the amount of energy needed for having one hour of work for different end-uses have become progressively larger over the 10-year period. Private consumption is more and more energy that is needed per unit of work for different end-uses. This is shown in the While the heavily service oriented municipal consumption has not changed at all over the years in the amount of energy needed per manhour.

These figures illustrate where some of the main conflicts are in the future energy policy :

Between private consumption and public. The future energy demand will increase more rapidly if we let the private consumption increase fastly. Since the relative weight of public versus private consumption is an issue in itself in Swedish politics this means that energy policy is interconnected with this issue.

Distribution between different groups in the population. Households with high income use more energy than households with lesser income. If energy becomes scarce, the question arises how this scarce commodity should be allocated. Higher taxes on electricity and oil for heating purposes are regressive, and thus hitting lower income groups more severely. Total (equals direct plus indirect) household energy consumption is dominated by end-uses such as homes, transportation, food and leisure activities. Changes in consumption patterns due to energy scarcity will primarily have no effect these end-uses.

Between the degree of autonomy and international specialization. The Swedish industry is heavily export-oriented, with a large share of the energy consuming industries operating mainly in the export market (paper and pulp etc.). How large an industrial sector we will have is thus important.

Other conflict areas are e.g. environmental issues. Recently the Swedish Environmental Protection Board has more or less banned increased disposal of waste hot water from nuclear reactors into the Baltic Sea. And at the same time the worry over acidification from the use of fossil fuel continues to mount. The room for maneuverability in energy supply is thus rapidly becoming tighter. This of course increases the role of an energy conservation policy, to which we now turn. For more details on conflicts between energy policy and other policy areas, see.[8]

3. Some aspects of an energy conservation policy

The shift from a primarily supply oriented towards a policy of deliberate management of both supply and demand marks as we see it a rather fundamental change.

These changes are both conceptual and organizational. A supply oriented policy is generally rather well defined when it comes to the actors that are supposed to be influenced, controlled and regulated. After all, there are roughly between 10 and 20 large companies—private and public—on the total energy supply side. And these sectors all have as their primary goal to produce energy of different qualities.

In contrast to this the demand side consists of a very large number of decision-makers and actors. For each one energy is not a goal in itself but one means of many to achieve something else. Be it production of goods in an industrial plant or the self-fulfillment of an individual consumer.

In other words—there are reasons to believe that energy conservation policies interact in a much more complicated way with other policy areas, and sometimes in a rather unpredictable manner. We will give examples of this later. And at the same time, since demand side aspects of energy traditionally are non-decision areas from the point of view of the public sector, there does not exist any administrative infrastructure in which to channel decisions on how to balance supply and demand.

An example from another policy area may be illuminating. The supply of water consists of large technical systems on either side of the consumer in his household, the industrial plant etc. You have to have a fresh water supply system and a water purification system, and both parts are very capital intensive. In many growing regions water supplies are tight, and water is taken through large tunnels from far away areas.

In Southern Sweden this was exactly the case. There existed a proposal to build a huge tunnel, which would cost a large amount of money. One alternative to taking the decision now was to consciously decrease the increase in water demand through water conservation policies, e.g. changing toilets, putting in new taps etc. It was argued that the latter approach would have been much cheaper in overall cost, and certainly would have strained the capital market less since the costs were more evenly spread out over time.

But the decision to build the tunnel was taken. There simply did not exist any decision making framework that was able to handle the allocation of resources between building the tunnel and changing the taps and the toilets.

And the moment of inertia in the existing supply oriented structure—organizations, trade unions, construction firms etc—of course pushed the same way.

This example has several characteristics which makes it an interesting analogue to energy. The water-system is a technically—and perhaps ecologically—very well defined system. A number of technical components—tunnels, waterplants, plumbing systems, toilets, taps, sewage systems, pollution plants etc—are all hooked together into one technical system which in itself is a part of a large ecosystem—the water cycle.

But these technically very interdependent components are handled by different organizational units. Which in turn are partially controlled and regulated by a large number of legal acts, statutes, rules of financing etc. In other words, the organizational and institutional framework in which the technical system is embedded is a very fragmented one.

Schon[9] suggests a relation between technical systems, the organizations in which the technical system is embedded and the theory or paradigm that these organizations have of what their roles are. In the water supply case above it is obvious that the different actors—who all were linked together through one technical system—did not accept the idea that they could cooperate and reduce the over all demand on resources. There simply did not exist any decision making unit which saw it as its role to look upon the complete technical system of water supply as its responsibility.

---

[8] A Progress Report from the Future Study "Energy and Society". Stockholm February 19, 1976.

[9] Donald Schon : Beyond the stable stage. New York 1971.

The analogies to energy are perhaps most obvious in the case of electricity. There we have a technically continuous system with—in Sweden—hydro-power stations, national grids, transformers, distribution grids, meters in the households etc and ending in the individual refrigerator. All these components are mutually interdependent. The organizational picture in contrast has the same fragmented outlook as in the water cycle case above. Other parts of the energy supply system have similar properties. The gas system is the most obvious one, but also the oil supply system has the same type of technical interdependencies.

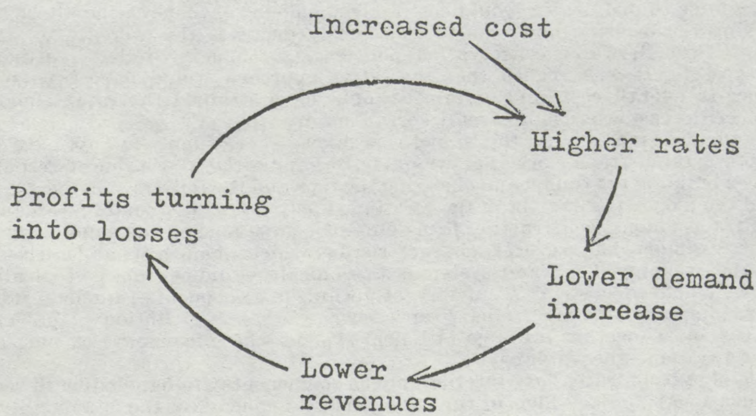
To our thinking these types of interorganizational systems are very poorly understood. The technical interdependencies are matched by a system of interorganizational rules. Price mechanisms etc are an integral part of this rule-system, but by no means the only one, or, perhaps, even the most important one.

Other parts of the rule-system consists of rules for how costs are defined, how capital is raised, how mortgages are defined, what the technical specifications should be, etc etc. Some of these rules are decided by the Parliament, others by different governmental agencies and others still by different industrial associations. Some of the rules are general rules for corporations, municipal authorities, etc, some are specific to the system.

To repeat, we think it is necessary to start analysing the whole interorganizational rule-system and not only the so called market-mechanisms.

There are signs that the market-mechanism gradually is becoming less and less efficient. And this not so much because of outside intervention by national government and/or regulations but through the mere fact that the energy technologies are becoming increasingly more capital intensive.

The leadtimes in investment decisions are thus growing, and thus the supply system is less and less able to respond to rapid changes in demand. Such changes in actual demand as compared to the demand forecasts on which the investment decisions were based can occur because of unexpected rises in capital or fuel costs which in turn requires higher rates. In other words, there are risks of the suppliers finding themselves in a vicious circle of the following kind.



The main reason for this is that many consumers are able to respond more rapidly towards rate changes than suppliers are able to respond to demand changes.

Tendencies of this kind have been observed in the Swedish water supply system, where essentially the same cost structure exists. Kahn et al.[10] discuss the same problem for electric utilities. The net result of such a situation is that prices rise when demand falls—quite contrary to textbook-economics.

A rigorous energy conservation policy is one of the changes that may throw the utilities into financial difficulties.

An amusing example of these types of difficulties is the problematic situation that the Swedish utilities found themselves in when the coal-wire lightbulb was replaced by the much less electricity consuming metal-wire lightbulb in the

---

[10] Edward Kahn, Mark Davidson, Arjun Makhijani, Philip Caesar and S. M. Berman: Investment Planning in the Energy Sector. LBL–4474. Energy and Environment Division, Lawrence Berkeley Laboratory, Berkeley, California.

1910's. This change also triggered a debate on how to expand the use of electricity. One issue was e.g. whose responsibility it was to supply tenants in the cities with electric wires etc. When this responsibility was taken over from the tenants by the landlords installment of electric equipment was easier and thus the use of electricity stimulated. Today this division of responsibility between tenant and landlord is taken for granted, but once it was not.

Therefore it seems that as the capital intensity of the supply system grows and the leadtimes of the investment decision grows the responsiveness of the suppliers to demand changes diminishes. Thus the price as regulator between supply and demand plays a decreasingly important role. All the changes in the rate structure of the electric utilities since the beginning of the century reflect this—the main objectives of the changes have been to stimulate demand.

Summing up, there are a number of interesting aspects of an energy conservation policy. One aspect is that it is administratively more complex—in other words, one might expect that conservation measures which have rather limited side effects and requires limited adjustments in other policy areas are favored. Another aspect is that some conservation measures may throw the utilities into problems. And a third aspect is that conservation technologies that do not fall neatly within the existing organizational boundaries but require new interorganizational rules are quite likely to be rejected because of the inherent complexity of the administrative situation.

The different measures of Swedish energy conservation policy can be described in these terms.

First of all the electricity tax was raised. From an earlier tax on the cost of electricity it has now been made a tax on the amount of electricity consumed. The result has among other things been that the actual development of electric resistance heating have been lower than the forecasts. The increased revenues of course finance parts of the conservation programs, but the money is not earmarked in any sense.

Secondly major efforts are directed toward decreasing energy use in space-heating. Retrofitting devices are stimulated, and partly subsidized by public money. Stricter building codes are under way, with the aim to cut energy use for space-heating by 50 percent in new buildings.

District heating, which is an efficient way of conserving fuel as compared to individual furnaces is promoted, but is also looked upon with some misgivings. This supply-system is very capital intensive, and the financial situation of the utilities is vulnerable to retrofitting. The rate structure reflects this—individual tenants pay a fixed charge, and have very little incentive to save energy.

The transportation sector is an interesting contrast to the space-heating sector. Here almost nothing has been done in terms of energy conservation. One reason is of course that the transportation sector only takes roughly 16 percent of energy use. Another reason is probably that stricter milage rules for Swedish cars doubtless would be regarded by the Common Market an "administrative hindrance" to international trade. So far the action taken can be described as pointing out that the proposed changes in national transportation policy—aimed at increasing the share of public transportation—also has virtues in terms of resources and energy.

On the industrial side it is felt that the market mechanisms are by and large adequate. There is a possibility to get financial aid for certain energy saving investments, provided the calculated payback time is not too short. There is also a program under way for analyzing the savings potential in the steel and paper industries, which together use roughly 25 percent of the total energy in Sweden.

Another program of great interest is a review of the possibilities of using industrial waste heat for district heating of residential areas. A number of projects have been discussed. Since district heating is primarily a responsibility for the local authorities this means a new type of relationship between industries and local authorities, and there are a number of rather interesting conflicts coming up.

Some of the projects involve combined energy systems, waste heat used for both electricity generating and hot water for district heating purposes.

The conflicts and the number of parties involved in these very efficient energy using devices are such that they probably cannot be solved in a decentralized way. There more or less has to be a credible threat of outside intervention in order to force the parties together in an energy efficient way. This threat by now comes from different central agencies.

This short discussion indicates that there are numerous and interesting problems in energy conservation. Some of these problems stem from the fact that energy conservation technologies do not always fit well into the present organizational framework. We shall return to this area later.

4. *Swedish energy policy in retrospective—issues and paradigms*

We will now turn to the discussion on how the Swedish energy policy has evolved over the years. The results are based on a rather thorough study of official documents like commissions, bills, debates in the Parliament etc. on energy related matters in Sweden since the end of the last century.

We believe this timespan to be necessary. In fact, certain critical aspects of present Swedish energy policy—and particularly some future alternatives—can only be understood as the result of an organizational and institutional framework that has its roots in the change from coal based electric generation to hydro electric generation around 1900.

The most obvious observation is that Swedish energy policy as reflected in legislative action is electricity policy. In spite of the fact that electricity has had roughly 15–20 percent of the energy market, and fuels of different kinds the rest, the legislative work has been almost solely directed towards electricity. The main and simple reason for this is that different new technologies demand radically different institutional adjustments. The switch from coal to oil and the subsequent expansion of oil use required almost no institutional change and thus went largely unnoticed in the official documents. The main exception being some worried notes on dependence on foreign countries etc. No action was taken, however, to seriously reduce the dependence apart from some measures on stockpiling.

Electricity, by contrast, demanded intense legislation. The most important period was 1900–1915, when a whole series of laws made long distance transmission economically feasible, changes in the laws that regulated ownership of land adjacent to rivers etc. Needless to say those changes were pushed by very strong pressure groups. In one sense, the fight was between the old non-industrialized agricultural countryside and the new industrial order. Since this breakthrough there has been a large series of committees, studying different aspects of electricity supply.

We think that the main lesson from this is the fact that different technologies demand different institutional changes. And the economic competitiveness of different technologies is to a largely unknown degree determined by these institutional aspects.

Thus what is generally regarded as solid facts, like costs, et cetera, becomes when more closely scrutinized, concepts that by and large are defines through a set of rules. The competitiveness of electricity from total energy plants in industries—the combined generation of heat and electricity—to no small extent is determined by the set of rules of the capital market, mortgage depreciation, the price of buying stand—by capacity from the utilities in case of a breakdown, et cetera.

This observation holds also for new technologies, such as the use of waste heat, the nuclear fuel cycle et cetera. One example of the latter is of course the Price-Anderson Act in the U.S., where the utilities only stand a limited liability in case of an accident. However, we have not seen any systematic studies on these types of problems. But our general impression is that the competitiveness of new technologies is determined by the rules tailormade for the existing technologies. The new technologies therefore demand very strong lobby groups in order to stand a chance of overcoming the inherent disadvantage in the above mentioned comparison.

The second interesting observation of paradigms on energy policy is that energy as a "gestalt" is fairly new. It emerged during the 1950's. Earlier Sweden did not have an energy policy but an electricity policy, a fuels policy, et cetera. The latter was to a large extent a wood policy, since wood was an important fuel. And thus fuels policy was very much a part of forest policy, which in Sweden has long traditions.

Fuels policy was also to some extent peat policy, since peat was a possible fuel. In other words, fuel policy was very much an integrated part of what could be called a policy of the agricultural population, especially since farmers in Sweden quite frequently also are owners of forest land.

This coupling between fuel policy and farmer's policy changed during the 1950's of course, when oil expanded rapidly.

The rather rapid merging of the fuel issue and the electricity issue into an energy issue during the 1950's is of course difficult to explain, but two interrelated aspects are clear.

Firstly, nuclear power emerged as a possibility to produce either hot water for district heating and/or electricity. Thus what was earlier essentially two different problems—namely how should energy consumers be supplied with space heating and how should they be supplied with electricity—now gradually merged into one problem.

At the end of the 1950's another technology stressed this merging of the two technical systems for producing electricity and space heating—namely the possibility to introduce oilfired plants for combined generation of heat and electricity. This in turn, as we shall see, changes the competitive situation between the established producers of electricity and the local authorities and became a serious threat to the rate of expansion of the nascent nuclear industry and was vigorously fought.

Secondly, the price of electricity fell gradually, and the use of electricity for direct resistance heating became a distinct possibility. The rate structure was changed in the beginning of the 1960's in order to promote electric space-heating.

To sum up—electricity and fuel became one energy issue because of technological change, which held out the possibility of merging two hitherto separate technical supply systems and which made electricity economically competitive with fuel for space-heating.

The third observation we would like to make is that the paradigm of an energy conservation policy was clearly visible in the early 1950's. At that time an official study on fuel was published, where the later discussion of the mid 1970's was clearly seen. A strong case was made for saving energy, putting investments in better insulation rather than importing oil, etc. The development of heat-pumps was advocated, etc. Three years later the same commission published a second report. And now the paradigm was back to normal again. The main emphasis was on energy supply, and the main emphasis within this area was on nuclear power.[11]

The reason for the proposed conservation policy in the first study was mainly foreign policy—the dependence on imported oil expanded rapidly. This dependence was, however, by and large accepted as normal five years later. It is not inconceivable that a contributing reason for this policy was that a major conservation policy would have been very complicated administratively. To increase the supply through nuclear power certainly looked much easier. The 1950's in Sweden marked a surge in the belief on the market mechanism as regulator between supply and demand. A surge which on one hand was a reaction to the austere administrative system that was necessary in order to allocate the scarce resources during the second world war. And on the other hand the very fast increase in GNP and welfare during the 1950's led many to believe that essentially all problems could be solved through the market mechanisms. The interrelations between paradigms and business cycles can easily be seen in e.g. transportation policy.[12]

What about future changes in paradigms of energy policy? This is for obvious reasons difficult to conceive of, but some hints can be drawn from the discussion above. Firstly, that the changes in paradigms during the 1950's to a large extent seem to be related to technological change. Secondly, that the present paradigm to a large extent is based on the implicit assumption that energy is sold on the market in what the thermodynamicists call high quality form.[13] Either as fossil fuel—oil, coal, gas—or as electricity, produced by fossil fuel or hydro or nuclear stations. Low quality energy—waste heat—is frequently not sold at all on the market but dumped.

This type of paradigm is consistent with a concept of efficiency that is based on the first law of thermodynamics. This law says that "energy is conserved", cannot be destroyed or consumed. But it can be saved. And the energy conservation policies of all (?) countries are based on the assumption that energy should be saved—in quantitative terms.

Therefore, a possible new paradigm evolves as a consequence of basing energy policy on the second law of thermodynamics. Which says, that while energy is

---

11 Fakta om olja, SOU 1953 : 12. Bränsleförsörjningen i atomåldern, Del I–II. Del I SOU 1956 : 46, Del II SOU 1956 : 58.

12 Lars Anell, Anna Hedborg, Måns Lönnroth, Lars Ingelstam : Ska vi asfaltera Sverige? PAN&Norstedts. Stockholm 1971.

13 Efficient Use of Energy : A Physics Perspective. American Physical Society. 1975.

conserved in quantitative terms each energy conservation process also means a degrading of energy in qualitative terms.

Such a paradigm would recognize that energy is abundant, but that high quality energy is a scarce resource. And what should be conserved is therefore not energy but what the thermodynamicists call free energy.

Weinberg and Goeller[14] have some interesting footnotes on the fact that the material's policy of the future is critically dependent on the scarcity of free energy.

If free energy is not a scarce resource, then materials, metals, etc. are not scarce either. But if free energy is scarce then (new) materials will become scarce.

High quality energy is necessary mainly for process heat—making steel out of iron ore—for transportation, some electrical machinery, etc. Low quality energy is sufficient for space-heating.

The argument can be carried further on, and it seems that a society where high-quality energy is scarce but low quality energy is abundant will look quite different from a society where also high-quality energy is abundant.

Summing up, it seems that a shift from an efficiency concept based on the first law of thermodynamics to an efficiency concept based on the second law should have some important technical and thus institutional consequences. We will return somewhat to this problem in the last section.

5. Swedish electricity policy

Swedish electricity policy has since the beginning of this century been based on hydropower. At the end of the 1950's the end of the expansion of hydropower could be seen, however, and gradually nuclear power came to be an alternative. By now it is fair to say that Swedish electricity policy to a very large extent is a matter of how large a role nuclear power can play. We shall dwell somewhat on these topics in this section.

Nuclear power could conceivably expand in Sweden, if the present worries about safety, et cetera, are reduced. Sweden also has a large amount of the uranium resources of the Western world. With present reactor technologies (LWR) the Swedish uranium reserve could sustain a reactor program of roughly 50–60 LWR's producing a total of 9,000 TWh, which should be compared to the annual energy consumption in Sweden of roughly 400 TWh.

The feelings of the electricity industry (both producers of electricity and the industries producing equipment for the utilities and consumers, et cetera) have been that the Swedish uranium is reason enough for a strong commitment to continued expansion of nuclear power.

Only recently have some doubts been heard. Global uranium reserves may be severely strained during the next 25 years and since Sweden's economy is a very open one it is not entirely inconceivable that Sweden will be forced into exporting some uranium.

It is therefore not entirely easy to evaluate the benefits and the costs of Sweden having a large uranium reserve. The mining of this low grade ore is furthermore highly controversial from an environmental standpoint. The Swedish uranium shales are situated in Southern Sweden, in an area that for ages has been inhabited and where the agricultural tradition is very strong. The main reserves are furthermore situated right at a unique mountain, very much claimed for its beauty, et cetera. The whole issue is from the decision-making point of view complicated by the fact that the local authorities (probably) have the right to veto any exploitation which they did not like. Under the present laws of physical planning it is not entirely clear whether the Government has the right to overrule the local authorities.

The issue of Swedish uranium is therefore interconnected with issues on environmental policy, the relations between central and local governments, the openness of the (Swedish) nuclear fuel cycle in particular and the Swedish economy in general. There are obvious possibilities for deadlocks, stalemates and coalitions in the decision processes.

---

[14] H. E. Goeller and Alvin M. Weinberg: The Age of Substitutability or What Do We Do When The Mercury Runs Out? Institute for Energy Analysis, Oak Ridge, Tennessee. The Symposium—"A Strategy for Resources"—Eindhoven, The Netherlands, September 18, 1975.

This situation by no means seems to be unique for Sweden. In fact, it seems that the major obstacle towards a continuing growth in the use of natural resources is not so much the physical or geological limits as the social impact of very large scale operations. The Swedish conflict between local interests and the national interest is clearly visible also in the U.S. when it comes to, e.g., stripmining, but also on an international scale. The position of Norway vis-a-vis the production of North Sea oil is a good example. Why should country A disrupt part of its social system just to satisfy country B's demand for raw materials? One can see conflicts coming up within and between the rich countries—conflicts of the same type as have been the rule, rather than the exception between the poor and the rich countries.

The development of the breeder reactor has to be seen against this general background. The breeder is thrifty with scarce resources like uranium but uses lavishly other resources like capital, skilled manpower, ability to organize large scale technological projects, et cetera. At the same time it is obvious that an energy supply system based on breeder reactors and a full scale plutonium fuel cycle has a large number of problems of its own.

One can thus summarize the situation right now in the following way. The Swedish authorities have accepted the step from hydro to nuclear power. The logical next step is the breeder economy. At the same time it is obvious that such an economy has some not entirely positive features. It is therefore necessary to understand how technical options are created and foreclosed in a decision-making process. Only through such knowledge will we be able to create an alternative to the breeder.

For all these reasons we think it necessary to understand the forces that introduce new technology into the electricity system. We have therefore started a rather deep retrospective study of Swedish electricity history.

The definition of technology is not very clear and frequently differs with different authors. We will try to make a difference between machine technology—composing of tools, technical systems, et cetera—and social technology, the organizational structure in which the machine technologies are always embedded. Obviously the machine and social technology interact. Certain types of technical solutions require certain types of organizations. And a given type of organization will choose new technologies according to certain patterns.[15, 16]

Thus it seems that technical change requires organizational continuity. And that organizational change most frequently occur along "technical continuities," upstream and downstream.[17]

This is obvious already in the very first phase of electricity. Electricity for light was first introduced by those towns and cities that already had production and distribution of gas. There are obvious similarities between electricity and gas from an administrative point of view. Moreover, the input was the same (coal).

We will go back to the end of the 19th century. This is not only of anecdotal interest but because the organizational structure of the 1970's by and large is the result of the overlapping of organizational structures reflecting two types of electricity production technology. For a slightly similar description of the interplay between technical and organizational aspects, see Novick.[18]

The development will be described in three rough historical phases, whereafter possible evolutions in the future will be discussed.

PHASE I: LIMITS IN TRANSMISSION TECHNOLOGIES

The situation up to around 1900 is among other things dependent on the limits on transmission technologies. Production was close to the consumers, and coal fired plants were used. The producers used DC (Direct Current), since DC-transmission was simpler and thus developed earlier. The high transmission costs of DC also created local monopolies.

---

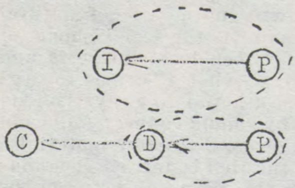
15 Donald A. Schon. Technology and change. The New Heraclitus. A Delta Book. New York 1967.

16 Bo Persson and Pierre Guillet de Monthoux: Filters—limits to technological choice. Eco Research Institute, Linköping, Sweden. January 25, 1976.

17 J. D. Thompson: Organizations in action. McGraw-Hill, Inc. 1967.

18 Sheldon Novick: The Electric Power Industry. Environment, Volume 17, Number 8, November 1975.

The situation can be described in the following diagram.



P stands for producer,
I for industrial consumer,
C for household consumer (in cities)
D for distributor
The dotted lines for organizational boundaries.

The above figure means that the distributor and the producer of electricity in cities belonged to the same organizational unit that the industries produced their own electricity.

The first important change was in transmission technology. When long distance transmission based on AC (Alternating Current) was feasible, hydropower became available. The industries that first used this conversion process was the paper and pulp and steel industries. The reason was simple—they were huge fuel consumers and had thus acquired large forests. Sometimes this meant that they owned both banks of a river—and, according to the law of that time, therefore had the right to use the river for hydropower.

Long distance transmission of AC and the subsequent possibility of using hydropower was an attractive prospect for the emerging industrial order. However, the legal framework was an obstacle, by and large reflecting the order of an agrarian and self-sustaining economy. Negotiations on hydropower where there were several owners of the river banks were extremely complicated under the law of the time.

Consequently the advocates of the industrial and market economy order attacked. In spite of resistance, the laws regulating waterflows, etc., were changed in order to increase the use of hydropower, irrigation schemes, etc. The emerging capitalist class had a highly pragmatic attitude towards the concept of to whom the private property was private.

When the older order finally was defeated a new conflict emerged. Who should control the natural resources—private ownership or the nation as a whole, i.e. the state? It is interesting to note that the conservatives at the time were split on the role of private ownership. Some of the conservatives reflected very much the views of the old aristocracy, firmly bound to the concept of a strong nation state. Others were more oriented towards the capitalist class.

The Government became involved in 1909. The first object was the electrifying of the railway between Kiruna and Narvik used for iron-ore exports. This was typical of the period. Hydropower expanded through direct user intervention—the earliest hydropower stations were built by the consumers themselves (mainly industry).

The project of the largest interest, however, was the hydropower station of Trollhättan in Southern Sweden.

A public utility was created for this project. This utility later evolved into the State Power Board. And conversely—the State Power Board can only be understood in terms of its role as a builder/constructor which in turn requires expansion.

The role of the consumers of electricity is interesting during this period. Especially the diffusion of electricity into the rural areas were frequently financed cooperatively by the consumers.

At the same time electricity use in the cities and towns expanded through local, frequently public utilities, frequently coal based.

The net result was that distribution of electricity successively was separated from the producers of electricity. This had important consequences for the future and reflected by and large the changeover from coal to hydro in the cities and the problem of raising capital and hooking up consumers in the rural areas.

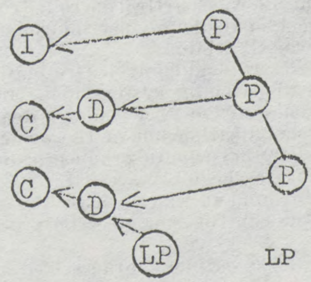
PHASE II—THE PRODUCER'S PHASE

Changes in the water law up to 1918 made expansion of hydropower possible, and the 1920's can be described as a decade when the prospective rivers were divided by the private producers and the state. The private producing companies were in turn owned by the big consumers of electricity—the big industries, but also some big cities.

The organizational pattern was in the beginning of this phase very fragmented. Local producers sold more or less directly to local consumers, and producers tried to create local monopolies through choosing different voltages, frequencies, et cetera.

The process of standardization of technical norms for voltage, frequency, stability etc is on the surface a process for increased efficiency but can also be seen as a prerequisite for concentration of power and the domination of the large and few over the many and small. These aspects seem to be poorly understood but are clearly visible even now on the international scale.

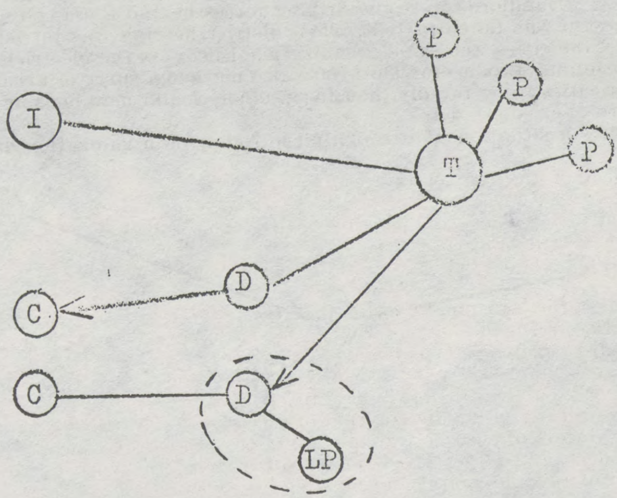
And gradually the system was organized in regional blocks, and cooperation between different producers began.



LP stands for local producer

The big distances between the north of Sweden—where the hydropower was—and the big consumer areas stimulated technical development for hydropower equipment. Through cooperation between producers—ASEA—and users of equipment—the State Power Board—Sweden developed a unique skill in long distance transmission of electricity.

But the heavy investments necessary for the long distance grid between Northern and Southern Sweden also raised the question of what the necessary organization should look like. A new and very important function emerged—the long distance transportation of electric power.



The figure is meant to show that after a period of regional cooperation one finally got a national "multiorganization."[19] The emerging of this national sys-

[19] Hans Esping and Måns Lönnroth: Strategisk planering och den offentliga sektorns struktur. Stockholm. June 4, 1974.

tem was not painless. On the contrary, there was a fierce struggle over the rights to build long-distance transmission-lines, a struggle that was brought to a head on conflict 1936. It was not resolved until 1946, when the government reserved the rights to the state power board. One of the reasons for the conflict was the fear that the organization that controlled the big lines *and* the transformers at the end of the lines also to some extent controlled the other producers.

The mechanism for this control is in itself worth mentioning. Under the existing laws, it was (and is) possible for two producers to compete with the same customer. If one of the producers has a contract with a customer and thus has transmission line to the customer, the other producer can offer this customer to build a line of his own and, perhaps, charge lower rates. When the State Power Board controlled the transformer stations from which the main producers had their regional lines, the State Power Board thus was able to raise a silent threat to build a line of its own to the customers of the producers. In other words, the rate structure of the private electricity producers was partly controlled by the State Power Board, and some of the producers existed almost on the mercy of the State Power Board. No wonder there was ill feelings.

This is a typical example of the struggle for strategic control. Gradually the transportation system made a central board dispatching system look efficient and thus possible. The net result was of course a series of very complex deals between the different producers and a gradual socialization not of the ownership but the management decisions. The bitterness of the private producers did not ebb out until the late 1950's, when other struggles began.

The national grid and the system of rules around it was perhaps the major factor in giving the State Power Board strategic control over electricity production.

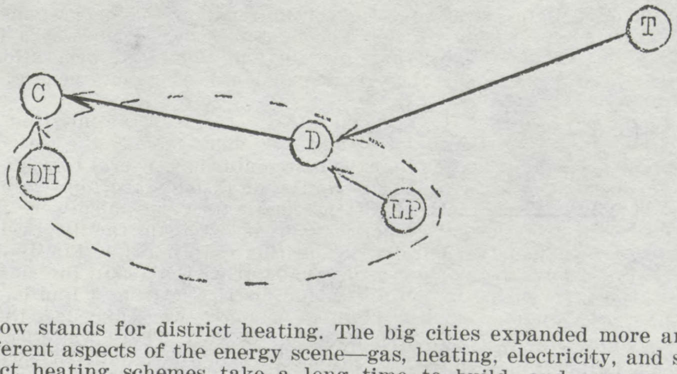
This phase between the 1920's and the late 1950's can be characterized as the period of the producers. Technical and geographic reasons led to a centralized multiorganization, dominated by the State Power Board.

PHASE III—THE BEGINNING OF THE MERGING OF THE FUEL AND THE ELECTRICITY SYSTEM

Up to the 1950's the fuel supply system existed side by side and independently of the electricity system. In the cities there had been an early change from individually heated apartments to central heating through hot water. This took place during the 1920's and 1930's. The hot water was generated first by coal-fired furnaces and later by oil. (The switch to oil was nearly completed during the 1960's). The landlords were the driving forces behind these changes.

The next step was taken in 1950, when district heating was introduced. This was done by the cities, the same organizational body as the electricity distributor (and sometimes producer). The 1950's also marked a surge of urbanization in Sweden, the cities grew rapidly, housing was short and new housing controlled by the cities.

In the cities a situation with roughly the following organization emerged.



DH now stands for district heating. The big cities expanded more and more into different aspects of the energy scene—gas, heating, electricity, and so forth.

District heating schemes take a long time to build, and consequently the change was gradual. But the rate of change was fast—roughly 20 percent increase per year.

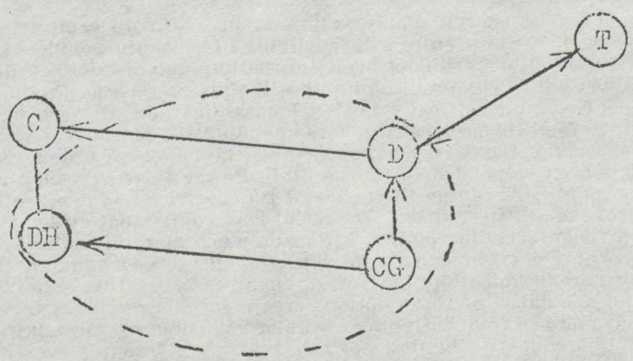
Roughly at the same time nuclear energy became a possible future alternative. The earliest discussion on nuclear energy was also almost exclusively focused on district heating. Nuclear energy was thus seen as an alternative to imported oil. Somewhat later cogeneration, that is, combined production of hot water and electricity, became an interesting combination for nuclear energy.

The first plant discussed was such a combined plant. It would have been placed in the city of Västerås, which also happened to be the home town of ASEA, a company which already at that time was interested in nuclear power as a future market. The plant should have been a joint venture between the city of Västerås and the State Power Board.

At the end of the 1950's oil became gradually cheaper. At the same time nuclear power gradually showed itself more complex. But the patterns of expectation still were such that electricity generated by nuclear power seemed to become very cheap.

And most of the rivers had been used for hydropower—the end of the hydropower era was clearly seen. This was stressed also by the growing environmental groups. Resistance to further expansion of hydropower became gradually stronger during the 1950's and 1960's and the private and public electricity producers more or less buried their internal fight in face of the new enemy. It was necessary to conceive of a different way to produce electricity.

Essentially two alternatives existed. One was steam plants—using either fossil fuel or nuclear power—and the other was combined generation of steam and electricity. The first was an extension of the electricity production of the past, the second was a radical break. The conceived system would have been the following in the cities with a growing district heating system.



CG stand for combined generation, and this meant that the local producers not only could have produced for local distribution and bought the rest from the national producer but also could have started to sell electricity to the national producer.

This meant changing situations for the national producing systems as well, and a rather fierce struggle started. The fight to some extent was a fight over the rate of expansion of electricity production. Combined generation by the cities—distributors was a threat to the expansion of electricity generated by the block of producers.

It has to be stressed that this struggle was the result of the fact that technical change allowed a new actor to enter the battle field. Namely the electricity distributor. The main point here is that the distributor has several roles at the same time—the Swedish cities are also in charge of district heating, water supply, roads, streets etc. To some extent district heating schemes also were foreclosed by the cities themselves—large suburban areas of single family dwellings are more expensive to heat through district heating than multiple family dwellings. In other words, much the same reasons that during the 1950's foreclosed public transportation as a viable option also made district heating a limited choice.

When the first planned nuclear plant in Västerås was cancelled, the city decided to build a combined oil fired plant of its own. There was also a strong movement to organize a number of other cities in the middle of Sweden in a block, more or less against the dominant State Power Board.

It seems that an electricity system based in a combination of hydropower and combined generation would have had a rather different organizational structure than a system based on simple electricity production. In the former the electricity production of the combined plants to a large extent would have been controlled by the market for hot water, and the hydropower stations used for "evening out" the load. In other words, the electricity system would have been much more restricted.

The fight over combined generation raged through the 1960's. A large number of cities wanted to build CG-plants during the 1960's, and the state power board responded by lowering the taxes so as to make the plants of the cities uneconomic. At the same time electric resistance heating was extensively promoted. The distributor's cartel was crushed but the combined generation was accepted by the State Power Board which also controlled the conditions for its use. Nuclear power was thus drawn into the system both through expanding the market for electricity and through keeping alternative means for producing electricity outside. What on the surface looked like a discussion of different technical options showed itself to be a struggle for domination of the total electricity system.

PHASE IV—SOME FUTURE COMPLICATIONS

The gradual merging of the fuel and electricity systems will accelerate as a result of the 1975 energy policy decision. The most probable outcome are increasing conflicts both between different producers of energy and also between producers and consumers. New technical options such as the use of waste heat from industries to produce perhaps both electricity and hot water for district heating of homes will inevitably confuse the hitherto well defined roles of producers and consumers.

Increased use of energy supply systems that are more capital intensive and thus have small variable costs will inevitably increase the conflicts between producers and users. Retrofitting of homes heated through district heating will mean reduced revenues to the producers and will thus be seen as threats. The same goes, of course, for electrically heated homes, but here the producers to some extent can defend themselves through expanding the market.

Other aspects of the energy policy such as the increased use of combined generation has been responded to by the State Power Board through contracts on which the plants are run on the terms of the electricity system, rather than on the terms of the heating market. One result is of course that attempts to organize cities as a "countervailing power" are made much more difficult.

It is probably a fair summary to say that on the one hand there is a large number of new technical options for an energy conservation policy. And on the other hand a number of these options create serious problems for existing organizations and are frequently hindered and hampered by rules, laws rate structures etc. Consequently the first obstacle towards a resource conserving energy policy is not technical but institutional. It remains to be seen how thorough the institutional changes have to be, but they cannot be limited to the demand side. In other words, actions that promote conservation of energy has to be complemented by actions that change the incentive system of the energy producers in a direction that make them less apt to solve problems through expansion of demand. How this is to be done is obviously not clear, but one of several ways probably has to be rather deep changes in the whole financial structure of the system. Another way is probably to strengthen groups with at least not entirely parallel interests, such as local and regional authorities. It is on these levels that many of the technical options for conserving energy have to be implemented, and it is on these levels that conflicts between both private and public interests—over the use of waste heat from industries—and between national and local public interests have to be solved.

Some of these ideas will be elaborated upon in the last section, where two different strategies for the future are hinted at.

6. *Two possible future strategies for the Swedish energy supply system*

The main theme of this paper has been to stress the interrelationship between technical and organizational systems. And also point at the importance of what could be called the "interorganizational rule system", i.e. the set of rules that decide legitimacy, division of responsibility, specialization and the role of coordination between different organizations. And in the concept of organizations we also include informal ones like households, groups of households in the same geographical area etc.

Now it is possible to use these admittedly vague ideas to speculate on the type of institutional environment or embedding that different technical options on the energy supply side have. In order to do this we have to recall the discussion on thermodynamics from section 4.

Energy occurs in different forms—very roughly they can be described as high quality and low quality forms. High quality forms can be used to perform mechanical work, drive electrical systems, produce high temperatures such as needed for melting ores etc. for the production of metals etc. Examples of high quality forms are fossil fuels, methanol, high voltage electricity etc. Low quality forms are essentially heat with a small difference of temperature between the hot body and the environment.

With some stretching of the concepts we can describe possible supply alternatives in the same terms—high and low grade. Low grade sources are then waste heat, solar heat, wind power, et cetera, and other sources of low quality and/or reliability. High grade sources are thus fuels like oil, methanol and electricity with high reliability.

We can also describe energy use in terms of high and low quality. But here low quality energy use refers to the form of energy that is sufficient in the process in question—not the actual form used. Waste heat, solar heat, et cetera, is sufficient for space-heating, even if electricity is more frequently used. In other words, energy use can be described in terms of whether high or low quality energy is necessary or sufficient for the process. High quality is necessary for producing metals, transportation, et cetera. We can thus make a simple matrix.

The energy supply system today is almost entirely based on high quality energy, box 1 and 2.

Whether low quality is sufficient or not for a given process obviously is dependent not only on the type of process but also on the technical system in question. In other words, to change the user's system from box 2 to 4 may demand substantial investments in new equipment, et cetera.

		Energy use	
		High quality necessary	Low quality sufficient
Energy supplied	High quality	1	2
	Low quality	3	4

In this perspective, we have two possible principles for the future.

The first principle is the continuation of the present one. The future supply alternatives may be breeder reactors for electric generation, synthetic fuels from coal, et cetera. Such a principle is very flexible for the energy user, and can thus be called a strategy of flexibility. In the matrix above, the principle is thus based on boxes 1 and 2.

The second principle is based on boxes 1 and 4. Low grade sources are used where these are sufficient and high grade sources where these are necessary. Such a principle calls for a close matching between the thermodynamic characteristics of possible supply alternatives with the user's process. An appropriate name is therefore a principle of matching. This seems to be the only principle through which the supply system can be used entirely on renewable sources.

These two principles, which admittedly are extremes and can be mixed to some extent, have obvious differences. The flexibility principle is bound to be more and more capital-intensive on the supply side. Demand will have to be predictable and surprisefree, otherwise the profitability of the supply sector will be in jeopardy. This principle is open to vulnerable vicious circles of the type described in section 4, and one can foresee that this principle will be stabilized through a system of rules—and in particular a rate-structure—that minimizes the risk for fluctuating demand. This principle also calls for institutions capable of generating not only large amounts but also large chunks of capital. The most typical technical component in this principle is the breeder and its fuel cycle. A technical system of such a size and complexity that the ensuing institutions will have to transcend national boundaries.

Another interesting property of this principle is that it in all probability will lead to an increased role for central governments as opposed to local authorities. The type of stalemate between local veto-power and national interests that is possible within the present legal system in many countries will have to go.

The matching principle on the other hand has to be aimed at adapting to local situations. It will in all probability be very capital intensive, perhaps more so than the first principle. But the institutions necessary for allocating the capital will be different. Large amounts of capital will have to be disseminated to a very large number of energy users such as individual households, blocks, cities, et cetera. This principle will also need a centralized energy supply system, partly for the high grade use, partly for backing up the low grade systems.

Another interesting difference between this principle and the former is the demand for professionals. The matching principle calls for a large number of persons skilled in adapting to local situations, in bridging consumers and suppliers. A flexibility principle calls for persons skilled in handling large centralized supply systems based on high technology such as the breeder etc. These differences obviously also have organizational consequences. A decentralized approach based on cooperation between local initiative and central knowledge, is necessary in the matching case, whereas the central production of energy is the single most necessary component in the flexibility case.

What about abundancy and cost of energy? Most likely energy is more plentiful and perhaps cheaper in the first principle than in the second. In all probability the first principle will give a higher standard of living, measured as it is today in terms of GNP.

Therefore, the choice between the two principles is not only a choice between how much energy we want, it is probably a choice between two different societies with different institutions and different ways of deciding what is good and bad. This does not make the choice easier.

Post-election epilog

In September 1976 the Social Democratic Government was voted out of office by a small margin. It is difficult to say which role nuclear power played in the outcome—both parties that rejected nuclear power lost votes compared to the 1973 election. But both the outgoing Prime Minister Olof Palme and the incoming Torbjörn Fälldin declared that nuclear power tipped the balance.

Nuclear power was not an issue in the campaign until during the last two weeks, when Torbjörn Fälldin made some very strong commitments on not letting reactors under construction get on-line.

The new Government is a coalition between three parties of which two by and large share the view of the Social Democratics on nuclear power. The third party, the Center Party, is the largest Party in the Government and its leader, Torbjörn Fälldin consequently Prime Minister.

Nuclear power seems to be the single most complicated issue in the Government. The Center Party backed down on its earlier commitments and accepted the starting up of the next reactor to get on-line, subject to the condition that the utility had signed a contract on reprocessing. Negotiations on reprocessing are under way with United Reprocessors. For the following reactors, starting up will be accepted only if reprocessing and a safe scheme for waste disposal can be demonstrated. The parties in the Government seem very much split on the problem of whether the proposed schemes for reprocessing and waste disposal are safe enough.

The coalition parties have declared that they will propose a referendum if they cannot come to an agreement on nuclear power.

Undoubtedly the uncertainty of nuclear power has increased and this has in turn generated shock waves of uneasiness through the utilities, capital market, trade unions, and so forth.

Bert Bolin

Energy and Climate

Secretariat for Future Studies.
Sweden.

80-533 O - 77 - 17

ENERGY AND CLIMATE

A summary of our knowledge about those mechanisms that determine the climate of the earth and the possibility that man directly or indirectly may influence the climate.

Bert Bolin
Professor of Meteorology

University of Stockholm

Stockholm, November 1975

Contents

Foreword

Following an initiative in 1971 by Prime Minister Olof Palme and committee work led by Mrs Alva Myrdal, then Minister of State, the Swedish Parliament first voted funds for future study projects in 1974. The Secretariat for Future Studies has then initiated four studies under the following headings:

- Energy and Society
- Resources and Raw Materials
- Sweden in the World Society
- Working Life in the Future

These projects run until the end of 1977, but results will be published consecutively during the project period.

In order to maintain international contacts and exchange of experiences a certain number of the reports will be published in English.

The public debate on energy policy in Sweden has included certain very broad problems, and has in a sense served as a "proxy" debate on the future of industrialized society. In its initial phase the project "Energy and Society" attempts to analyse certain of the broader, long-range questions in this debate: what is known about the nature of the relationship between energy and other elements of society? This will be done through a number of survey reports on the present state of knowledge.

The present report on "Energy and Climate" was the first of these to be completed and is the first to be published in English. We are very grateful to Professor Bert Bolin of the University of Stockholm and the International Meteorological Institute in Stockholm for his willingness to contribute his outstanding knowledge in the field.

Stockholm 1975-11-05

Lars Ingelstam
Head, Secretariat
for Future Studies

Måns Lönnroth
Project Director,
Energy and Society

1. INTRODUCTION

The increasing production of energy by man has begun to modify significantly the environment that the earth naturally offers man. At first these effects were local and limited to larger cities and industrial areas. In recent years those regions have grown rapidly and they extend today over considerable areas whereby man's influence on the environment has become regional. Also the increasing amount of available energy has led to modifications in the environment that merely a few generations ago were not even thought to be possible. Modern forestry, agriculture, the exploitation of water power, the building of roads and mining often imply very significant changes of the natural environment over large areas.

The question to what extent the climate of the earth is being influenced by the increasing energy production*) obviously represents an important aspect of the total environmental problem. We can distinguish between three principally different ways whereby man is able to influence the climate:

1) All energy that modern civilization makes use of sooner or later is transformed into heat that may influence the climate.

2) When energy is being produced man is changing the physical, chemical and biological processes that together shape the climate of the earth.

3) With the aid of the very large amounts of energy becoming available man is able to change the natural environment and thereby also possibly the climate.

*) The use of the words "energy production" or "energy consumption" is scientifically incorrect. It is more proper to speak of an energy conversion, the effects of which are utilized by man in various ways. The efficiency of this conversion for use by man is at present low (10 - 20 %) and can be raised considerably. This problem will not be discussed in the present context and the expressions quoted above and used throughout this paper thus refer to the total amount of energy which is handled by man and which ultimately is converted into heat.

The first effect is easiest to assess. On the other hand the fact that so many indirect changes may occur as a result of an increasing energy production represents a considerable difficulty when we wish to estimate probable indirect climatic effects, since they can amplify or counteract each other in many different ways. In which ways man may deliberately and systematically influence the processes in the environment is almost impossible to foresee, since we hardly can imagine what for example a tenfold increase of the amount of energy at our disposal might be used for. In the following we will mainly deal with the two first aspects of the problem.

The interplay between energy production and the climate of the earth was early considered by some few scientists but it is only during the last few decades that a more common interest in these problems has developed within the scientific community. Not until the last few years have these problems become a reality for the politicians and the general public. We may recall that the Swedish chemist, Svante Arrhenius, already at the turn of the century pointed out that an increasing combustion of coal and oil might cause an increase of the amount of carbon dioxide in the atmosphere whereby the climate of the earth might change. During the 1930's these problems were again discussed among researchers in the field of climatology, since for the first time it seemed possible to show that the amount of carbon dioxide in the air actually was increasing.

Today the research activities with regard to the global climatic problems and man's possible role in this context are receiving increasing attention above all in the United States and the Soviet Union. On the initiative of scientists in the United States (Massachusetts Institute of Technology) and in cooperation with the Academy of Engineering Sciences and the Royal Academy of Sciences in Sweden, a conference was arranged in the summer of 1971, the SMIC conference (Study on Man's Impact on Climate). A well written account of our present knowledge resulted (1). Since then very ambitious research plans have been developed by the National Academy of Sciences in the U.S. (2) and the National Oceanic and Atmospheric Administration (NOAA) has taken the central responsibility for coordination of such research in the United States.

Within existing international organizations, above all the World Meteorological Organization, WMO, and the International Council of Scientific Unions, ICSU, extensive plans for co-operative research efforts are being worked out. This is a direct consequence of the resolutions that were adopted at the UN Conference of the Human Environment held in Stockholm in the summer of 1972 and the work is being supported by the UN Environmental Program, UNEP. As part of this international effort the International Meteorological Institute in Stockholm was given the responsibility of arranging a conference in the summer of 1974 concerning international cooperation in research on climatic change. The following account is based on the material available at the conference and the conclusions that were drawn on this occasion (3) and also on relevant literature in the field. Our knowledge is, however, still very fragmentary, which also will be clear from the following presentation.

2. THE CLIMATIC SYSTEM

In order to understand the climate of the earth and its variations we need knowledge from the fields of meteorology, oceanography, glaciology, hydrology, geology and also from a number of special fields within the biological sciences. It is the interplay between processes in the atmosphere, the sea, glaciers, lakes and rivers and biota on land and in the sea that creates the climate of the earth. These media together comprise the climatic system. In most theories of climatic change this total system has not been considered, but attempts to understand the climate of the earth and the reasons for its changes have usually implied a focus of attention on one or a few processes and a qualitative discussion of their importance. Not until it becomes possible to build quantitative models of how these most important processes in the climatic system interact and observations are available that make it possible to verify computations with such models, can we answer questions with regard to the relative importance of different physical, chemical and biological processes in this complicated system. We then can say that we begin to understand what determines the climate of the earth and in which way possibly man may play a role in changing it. The models that have been developed so far are still very incomplete and the following discussion is therefore by necessity uncertain, but may still be of considerable interest in the present situation.

It is necessary to discuss how man possibly influences the climate on the earth with background knowledge about the natural climatic changes that have occurred in the past, since such changes certainly also will take place in the future regardless of whether man exists or not. Before we give a short account of the climatic changes during the last 10,000 years it is, however, important to have a general idea of the interplay between the different components of the climatic system and to define what we in the following will mean by local, regional and global climatic changes.

Each part of the climatic system such as the sea or the atmosphere can be roughly characterized by an adjustment time, which describes the rate at which an adjustment occurs to changing external forces. The atmosphere has a relatively small heat capacity and moves easily and quickly. It therefore adjusts itself to different external factors rather rapidly. Its characteristic adjustment time is about one month and this fact also shows up in that the annual temperature cycle is delayed about one month relative to the annual variations of solar radiation. The sun is highest on the sky in the northern hemisphere at the end of June, but the temperature reaches its maximum in the latter part of July.

The sea on the other hand is a very much more slowly changing component of the climatic system. The uppermost 10 meters, in parts of the ocean maybe 100 meters, interact rather rapidly with the atmosphere through the action of the winds and through heat exchange with the atmosphere. The characteristic adjustment time of this surface layer is merely a few months, perhaps a year, while the world oceans as a whole mix very slowly. It takes about 1,000 years for a reasonably effective exchange of heat and other properties between the surface and the deep layers of the sea.

It is a rather thin layer of the soil that is of importance for the climate and its variations. The heat capacity of this soil therefore may be considered as rather small in comparison with that of the world oceans. In this regard the adjustment time of the surface of the earth is short. On the other hand the hydrological cycle, the circulation of water between land and sea, which to a considerable degree is dependent upon the characteristics of the soil and its vegetation, is a considerably slower process. The adjustment of the vegetation to changing climatic conditions may take years or even decades.

The extension of sea ice changes markedly with the season and the fact that the thickness of sea ice never increases beyond a few meters indicates that this component of the climatic system rather rapidly responds to changes in external conditions such as solar radiation, air and sea water temperature. The characteristic adjustment time is measured in years or perhaps decades. The thick ice sheets that cover Greenland and the Antarctic, on the other hand, are very slowly changing components with characteristic adjustment times of probably 1,000 or thousands of years. This is clear from the fact that several thousands of years went by before the ice sheets over North West Europe and Canada disappeared after the last glaciation. It should also be emphasized that a system that has components, such as the atmosphere and the oceans which are in motion, has characteristic random variations even if the external components such as solar radiation do not change. A certain part of the variability that characterizes the climate in the past is probably a result of such random variations. It is, however, not known to what degree this is the case. It is clear that the possibility to "explain" variations in the climate to a large degree depends upon how significant such random variations are. This fact is also of importance when we wish to assess the possibility to determine in which way or to what extent man possibly influences the climate. It is important to remember this fact in the following.

In the discussion of possible future climatic changes it is important to realize the geographical extent of such changes. It is almost trivial to state that climatic changes caused by man are most probable on a small scale, i.e. within limited areas such as cities or metropolitan areas. It is beyond doubt that man to some extent already has changed the climate within areas that extend over 10 or maybe 100 kilometers. We shall in the following call changes on this scale the local climatic problem.

As we shall se below the characteristic weather patterns such as storms and cyclones as well as the distribution of land and sea play a decisive role for the climate of the earth. In this way climatic zones are created with characteristic dimensions of one or several thousands of kilometers. Climatic changes on this scale we shall consider as the regional climatic problem.

Finally, changes may occur on a global scale. Even if those changes often are intimately linked to changes on a regional scale it will be useful in the following to consider the global climatic problem separately.

3. CLIMATIC CHANGES SINCE THE LAST GLACIATION

For a discussion of possible future climatic variations it is of fundamental importance to have as clear a picture as possible of the changes that have taken place in the past. The history of the earth shows that large changes of the climate have occurred naturally. Sediments, the stratified structure of the glaciers, pollen in the soil, ancient shore lines, varying width of tree rings are facts that give us a rather good idea of what has happened, particularly since the last glaciation. It is not more than about 10,000 years since the ice over Europe and North America disappeared. The temperature variations in the Greenland area can be reconstructed with the aid of composition of the ice in the deeper strata that were formed before and during the time for the change to warmer climate. Figure 1 shows how quickly the heating occurred between 12,000 and 15,000 years ago. Still, it took between 5,000 and 7,000 years before the ice almost completely disappeared from northwestern Europe and the interior parts of Canada. The conditions were very variable especially during the first 2,000 years after the occurrence of the marked climatic improvement. A comparatively warm period, "Alleröd", was replaced by a cooler period, "late Dryas", which meant that the

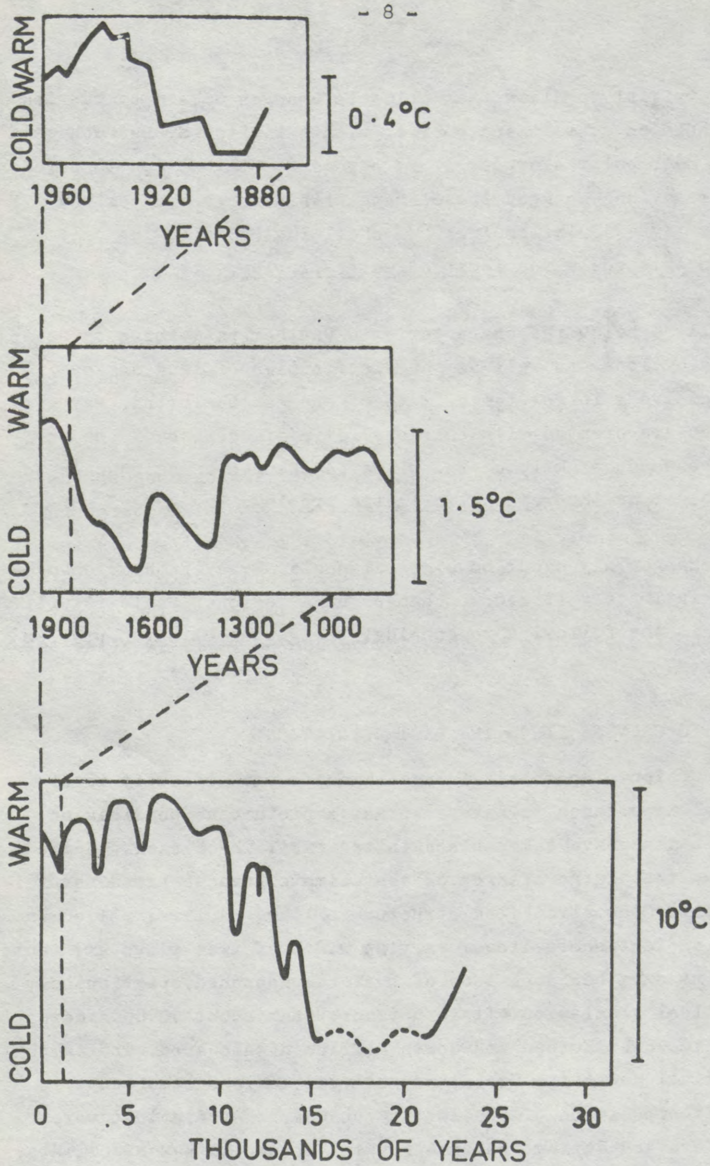


Figure 1. Variations in the climate on different time scales (after (2)). The uppermost diagram shows the changes of the five-year mean values of the temperature for the northern hemisphere based on direct observations during the last hundred years. The middle diagram extends about 1,000 years back in time and is an attempt to characterize the severity of winters in western Europe with the aid of historical information. The lower diagram represents a compilation of tree-ring data, geological information about the extension of glaciers, temperature conditions computed with the aid of analyses of Greenland ice and the extension of vegetation during the thousands of years that have elapsed since the last ice age.

glaciers again were advancing during a few centuries. The figure also shows that a climatic optimum seems to have occurred about 5,000 to 7,000 years ago. It should be emphasized in this context that this relatively warm period was not limited to only high latitudes but a relatively mild climate at that time prevailed also in other parts of the world.

The closer we come to present time the more detailed is the information about the climate and its variations. From the last 1,000 years we may also gather information about the climate from historical notes. We know for example rather well the changes of the time for cherry blossoms in Japan, the frequency of icebergs in the Icelandic waters and the extension of human settlements in northern Africa, which all indirectly tell about variations in precipitation and temperature. About 1,000 years ago the climate was rather mild in north western Europe and it is interesting to note that this was the time for the colonization of Iceland by the Vikings. During the latter part of the Middle Ages the climate again turned colder, which conditions culminated during the 17th century. This period has been called "the little ice age" since a number of glaciers were formed in the Scandinavian mountains and advanced towards settled areas. Since then the glaciers have again retreated except for brief advances in the beginning of the 19th century.

Since the middle of the last century we have numerous meteorological observations, some of which even extend back to the middle of the 18th century, as is the case of the Stockholm record. A more detailed compilation of observations from the last century is shown in <u>Figure 2.</u> The three curves show the temperature changes in the northern hemisphere between the equator and 80°N, between the equator and 60°N and also between the equator and 60°S. The curves clearly show that the climate of the earth became about half a degree warmer between 1880 and 1940. Since then a return to cooler conditions again seems to have occurred. It is on the other hand too early to tell if the series of warm winters that have occurred in northern Europe during the 1970's is a sign that the climate again is becoming warmer or if it represents a random variation of short duration.

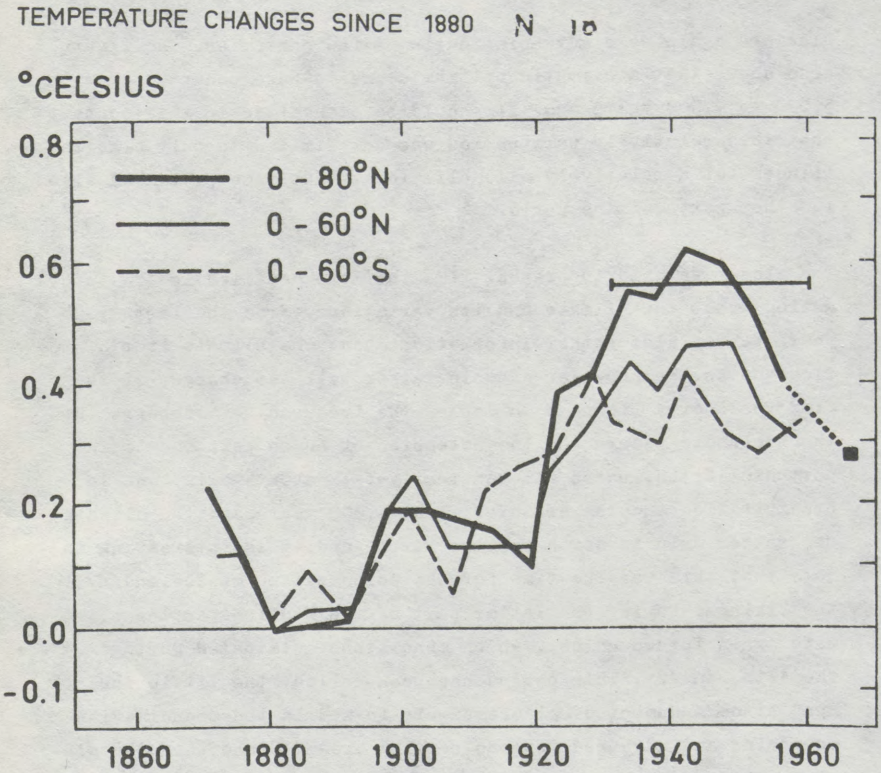


Figure 2. Temperature variations during the last hundred years in the northern hemisphere within the region between the equator and 80°, between the equator and 60° and in the southern hemisphere between the equator and 60° (after Mitchell (4)).

The change during the last 100 years is still more pronounced within the Arctic Sea area and particularly within the part that is close to the Atlantic Ocean and Northern Europe. Thus the winter temperature has increased several degrees on Spetsbergen and ice conditions around Spetsbergen were considerably more favourable during the 1930's and the 1940's than was the case during the latter part of the 19th century or during the last decade. It is worth noting that "normal climate" internationally has been defined to mean conditions during the 30-year period from 1931 to 1960. Probably this is one of the warmest 30-year periods that has prevailed on earth during the last thousand years.

It should be emphasized that a careful choice of observation sites must be made in order to deduce the curves in Figure 2, since in addition to the variations that are shown and that can be considered as globally representative, we also find an additional increase of the temperature with about one half degree or even more in metropolitan areas. This is for example the case in Stockholm where the mean annual temperature in the 1930's was about 1 degree higher than in the middle of the 19th century and the mean January temperature rose about 2½ degrees during this period.

It is also clear that marked variations of precipitation have occurred during the last 100 years (5). This is most noticeable in Africa and Southern Asia. The drought that has prevailed during several years to the south of Sahara (Sahel) has probably been more severe than at any time during the last 60 years. The frequency of monsoon failures in India decreased significantly after 1920, but has apparently again increased somewhat during the last few decades and particularly 1972 was a very bad year. A large part of the Soviet Union was hit by extensive droughts and crop failures that same year. Our knowledge about the variability of precipitation is, however, very much more incomplete than our knowledge of temperature variations in the past.

It is important to point out that the description that has been given above refers to the slow <u>changes of mean conditions</u> for one or a few decades. In addition weather conditions vary and so does the climate from year to year. The difference between the coldest and warmest year in Sweden since observations started in the middle of the last century is between 4 and 5 degrees. During the wettest year the annual precipitation was between 75 and 100 % bigger than during the driest year on record.

This variability of climate from year to year implies a considerable difficulty when we wish to assess if slow changes towards colder or warmer climate are under way. It is for example still impossible to tell if the mild winters that have occurred during the first part of the 1970's merely represent a short term fluctuation or if they show that also on a longer time scale a warmer climate is developing in northern Europe.

Since human activities, above all agriculture, are very dependent on weather and climate, a better knowledge about the natural variability of climate and the factors that determine it is of great interest. Better ways and means of assessing the probability of departures from "normal" conditions and possible changes in this regard are obviously of importance for the long term planning of agriculture and for assessments of desirable food reserves in case of crop failure because of climate variability. This problem is of importance not only for national planning, but particularly for the international cooperation that is required in order to approach the problems of the world as a whole. We still have inadequate knowledge about the interrelation between climatic variability and food production in order to be able to assess the probability that a crop failure might occur simultaneously in for example the Soviet Union and the United States because of bad weather conditions. It is important to point out these circumstances, since the problem area "energy-climate" not only concerns how the increasing energy production in the future may change the climate but also what climatic changes generally might imply for man.

As far as we now can judge, the variability of climate from one year to the next probably is almost random. This does not exclude the possibility that we one day will find certain regularities in these variations. There are scientists who mean that the variability of climate has increased during the last decade and that this is associated with the somewhat cooler climate.

Statements of this kind must, however, still be considered as working hypotheses for climate research.

4. SOME ASPECTS OF THE GENERAL CIRCULATION OF THE ATMOSPHERE AND ITS IMPORTANCE FOR THE DISTRIBUTION OF CLIMATIC ZONES ON THE EARTH

Only a few basic facts concerning the general circulation of the atmosphere will be summarized here as a background for the following discussion. A simple schematic picture is shown in Figure 3. The earth receives considerably more energy by solar radiation in tropical regions than in polar regions. The air is found to rise in a zone close to the equator, the intertropical convergence zone, which moves about 10 degrees of latitude towards the north and south in phase with the sun. This zone is characterized by a tropical rain forest climate with one or two rainy seasons yearly. The rising air moves towards polar regions and is forced to descend towards the earth's surface at about 30 degrees of latitude, where the extended subtropical high pressure areas are found with dry and hot desert climate. We find such extended deserts both in the northern and southern hemisphere, in the latter case, however, essentially only in South Africa.

Furthermore the rotation of the earth creates two zones of westerly winds, one in each hemisphere, that have their maxima at high elevation between 30 and 40 degrees of latitude and that oscillate northward and southward around the earth in long waves (see Figure 3). Cyclones are formed in these westerlies and move eastwards. In the summertime some of these move far towards polar regions, while in the winter the lack of solar energy creates an almost permanent anticyclone over the polar regions which rather effectively prevents heat exchange with lower latitudes. Within the belt of westerlies the weather is variable and the climate is mild. The more precise position of this westerly wind belt as well as the characteristics of the climate is furthermore influenced by the distribution of land and sea and the position of the long waves (see Figure 3). Most industrial countries are located within this climatic zone. Further towards the poles the solar radiation is too weak to permit a richer vegetation. Large areas of tundra extend

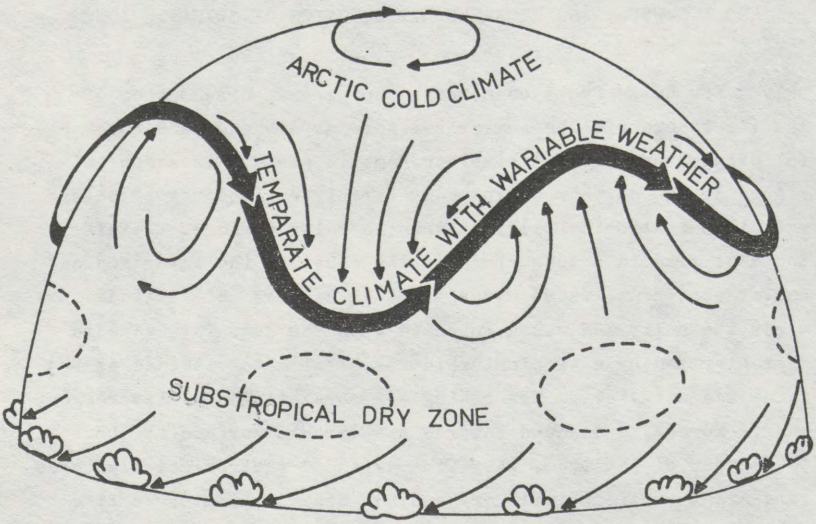


Figure 3. A schematic picture of the basis circulation of the atmosphere that creates the climatic zones around the earth. The heavy band around the earth illustrates the westerlies in the middle latitudes with a temperate climate, while south of this region subtropical desert areas extend, and to the north the cold climate of the Arctic.

over the northern part of Asia, Europe and America. In the interior of the Arctic and the Antarctic the possibility for vegetation is lacking because of the permanent ice cover, in the north polar region as floating ice in the Arctic Ocean, in the south polar region in the form of a thick ice sheet.

All climatic changes within the time periods that will be discussed below imply that these climatic zones move. A general warming is associated with a displacement of the belt of westerly winds towards the poles and subtropical high pressure belts also extend further poleward, while the opposite is the case when the climate becomes colder. The latter occurred during the last ice age. The Arctic tundra extended far towards the south in Europe and a mild and moist climate prevailed in the Mediterranean area with completely different vegetation than today. It should also be pointed out that Bryson (6) is of the opinion that the drought that has occurred in recent years to the south of Sahara is related to a southward motion of the subtropical high pressure belt because the climate has turned cooler since the 1940's. He also points out that the changes in frequency and character of the Indian Monsson probably are associated with such changes of the general circulation of the atmosphere. We further know that some changes in the distribution of dry and moist climatic zones in Central America have occurred during the last decade.

There are thus several facts to indicate that such interrelations between climatic variations in different parts of the world exist. However, the reasons for the variations that have occurred are not clear. We shall come back to a discussion of this problem in a later section.

5. ENERGY FLUXES IN THE CLIMATIC SYSTEM

In a discussion of energetics of the climatic system it is important to distinguish between externally given quantities such as solar radiation, heat flux from the interior of the earth and on the other hand changes of the internal energy fluxes that are associated with changes of the climate. Table 1 shows the magnitude of some of the most important externally given quantities that are of interest in this connection and as a comparison the amount of energy involved in photosynthesis and the amount of energy that at present is produced by man are given. The values are mean values for the earth as a whole expressed in billions of kilowatt (10^{12}W) = terrawatt (TW), and also in energy per unit time and unit area (W/m^2).

Table 1. Externally given energy fluxes in the climate system (compare (7))

	Total energy flux 10^{12}W=1 TW	Energy flux per unit area W/m^2
The solar constant	-	1 360
Solar radiation at the outer limit of the earth's atmosphere	170 000	340
Solar energy absorbed by the atmosphere and the earth	120 000	240
Heat flux from the interior of the earth	92	0.06
Photosynthesis	90	0.18 (over land)
Human energy production, 1970	8	0.016 (over land)

The table shows that the energy used in photosynthesis is not more than about half a permille of the total amount of the energy that the earth receives in the form of solar radiation. We also note that the energy production by man per unit time not yet has reached 0.1 per mille of the solar energy that is converted into heat in the atmosphere, the seas and the uppermost layer of the earth. This energy production is, however, not evenly distributed over the earth. Table 2 gives an idea of the energy consumption by man in densely populated and highly industrialized areas.

Table 2. Energy consumption per unit time in industrial areas (1)

	Surface (km^2)	Population (millions)	Energy per unit time and unit area W/m^2	Energy per capita and per unit time kW	Mean solar radiation at the earth's surface
U.S. North East Coast	87 000	33.0	4.4	11.2	90
North Rhine -Westphalia	34 000	16.8	4.2	8.0	50
North Rhine - Westphalia Industrial area	10 300	11.3	10.2	8.9	51
Los Angeles	3 500	7.0	21	10.3	108
New York Manhattan	59	1.7	630	21.0	93
Fairbanks Alaska	37	0.03	18.5	21.8	18

Even if thus the mean production and consumption of energy for the earth as a whole is only a few hundreds of a watt per m^2 and thus only a small fraction of the solar radiation at the earth's surface, the energy consumption that is converted into heat and transferred into the atmosphere is comparable or even larger than the natural energy flux within small regions. We shall return to the climatological importance of this fact.

First, it will be important to describe the principal relation between solar radiation and the temperature of the earth.

The earth is in approximate radiative balance with space, i.e. as much energy is absorbed by the earth in the form of solar radiation as is returned to space in the form of infrared radiation. If the earth were not surrounded by an atmosphere the mean temperature of the earth's surface would be about -20° instead of +15° as is the case at present. Both oxygen and nitrogen in the air are quite transparent both to solar radiation and to infrared radiation and therefore except for scattering solar radiation back to space they play a comparatively unimportant role for the radiative balance of the earth. Three gases that exist in small but variable amounts in the atmosphere rather have importance in this regard, namely water vapour, carbon dioxide and ozone, i.e. the oxygen molecule consisting of three atoms. Water vapour and carbon dioxide are rather transparent to solar radiation and permit the incoming energy to penetrate deep down into the atmosphere and to be largely absorbed at the earth's surface. The infrared radiation that is emitted from the earth's surface, on the other hand, is partly absorbed by the atmosphere which in turn radiates both toward space and back to the earth's surface. This improves the heat economy of the earth and permits considerably warmer climate at the earth's surface than otherwise would be the case. The ozone, on the other hand, absorbs solar radiation in the ultraviolet part of the spectrum already at high elevation, whereby the temperature at levels between 25 and 70 kilometers is increased by up to 100° above what otherwise would be the case.

It is furthermore important to have an idea of how a change of the energy exchange between the earth and space would modify the temperature at the earth's surface. Complicated models of the atmosphere are required in order to estimate this, even if it is possible to disregard geographical differences in a first approximate treatment of the problem. Schneider and Demett (8) have tried to summarize what such model computations so far have yielded and conclude that a change of the energy flux to the earth by about 1 % probably would imply a change of the mean temperature of the earth by 1.°2 C. This figure is uncertain and could well be only one quarter, i.e. 0.°3 or four times as large, i.e. 5°C.

6. CLIMATE CHANGES AND THEIR POSSIBLE CAUSES

A large number of theories have been advanced to explain the climate changes that have occurred in the past. There is no possibility to consider them all critically in this brief summary, nor is it a particularly meaningful way of treating the subject, since there is hardly anyone of them that has been confirmed by factual information about the climatic changes that have occurred and thus generally been accepted. It is, however, important to describe the physical, chemical and biological processes that research workers in the field today consider as being most important and which therefore should be incorporated into the climatic models that are under development. It is furthermore possible to get a general idea of what role these different factors separately might play for the climate and its possible changes. We know, on the other hand, very little about the way these factors may interact with each other, which certainly is important. We can describe qualitatively possible positive and negative feed-back mechanisms, but it is difficult to estimate quantitatively their interaction. Below we shall give a survey of the most important processes that are at work.

6.1 <u>Variations of the intensity of solar radiation</u>

Since solar radiation is the prime factor that determines the climate of the earth, it is natural to expect that possibly some climatic changes in the past may have been caused by changes of the solar radiation. Since the latter part of the 19th century many attempts have been made to determine by direct observations to what extent the intensity of solar radiation possibly may have varied. The atmosphere partly absorbs solar radiation and it is therefore not possible to determine by observation at the earth's surface variations of the radiation that reaches the outermost parts of the atmosphere to a better accuracy than about 1 %. Measurements so far give no reason to believe that variations that large have occurred in the past. Nor is it possible as yet to determine the variations of the intensive solar radiation with the aid of satellites with a greater accuracy than has been mentioned above but most likely this will soon be achieved.

On the other hand very marked variations of the solar radiation have been observed in the ultraviolet part of the spectrum, for example in association with the solar cycle, over a period of about 11 years. The total amount of energy that arrives to the earth in the form of ultraviolet radiation is, however, small and the total flux of energy to the earth is not significantly changed.

The Jugoslavian astronomer Milancovic had advanced the theory that even though the total energy that is emitted by the sun may not change, the amount arriving at the earth and its distribution over the earth's surface may vary depending upon secular changes of the orbit of the earth around the sun. These changes are, however, slow and can possibly be of some importance for changes between glacial and interglacial periods but an agreement has not been reached on this matter. In any case this theory cannot explain the minor variations of the climate that have occurred during the last few thousands of years.

6.2 Variations of cloudiness

Clouds that are more than a few hundred meters or half a kilometer thick reflect back to space as much as about 80 % of the incoming solar radiation. Possible variations of cloudiness therefore are of great importance for the radiative balance of the earth as a whole. Flohn (7) has estimated that an increase of the cloudiness by 2 % would mean a decrease of the energy that can be transformed into heat by about 350 TW (TW = terrawatt = 10^6 kilowatt), i.e. about 0.7 W/km^2 (compare Tables 1 and 2). The clouds, however, also prevent the earth's long wave radiation from passing through the atmosphere to space, which also is the reason why even a rather thin cloud may prevent night frost. With the aid of model computations Manabe (9) has estimated how changes of the mean cloudiness might change the mean temperature of the earth considering the way in which radiational conditions vary with varying amount of clouds. The results are shown in Table 3.

Table 3. The importance of clouds for the equilibirum temperature of the earth.

	Temperature change caused by 1 % change of cloudiness
High clouds (6 - 12 km) (not transparent to long wave radiation)	+ 0°.4
High clouds (6 - 12 km) 50 % transparent to long wave radiation	± 0.0
Intermediate clouds (2 - 6 km)	- 0°.4
Low clouds (< 2 km)	- 0°.8

So far it has not been possible to determine with the aid of satellite pictures if the mean cloudiness around the earth has appreciably changed since the first meteorological satellite was launched about 15 years ago. On the other hand changes in cloudiness have occurred on a local, and possibly on a regional scale due to man's activities. It is well known that the regulation of the Swedish rivers in association with water power generation projects has changed the frequency of fog and clouds in the river valleys and one has also been able to establish a somewhat increased frequency of clouds and fog in the lee of cooling towers where evaporation takes place. Finally, the frequency of high cirrus clouds over parts of the United States with intensive air traffic probably has increased. These changes are, however, not sufficiently widespread to have had any appreciable effect on the climate on a global scale.

6.3 Variations in the composition of the atmosphere

6.3.1 Water vapour

The amount of water vapour in the air varies considerably from one part of the atmosphere to another and also in time. The mean residence time of water vapour in the atmosphere is comparatively short, about ten days. As has been mentioned already water vapour plays a decisive role in the heat balance of the earth.

An increasing amount of water vapour in the atmosphere implies an improved energy economy of the lowest layers of the atmosphere whereby the temperature increases at the earth's surface. Such a change probably would lead to an increased evaporation from the oceans possibly leading to a further increase of the amount of water vapour in the atmosphere and further temperature change. Such a chain reaction represents a typical feed-back mechanism. It is in principle not possible to compute the resulting equilibrium state by only considering this interplay, since other mechanisms, e.g. more clouds because of the increasing amount of humidity in the atmosphere, will determine how far and maybe even in which direction such a change might go. The extent to which man may change the amounts of water vapour in the atmosphere depends above all upon how the surface of the earth and the surface of the world oceans mya be modified by man's activities. We shall return to this question in sections 6.4 and 6.5.

It is essential to keep in mind that the stratosphere is dry and contains only a few hundreths of a percent of the total amount of the water vapour in the atmosphere. Comparatively much smaller amounts of water vapour need therefore be introduced into the stratosphere in order to change the radiational conditions by a certain amount. It should also be pointed out that water vapour may play a certain role in the photochemical balance that maintains the amount of ozone in the stratosphere (compare 6.3.3.). This is the reason why the question has been raised of which role the water vapour released in the exhaust gas from airplanes might play for the conditions in the stratosphere and thereby also possibly indirectly for the lower atmosphere. So far no changes that can be related to water vapour release in the stratosphere have been established and there is hardly either any reason to expect that such changes may occur in the forseeable future. As will be indicated below other changes in the stratosphere might well be more important.

6.3.2. Carbon dioxide

The atmosphere contains a little more than 0.03 percent carbon dioxide, which from a radiational point of view acts in a similar manner as does water vapour, i.e. the presence of carbon dioxide in the atmosphere implies a higher temperature of the atmosphere and the earth's surface than otherwise would be the case. Man burns large amounts of coal and oil and thus emits large amounts of carbon dioxide into the atmosphere.
It has been generally accepted that for this reason the amount of carbon dioxide in the atmosphere has increased from a value between 290 - 295 ppm (parts per million) at the middle of the last century to about 325 ppm today, i.e. an increase of about 12 %. About 13 ppm of this increase has occurred since 1958 (see Figure 4). The present consumption of fossil fuels implies an injection of about 16,000 million tons of carbon dioxide into the atmosphere per year which corresponds to an increase of about 2.1 ppm per year, but the observed increase is only about half of this value. The reason for this fact is partly that an increased assimilation by land biota probably occurs, and parti-

cularly because the oceans serve as a sink for carbon dioxide. The exchange processes between the natural reservoirs that contain carbon, i.e. the atmosphere, land biota and the oceans, is slow and particularly the characteristic mixing time of the world oceans is about 1,000 years, which implies that it only is able to absorb slowly the carbon dioxide produced by man. If the emission to the atmosphere is to decrease, a return to pre-industrial conditions in the atmosphere will take a very long time, several thousand years. Therefore in practice the human activity of releasing carbon dioxide into the atmosphere is an irreversible process over the time periods for which it is at this moment meaningful to try to consider man's interplay with his environment. We shall return to the question of the likely changes of the amount of the carbon dioxide in the atmosphere based on various assumptions about the future consumption of coal and oil.

Estimates of the possible climatic effect on an increasing amount of carbon dioxide in the atmosphere have been made by Manabe and Weatherald (12). It should be emphasized that only a few feedback mechanisms have been considered in these computations, among those, however, the secondary effects of changes in the extension of snow and ice in polar regions as a result of temperature changes and the associated changes of the earth's albedo.
In spite of this reservation the results are most interesting. Manabe and Weatherald find that a doubling of the carbon dioxide in the atmosphere might imply an average increase of the temperature at the earth's surface of about three degrees, whithin polar regions considerably more (see Figure 5). The amount of fossil fuel so far burned by man thus have caused a temperature increase of a little less than half a degree, in polar region possibly a degree.

Observations show that only a rather small net change of the air temperature has occurred during the 20th century. The increase until about 1940 has been followed by a small decrease of the average temperature of the northern hemisphere. Other important factors that determine the climate of the earth therefore probably have been of importance during this time. If accepting the computations by Manabe and Weatherald as being approximately correct and also assuming that the natural variations of the climate of the earth will not increase over the next decades, a measurable

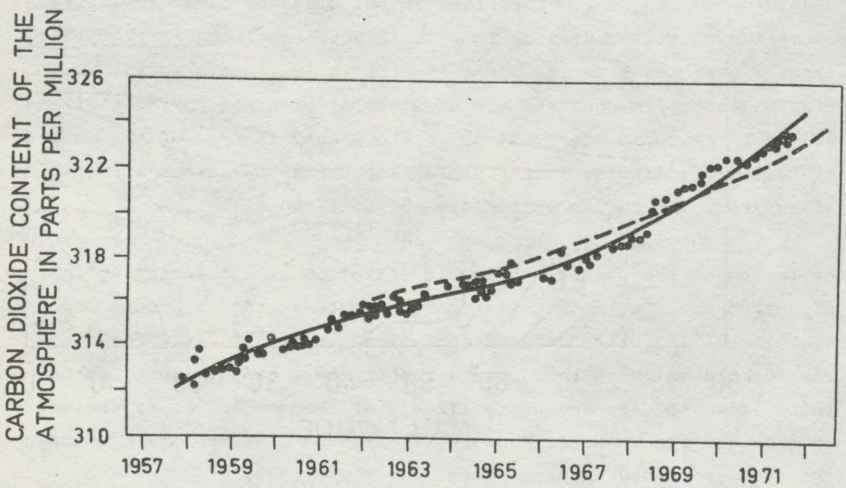


Figure 4. Changes in the carbon dioxide content of the atmosphere. The points show measurements in Antarctica and the full curve represents a best fit to these points (10). The dashed curve shows Swedish measurements at an elevation of about 10 kilometers above the north polar regions north of about 40° (11).

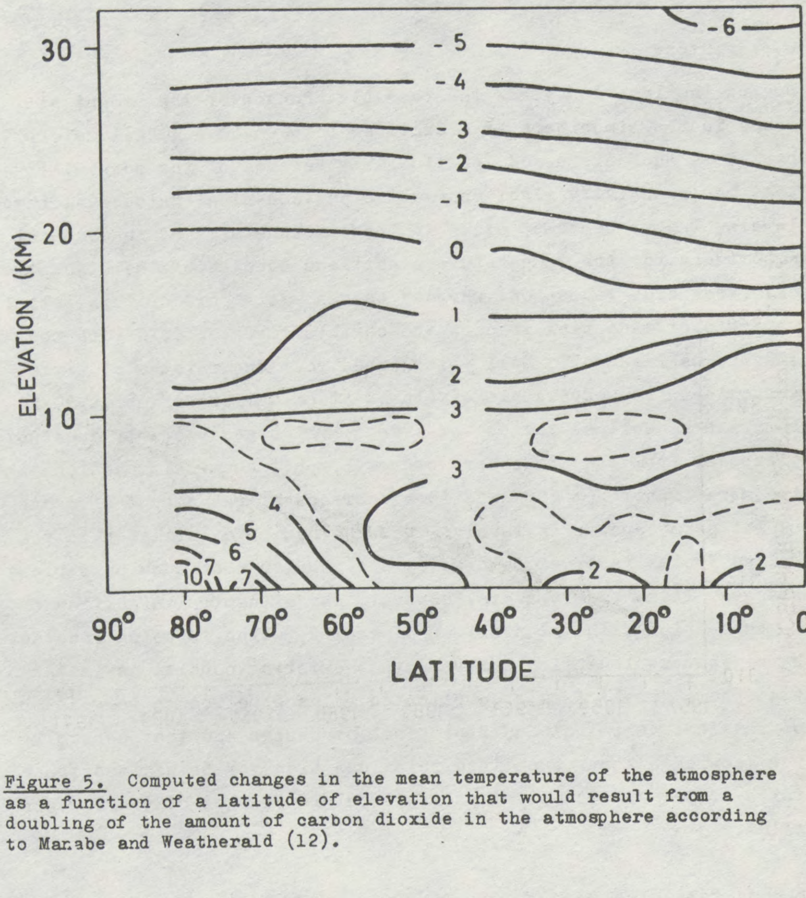


Figure 5. Computed changes in the mean temperature of the atmosphere as a function of a latitude of elevation that would result from a doubling of the amount of carbon dioxide in the atmosphere according to Manabe and Weatherald (12).

effect of the changes of amount of carbon dioxide in the atmosphere might be expected towards the end of this century.

6.3.3 Ozone

During the last few years the possible changes of the amount of ozone in the atmosphere at elevations between 20 - 40 kilometers have been much discussed, particularly because of the possibility that man's activity might change the photochemical balance at these levels. The presence of ozone in the atmosphere is of fundamental importance for the temperature conditions because of the absorption of ultraviolet radiation, whereby only a small part of this lethal ultraviolet radiation reaches the earth's surface. It may be considered as reasonably well established that the release of nitrogen oxides from supersonic airplanes at elevations of about 20 kilometers as well as the use of freons, which gas probably does not disappear from the atmosphere except by photochemical reactions in the stratosphere, might lead to a decrease of the amount of ozone in the stratosphere. Extensive research has been initiated in the United States in order to clarify the magnitude of such possible changes. These problems are, however, not of central significance in connection with the problems of energy, which is being considered here. What we learn is, however, that existing conditions in the atmosphere result from a complicated balance between a large number of physical, chemical and biological processes and that possibly new knowledge about such interrelations also may be of importance for a proper assessment of possible future changes of the earth's climate.

6.3.4 Particles

Even very clean air, as we find it in the mountains or high up in the atmosphere, contains particles, aerosols. The lowest concentration observed in the atmosphere is about 100 particles per cm^3. Over the continents the number of particles may be 100, sometimes thousand times larger and in the industrial areas that man has created the number of particles may be 10, perhaps 100 million particles per cm^3. Particles must be less than a 0.001 millimeter (a micron) in order to remain airborne for an appreciable period of time. Particles less than about a micron, 0.1 - 1 micron, are the ones that are optically most important for the radiative balance of the earth. There are many sources for particles in the atmosphere. When waves break and bubbles burst in the sea small water droplets are injected into the lowest layer of the atmosphere, where they evaporate and change into small sea salt nuclei. This type of aerosol is primarily found over the oceans and in coastal areas. Over the continents dust is formed by wind action on the soil, whereby particles are brought into the atmosphere, particularly consisting of minerals and quartz. Furthermore many particles are formed in the atmosphere by transformation of gases into solid form. This is for example the case with sulfur dioxide, which is brought into the atmosphere either as sulfur dioxide or as hydrogen sulfide which later is oxidized into sulfur dioxide. Furthermor plants on land form gases that are emitted into the atmosphere and which also later may be transformed into solid particles.

Man is also changing the aerosol load of the atmosphere. Solid particles, particularly soot, are formed when coal and oil are burned, as well as gases, for example sulfur dioxide, that later is transformed into sulfate particles. Furthermore man changes the characteristics of the earth's surface whereby considerable amounts of dust may be injected into the atmosphere by the winds.

Agreement has not been reached about the possible role that man today plays for the global balance of particles in the atmosphere. Undoubtedly a marked increase of the amounts of particles has occurred in cities and industrial regions, as anyone who has travelled by air over Europe or the eastern United States certainly has observed. These regions, however, only represent a few percent of the earth's surface. Probably also the developing countries contribute considerably to the amount of dust in the atmosphere. Estimates of the present human production of dust to the atmosphere varies from a few percent to about 50 percent of the natural amounts. The slowly increasing curve in Figure 6 shows the estimated increase during the last hundred years as deduced by Mitchel (14).

It should be emphasized that in contrast to what is the case for carbon dioxide, the residence time of particles in the atmosphere is com-

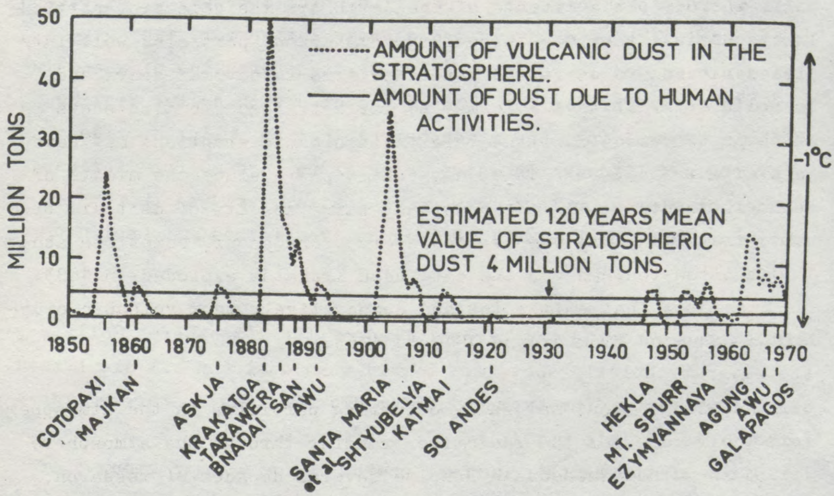


Figure 6. An attempt to reconstruct the load of dust in the atmosphere as a result of volcanic eruptions indicated by a dotted curve. The horizontal full line shows the mean load as a result of volcanic activity and the slowly rising curve shows the load due to man's acti ity (4).

paratively short. In the lowest part of the atmosphere particles on the average remain in the air only for a few days or possibly a week, while it may take some years before particles in the stratosphere again are brought down to the earth's surface.

Maybe the most important sources of particles in the atmosphere in relation to the climate of the earth are the volcanic, particularly because they may throw large numbers of particles well into the stratosphere where the residence time is several years and where their radiative role may be largest. Figure 6 also shows an attempt to reconstruct the role that volcanic eruptions may have played as a source of dust in the atmosphere since the middle of the last century (14). We note that large amounts of dust are brought into the atmosphere when volcanic eruptions occur, sometimes about 100 million tons as was the case when Krakatoa exploded in 1883. We also note that only a few and comparatively weak volcanic eruptions occurred from around 1910 to 1963.

Our knowledge about naturally occurring particles in the atmosphere and their role for the radiative transfer through the atmosphere still is rather inadequate despite several decades of research. Therefore all estimates of the possible role of man in changing the climate of the earth are very uncertain. Particles in the atmosphere have an influence on the radiation in two ways. Solar radiation is scattered whereby part of the incoming solar radiation is reflected back into space without having been transformed into heat. Particles, particularly metallic particles, also absorb part of the radiation whereby the air in the immediate environment is heated. Since particles in the atmosphere are of varying size and composition it is difficult to compute their role for the heat balance and also what the possible effects might be of what man so far may have contributed. The dominating view is that the scattering of radiation is most important and will lead to a less efficient heat balance between the earth and space and thereby a lower mean temperature of the earth, but this view has been questioned by some researchers (Rasool and others (15)). But if this were the case, which seems the most likely one, an increasing amount of particles in the atmosphere due to man would lead to a lower temperature of the atmosphere and the earth as a whole, even if perhaps the temperature locally may be increased by the absorption of radiative energy by the particles.

There is one observation that rather clearly seems to show the role an increasing amount of particles in the atmosphere may have had for the heat balance of the atmosphere and the vertical temperature structure. The volcanic eruption on Bali in 1963 changed the radiation balance in the stratosphere markedly for a few years, as is shown by Figure 7. The temperature increased by 6 or 7 degrees at levels between 10 or 20 kilometers and it took about for years before normal conditions were re-established. The sulfur dioxide that was emitted was transformed into sulfate and a sulfate layer was formed at about 20 kilometers' elevation. No noticeable effects on the temperature in the troposphere were recorded, nor at the earth's surface. It should be pointed out that the volcanic eruption on Krakatoa in 1883 emitted many times more dust and sulfur dioxide into the atmosphere than the one on Bali.

6.4 The role of the earth's surface

The earth's surface plays a role in the heat balance of the earth by reflecting, absorbing and emitting radiation, but also by receiving, storing and releasing heat and moisture. Its characteristics and capability in these regards are very variable. Soil covered by vegetation generally has a rather high capability of absorbing radiation while a much larger part of incoming solar radiation is reflected in desert areas and particularly ice and snow are very effective in this regard. Therefore the fact that the earth's surface is covered by vegetation is of fundamental importance for the maintenance of the present climate and conversely the vegetation is dependent on the present climate. One finds interplay and feed-back mechanisms here.

The heat capacity of the uppermost layers of the earth of importance in the present context usually is small, particularly if the soil is dry and its heat conductivity small. Moisture conditions, however, vary very much from desert areas with hardly any water in the soil to the tropical rain forests with large reservoirs. A large heat and water capacity of the earth's surface means rather small daily variations of temperature, while a small capacity in this regard implies large changes from night to day.

As has been mentioned before the heat balance of the earth is primarily determined by the amount of solar radiation that is transformed into heat. This, of course, depends upon the intensity of solar radiation but also on the amount of solar radiation that is reflected from the earth, i.e. the albedo of the earth. Satellite observations during the last years have shown ways whereby man possibly is changing the albedo of the earth. Figure 8 shows the coastal area from Israel to the Nile river. The former border between Israel and the United Arab Republic is clearly shown as a discontinuity in the albedo of the earth. Within these dry areas the vegetation obviously is very sensitive to how the soil is being used and different land use has resulted in a change of albedo. It has been suggested that something similar may have happened in the areas south of the Sahara and may have been an important reason for the perennial drought in Sahel. It is not likely that this is the prime cause since changes have also occurred in other parts of the equatorial zone which can hardly be explained in this way. Model studies have, however, shown that the increase of the albedo of the earth within a subtropical desert region creates an air circulation in the subtropical anticyclone, which may increase the subsidence of air over the desert areas and decrease the amount of precipitation. If man were able to change the earth's albedo over an area of a million square kilometers or more, which is on the order of one percent of the earth's surface, it might have repercussions on the climate in a region that is several times larger. It is, however, not possible with our present knowledge to estimate the possible magnitude of such climatic changes. It should also be noted that the forest clearing that takes place in Brazil might imply a change of the albedo, the importance of which also will be dependent on the way in which the soil later is going to be used. Without knowledge in this regard it is impossible even to say anything about the possible risks that may exist.

Over centuries and millenia man to a considerable degree has changed the vegetation cover on the earth over large regions. Cultivated fields have replaced the forests and animal grazing in Africa probably has implied that at least within certain regions the sparse vege-

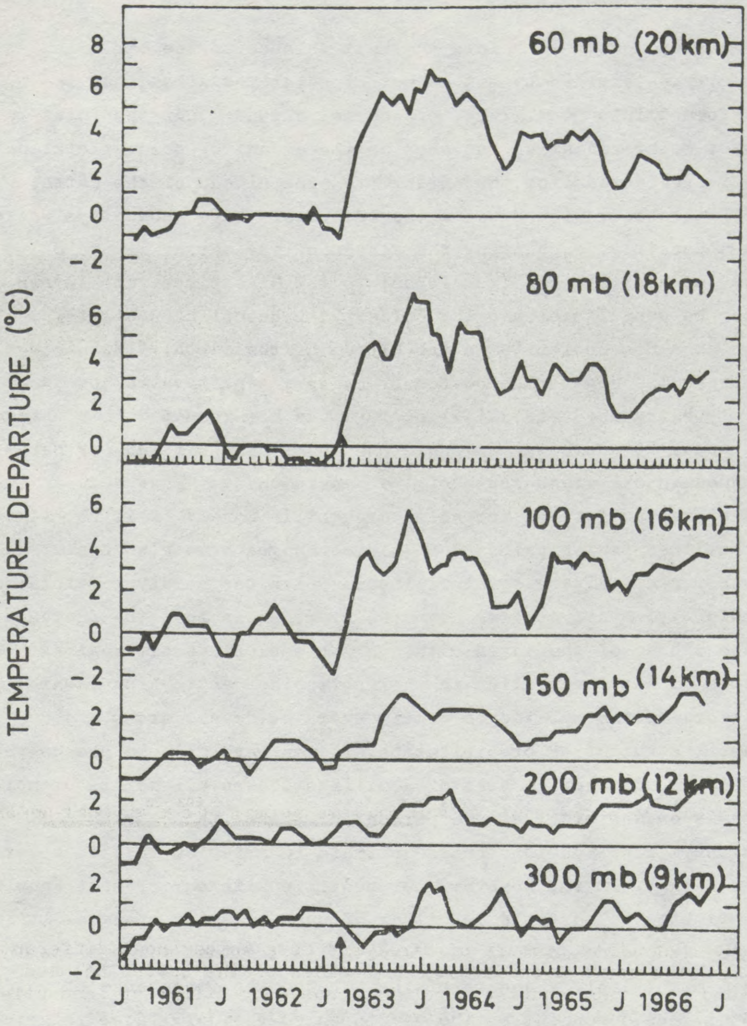


Figure 7. Temperature variation at different elevations above Port Hedland (20°C) given as the departure from the mean temperature during the five-year period 1958-1962. The temperature increase after the volcanic eruption of Mount Agong on Bali in March 1963 can be observed down to a level of about 9 km (Newell (6)).

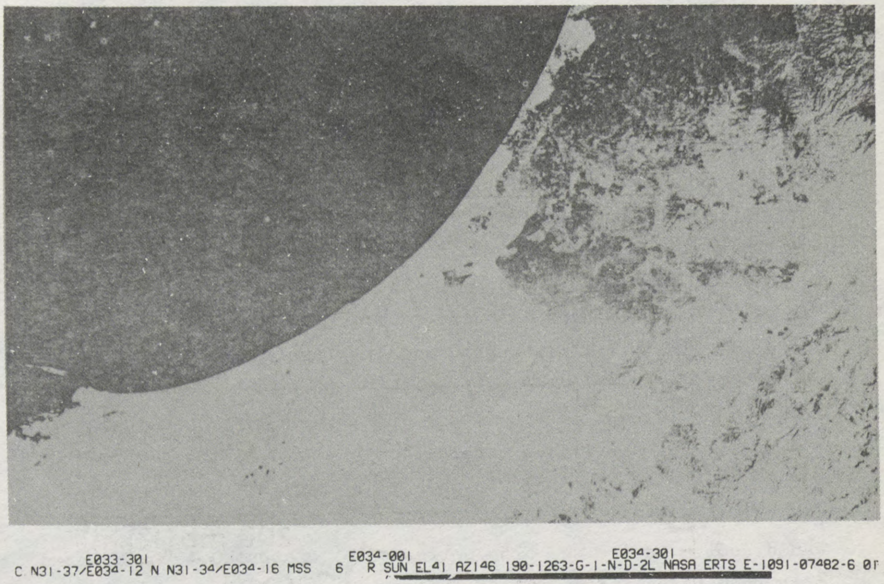


Figure 8. Satellite picture of Sinai and Gaza which shows different albedos of the earth's surface on both sides of the border between Israel and the Arab Republic, probably caused by different land utilization (ERTS picture by J. Otterman, Tel Aviv University).

tation has been still further diminished. The extent to which the change of the forests in Europe and North America into cultivated field may have changed the climate is impossible to determine. Nor can we with any degree of certainty state that the clearance of forests in the Mediterranean that occurred some two thousand years ago changed the climate to become more arid. It might just be the other way around: the climatic change may have led to a change of the vegetation in this part of the world.

The interplay between vegetation and the atmosphere also implies an exchange of oxygen. Also the biological activities in the sea involve oxygen and the burning of fossil fuels means the use of oxygen in the atmosphere. The fear has been expressed that man is influencing the natural cycle of oxygen and thereby might change the amount of oxygen in the atmosphere to a significant degree. It should first of all be stated that very careful measurements of the amount of oxygen in the atmosphere do not show any significant changes from the generally accepted mean value 20.946 %. Simple estimates also show that one cannot possibly expect that any change so far should be detectable, nor would be very significant in the future. The amount of oxygen that is present in all the living material on land and in the sea together does not correspond to more than about 0.1 % of the oxygen found in the atmosphere. The total amount of the oxygen that can dissolve in the sea also corresponds to about 0.1 % and burning fossil fuel to an extent that would imply a doubled amount of carbon dioxide in the atmosphere decreases the amount of oxygen by 0.03 %. We therefore may assume that the amount of oxygen in the atmosphere will not change significantly due to man's activities during the next few centuries or even longer time periods.

The total amount of precipitation over the earth during one day amounts to about 1,000 billion (10^{12}) tons and since the amount of water vapour in the atmosphere does not change significantly from one day to the next, the same amount of water must evaporate from the seas and the continents during one day. This implies that the residence time for water vapour in the atmosphere is about 10 days. It is obvious that very extraordinary changes are required in order to interfere directly with the natural hydrological cycle. Only on a local and possibly on a regional scale can man's activities today play a role in this regard. By creating artificial lakes, changing the evaporation by irrigation or by using evaporation into the atmosphere, say in order to cool nuclear power plants, man can locally change the humidity of the atmosphere. One may also envisage changing the evaporation from lakes or perhaps smaller parts of the oceans by changing the characteristics of the sea surface through which the water vapour exchange takes place. To take an example films on a water surface have some effect on the flux of water vapour between the sea and the atmosphere, but no clear proof that a significant change even over local or regional areas has occurred exists at present.

It should be emphasized that man's interference with the hydrological cycle, even if it were to imply large amounts of water, usually means that evaporation is moved from one region to another, as is generally the case for irrigation or from one time of the year to another when creating big dams for irrigation. It is only if these changes in time and space are significant that they may play a role climatologically. Many of the ways whereby man is changing the hydrological cycle do not imply such changes and are accordingly also rather insignificant climatologically. The building of dams for water power, for example, delays the arrival of the river water to the sea a few months and in this regard is hardly of great importance except locally around the dam. The regulation of the Nile river on the other hand represents a redistribution in time of the evaporation of the water that might be of climatological significance.

6.5 Ice and snow

The extension of ice and snow in polar regions evidently must be of great importance for climatic conditions since the reflection of solar radiation is very much influenced thereby. Large variations of the area covered by ice and snow occur as shown by Figure 9. Twelve months' running mean values have been computed with the aid

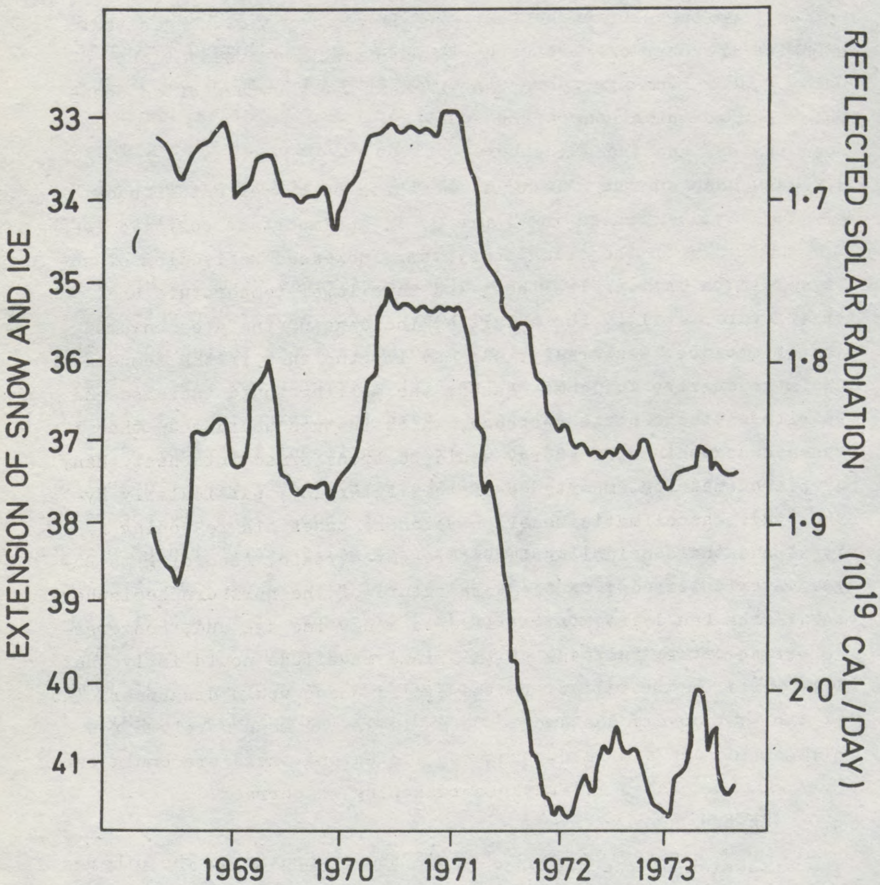


Figure 9. Running 12-month mean values of the extension of snow and ice in the northern hemisphere (upper curve, the seasonal variations have been eliminated) and computed variations of the energy that is reflected back to space because of this change of the earth's albedo (lower curve) (18).

of satellite observations, and thereby the marked annual cycle has been eliminated. Changes of the size of the area covered by snow and ice by about 4,000,000 km^2 occurred from 1971 to 1972, which is almost 1 % of the total area of the earth. The extent of snow and ice during the last ice age is estimated to have been between 50 and 60 million km^2 as compared with a present average of about 35 million km^2. We do not know the cause of the last ice age, nor do we know the reason for the changes that occurred within merely one year. Since satellite observations are available for only a few years we do not know how often changes of this magnitude may take place.

The dependence of the albedo of the earth on the extent of snow and ice, as illustrated in Figure 9, is an important positive feedback mechanism in the climatic system. Increased reflection of solar radiation implies less heat and thus lower temperature and thereby a possibility for a further increase of the area covered by snow and ice. Conversely, one may imagine that if the temperature were to rise for some reason, the melting would increase and the albedo of the earth decrease, which in turn would mean that even more of the solar energy would be transformed into heat. Many have discussed the importance of this interplay, particularly Bydyko (19). The climatic model on which he bases his reasoning is simple and the conclusions therefore not certain. According to Budyko, even a decrease of the temperature of the northern hemisphere by one or a few degrees might lead to a new ice age and, conversely, a temperature increase of that same magnitude could imply that the sea ice that today covers the Arctic Ocean would disappear. The sea ice that covers the Arctic Ocean is in the mean merely a few meters thick and a marked change of its extent therefore could take place within decades if Budyko's reasoning is correct.

The ice sheets covering Greenland and the Antarctic on the other hand are very much more inert components of the climatic system with a characteristic time of adjustment of thousands or tens of thousands of years. The idea has been put forward that marked changes of the climatic condition might lead to an unstable distribution of ice within such an ice sheet, which in turn could lead to ice surges. There is as yet no clear evidence that such processes might have been of importance in changing the climate over the last tens of thousands of years. This idea is therefore so far rather to be considered as a working hypothesis.

If all the sea ice were to melt, the sea level would not change. Melting all the ice in the north polar region except the Greenland ice sheet thus would not lead to any changes of the sea level. Conditions are, however, very different if we think of the continental ice sheets. The amount of water that is stored in those corresponds to an increase of the sea level by about 60 meters. Figure 10 shows what such a change would imply for Europe. However, it should be emphasized that the increase of the temperature in polar regions does not necessarily entail a significant increase in the melting of the ice sheets. The mean annual temperature in Antartica at present is many 10 degrees below freezing and only during a very limited period of the year does the temperature exceed freezing point. Therefore, probably, a considerable temperature increase is required to increase melting form the Antarctic ice sheet appreciably. The Greenland ice sheet might be more sensitive to a temperature change in polar regions. It should furthermore again be emphasized that the ice sheets are slowly changing components of the climatic system. 300,000 million tons of ice must melt in order to increase the height of the sea level by one millimeter, which correspondens to the melting of an ice sheet of about one meter's thickness of the size of Sweden. It is not likely that the sea level would change by more than one or possibly a few milliliters per year even if a rather rapid change of the climate occurred.

6.6 Interplay between the atmosphere and the sea

The interplay between the atmosphere and the sea is of fundamental importance for an understanding of the climate and its variations. Our inadequate knowledge about the way in which the oceans respond to changes in the atmosphere and how those in turn may influence the atmospheric processes constitute the most serious gap in the knowledge we need in order to understand climatic changes in the past. Refined analyses of organisms that are found in the deep sea sediments yield information about the sea surface temperature in the north Atlantic far back in time

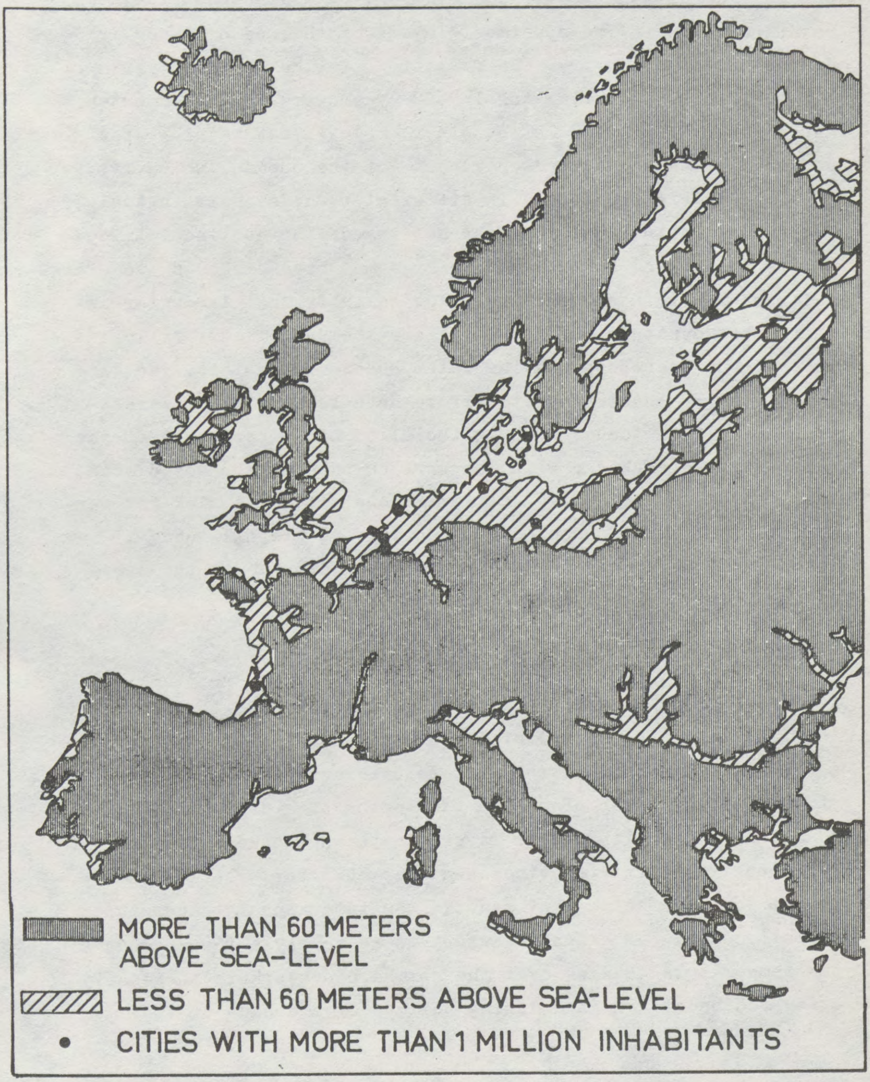


Figure 10. The picture shows those parts of Europe that would be flooded if the ice on Greenland and Antarctica would melt, which corresponds to an increase of the sea level by about 60 meters (20). See further the text for a discussion of the possibility for such a development.

and show that it was much lower during the last ice age as compared to conditions today; see Figure 11. We also know that temperature changes in the uppermost layers of the sea have occurred during the 20th century. The variations in the northern parts of the Pacific Ocean during the last 20 years are best documented as shown in Figure 12. On the other hand we know nothing about possible changes in the deeper parts of the oecans, which may be of considerable importance in different regards. Worthington (23) for example points out that the melting of the continental ice sheets at the end of the last ice age may have produced such large water masses with comparatively low salinity that the water exchange between this surface layer and the deeper more saline layers, and therefore heavier water became impossible. The climatic role of the sea may therefore have been quite different from what it is today. Such an isolation of deeper parts of the ocean from an exchange with the surface layers also would mean that the ocean had quite a different capacity as a sink for carbon dioxide, and if such conditions were to prevail today it would imply more marked changes of carbon dioxide in the atmosphere than those that now occur.

Generally, however, the sea primarily represents a stabilizing factor in the climatic system. This is maybe best illustrated by the fact that the storage of 1 % of the annual radiation from the sun would lead to an average temperature increase or water layer of 100 meters' depth of only a few tenths of a degree. If an exchange of water with deeper layers in the sea takes place it would be even more effective as a heat absorber. The sea is the most important factor that reduces the interannual temperature variations in, for example, Europe to be merely a few degrees and the temperature changes over the northern hemisphere to be only a few tenths of a degree during periods of a decade or two.

7. POSSIBLE FUTURE CLIMATIC CHANGES CAUSED BY AN INCREASING ENERGY PRODUCTION

7.1 Basis for judgement

It should be clear from the preceeding presentation that it is not feasible to forecast more precisely possible future climatic changes as a result of an increasing energy production. We may, however, form an opinion about the circumstances under which

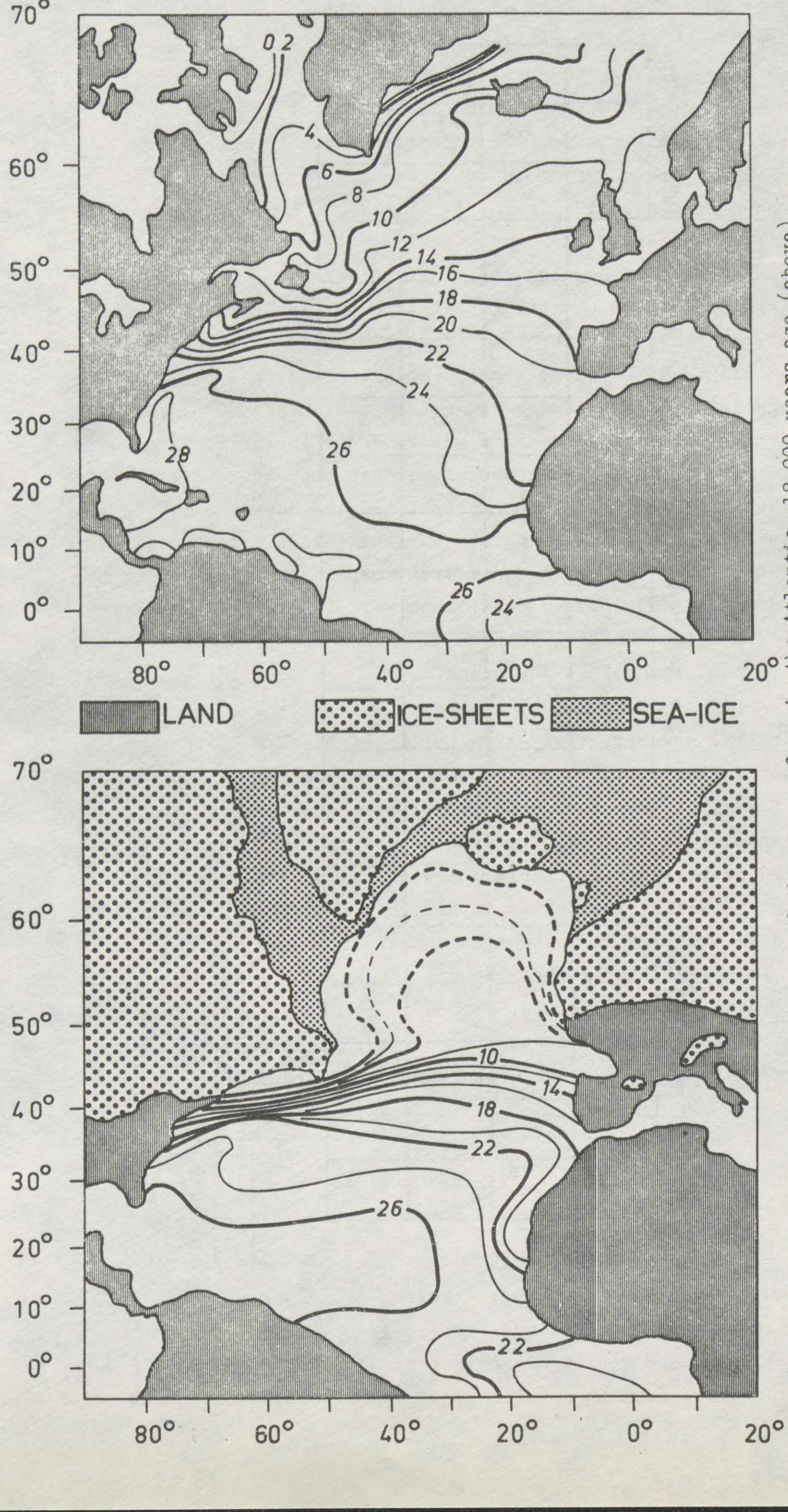
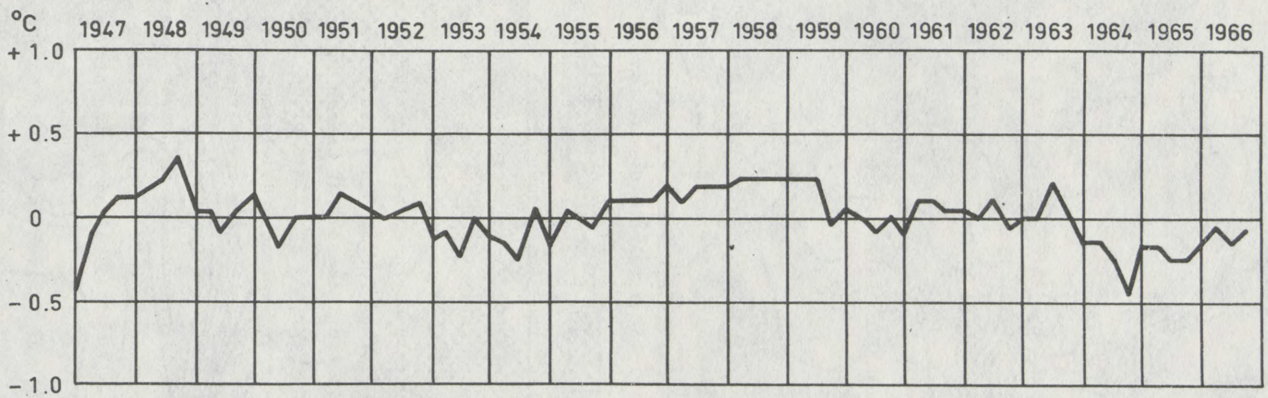


Figure 11. The temperature of the sea surface in the Atlantic, 18,000 years ago (above) and today (below). The region with densly packed isotherms shows the position of the Gulf Stream, which thus reached Europe in the vicinity of the Spanish Coast during the ice age (21).



<u>Figure 12.</u> Variations in the sea surface temperature of the northern Pacific Ocean expressed as the departure from the mean value during the 20-year period 1947-1966. Note the slow variations, for example the comparatively warm surface water during the years 1956-1960 which gradually was cooled during the 1960's (22).

man's activities may begin to interfere with natural processes in a significant manner. When it is impracticable to foresee possible consequences this fact should be taken as a warning and the situation should be handled with care. It must not be permitted that we even approach a situation in which we may significantly interfere with natural conditions on a regional and global scale without knowing the consequences reasonably well. This is particularly so when the changes that man may cause are irreversible. An increase in the amount of carbon dioxide in the atmosphere will be with us for thousands of years. Melting of the ice in the Arctic Ocean probably may imply difficulties for its reformation. We shall return to a more precise discussion of this in the very last section of this chapter.

The discussion of our future energy requirements is partly a discussion about the most feasible energy source, fossil fuel, nuclear energy or continous energy sources such as solar radiation, wind and water power, but is also a discussion of the desirable or permissible energy consumption in the future for the earth as a whole. One should first of all realize that an energy consumption of, say, ten times the present level is a possibility only if nuclear energy is accepted as a major energy source. The fossil fuels simply are inadequate, as is power derived from winds and rivers. It is true that large amounts of solar energy reach the earth's surface, but very large areas are required in order to extract for man's use ten times more than is consumed today. At the latitudes of Sweden it is simply not possible. This is, however, not the right place for a more general discussion of the most desirable development of energy consumption in the future. We shall limit ourselves to a qualitative discussion of the climatological consequences of a tenfold increase of it, which corresponds to an average consumption per capita for the present population of the earth approximately equivalent to the one we today find in the highly industrialized countries of the world (USA, Sweden). A 5 % increase in energy consumption per year implies that it takes 50 years to reach a value which is 10 times the one today and with a 2 % increase per year the corresponding time is 110 years. These two alternatives should be compared with the expected impacts on the climate of a future energy consumption on the scale that we have today.

The use of continuous energy sources such as solar radiation, wind and water power does not in itself influence the global energy balance of the earth and therefore would not lead to global climatic changes. It will, however, be required that energy is consumed in other parts of the world than where it is being produced. Thereby man will interfere with the natural flux of energy between, for example, equatorial and polar regions, which is normally taken care of by motions of the atmosphere and the oceans. The continuous energy sources at present only constitute a small part, less than 10 %, of the total energy consumption in the world, and since energy transfer implies considerable energy losses it is hardly realistic to expect large long distance transfer of energy from continuous sources from one part of the world to another. We are therefore probably permitted to disregard the climatic effects of such interference in the natural transfer of energy by the atmosphere and the sea, even if a considerable increase in the use of continuous energy sources will take place. Burning of wood, peat and animal excrements is not without air pollution problems, as can be seen in many developing countries. Technical solutions to this problem exist and will probably be introduced in the decades to come.

The use of fossil fuel for energy production causes air pollution. These emissions can be considerably reduced, but this in itself requires an increased energy consumption. To reduce the exhaust from more energy would be required and several percent of the energy automobiles in the oil would be used in order to eliminate the emission of sulfur dioxide. In the following discussion we shall, however, assume that the production of aerosols in the atmosphere caused by the emission of smoke and gas can be kept under control even if some increase in energy consumption will thereby result. The problem is, however, not being satisfactory solved and it will require clear incentives, such as fears of possible climatic changes, and considerable economical resources in order for more effective measures to be undertaken.

Production of energy using nuclear power stations, on the other hand, does not cause air pollution that is of direct importance climatologically. Secondary effects such as evaporation in cooling towers and perhaps also other effects may well be noticeable, but should be possible to keep under control. In the present context there is no reason to discuss more closely the question of radioactive release and radioactive waste. It is not likely that there are any significant climatological effects that need to be considered for present purposes. In any event these effects are insignificant in comparison with the problem of radiation and its immediate or longer-term biological effects. Reactor accidents may possibly have an effect on weather and climate but only if they, with regard to the energy involved, are comparable with the largest hydrogen bombs that were tested in the early 1960's. Again in such cases it is not the possible climatological effects that should be seriously considered in the first instance.

7.2 Climatological changes on a local scale

Measurements show clearly that the climate changes within densely populated and industrial areas when the energy released to the environment becomes about 10 W/km^2 or more. Table 2 in Chapter 5 shows that this heat supply is about 10 % of the heat supplied by solar radiation. A city is therefore heated and the bigger its extension is the more significant becomes this temperature increase because the ventilation by the wind becomes less effective. The haze that constantly prevails because of air pollution in such regions (which both in Western Europe and the United States have a regional extension) also contribute to climatic changes, partly because the incoming radiation is reduced during the day, partly because also the outgoing radiation is diminished. On an average air pollution probably implies less profitable radiation economy in low latitudes because of the increasing reflection of solar radiation, while it may mean heating at high latitudes by a reduction of the outgoing radiation. In industrial regions and cities the difference between day and night decreases and in addition the climate becomes somewhat warmer. Figure 13 shows schematically the air circulation that is created because of warmer climate in a city. This in turn may lead to a somewhat increased precipitation. When the wind blows across a city, local changes can also be found in lee in an area which is a few times bigger then the one that is primarily influenced by

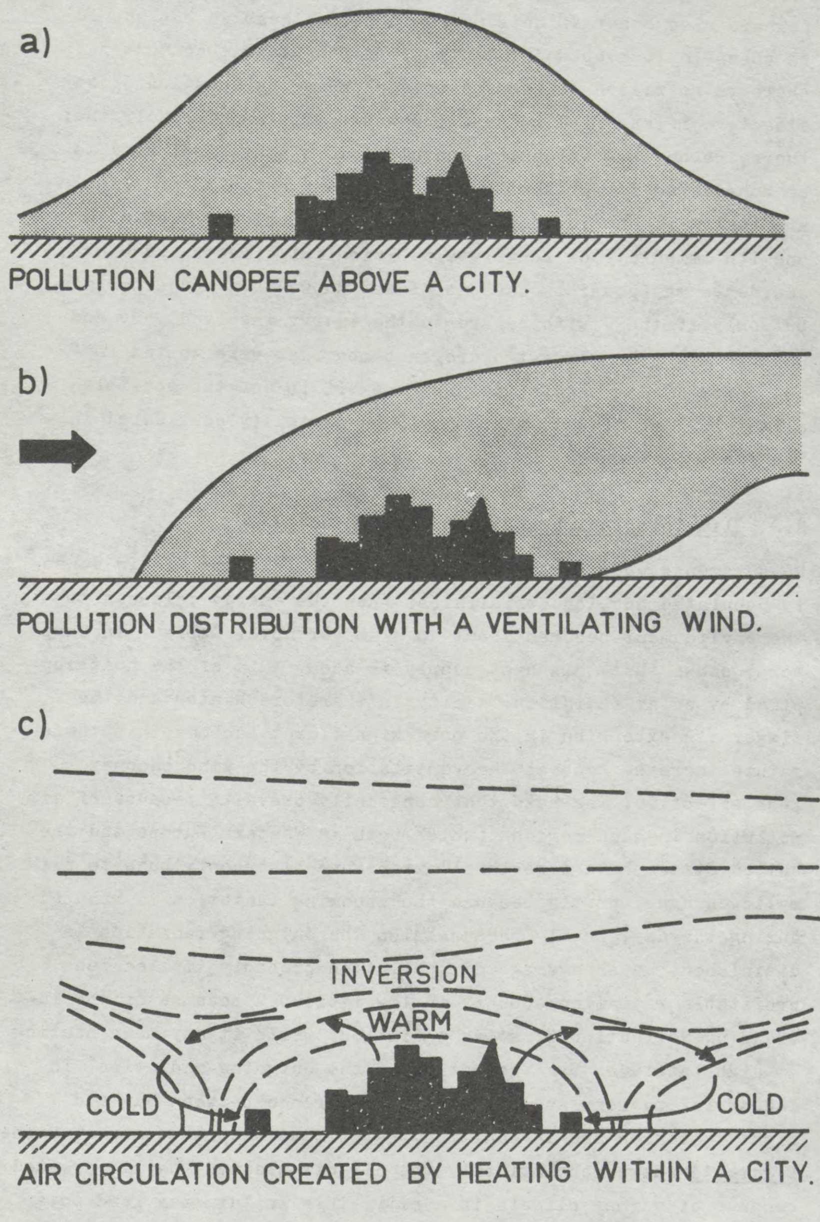


Figure 13. a) shows the distribution of pollution within and around a city during calm weather, b) shows how heat and pollution is transported by the winds and c) illustrates the local air circulation that is created by the warmer climate within the region (see further (24)).

man's activity.

The most noticeable climatological change on the local scale is the increasing frequency of haze and fog and the associated decrease of solar radiation. The unsatisfactory conditions in this regard, which also possibly influence man's health, may, however, be markedly improved by an active environmental policy. In the latter part of the 1950's several smog situations occurred in London with catastrophic consequences, but since the beginning of the 1960's it has by and large been possible to avoid such incidents by appropriate legislation ("The Clean Air Act").

Even if abatement of pollution requires energy in order to achieve significant results, it is certainly possible to improve further the present situation even if the costs will be appreciable to keep air pollution within present bounds even if the energy production increases significantly. It should also be emphasized that the temperature and precipitation changes that the present energy production may cause are not so large, not even in Manhattan, as to inflict appreciable inconviences on people living in the area concerned.

A further increase in the heat release due to man's activities which appreciably exceeds the level now prevailing in Manhattan will, however, give rise to other and more noticeable effects. The convection that would be created may break through stably stratified layers with increased cloud formation and precipitation, and there are observations showing that energy release in volcanic regions corresponding to 30,000 W/km^2 or more can generate tornadoes. This should be kept in mind knowing that future nuclear power stations generate large amounts of waste heat and the value mentioned above therefore probably represents an upper bound for the waste heat from such nuclear station parks that should be permitted from the point of view of local climatic effects.

7.3 Climatological changes on a regional scale

The question about the way in which man may influence the climate on a regional scale above all concerns the extent to which climatic zones may be shifted geographically. As was discussed in Chapter 3 their positions are primarily determined by the position of the circumpolar jet stream and the character of the long waves that exist in the westerlies; see Figure 3. When the jet stream moves towards the north the warm and dry climate to the south of this stream, of the kind that we find in subtropical regions, also moves towards the north and when conversely the jet stream is located further towards the south it implies that the more humid and cooler climate that prevails in the temperate zone moves towards the south. Also the cold climate in the polar area extends further equatorward. Being concerned with the possible role man might play in changing the climate on a regional scale we must primarily consider the direct heating and the changes in the radiation balance that may be caused by the increasing amount of smoke and dust. The present heat input to the atmosphere on a regional scale because of human activities within the industrial countries corresponds merely to a fraction of 1 W/m^2, which might cause a temperature increase of a tenth of a degree, probably less. A tenfold increase in energy production would in these countries imply that we would approach a situation in which the effects would become noticeable as a regional temperature increase.

The air pollution situation over Europe and the United States is a climatic change on a regional scale in the sense that the frequency of fog, visibility and number of hours with sunshine probably have changed significantly as compared to conditions about a hundred years ago. The changes of the temperature and precipitation climate because of these pollutants probably is less than those that may have occurred naturally during this same period of about one hundred years. A tenfold increase in energy production by use of fossil fuels (which is not very probable) without effective smoke cleaning might possibly lead to a cooler climate in these countries. As seen the direct effect of the waste heat and the indirect ones due to increased pollution counteract each other, but on the regional scale it is probable that the latter will dominate. It is, however, not possible to say anything about the likely magnitude of such changes.

A cooler climate over regions of the size of Europe or the United States probably would imply that the climatic zones within neighbouring parts of the world might be displaced. Even if we cannot infer the possible secondary effects that may occur as a consequence, this effect on the climate is not immediately disturbing, since the effects of human activity probably still would be less than the natural variability, even though possibly not negligible. We still have time to understand the climatic system better and thereby also try to establish which level of energy production might be acceptable over areas of a regional size.

7.4 Climatic changes on a global scale

Even if local climatic changes because of man's activities certainly have occurred and even if man in certain respects possibly even may play a role for climatic changes on a regional scale, possible global changes in the future undoubtedly represent the most serious problem, in spite of the fact that activities so far probably only imply marginal changes as compared with those that have occurred naturally. The earlier discussion of global energy fluxes shows that a tenfold increase in energy production by human activities and thus a tenfold increase in heat input to the atmosphere possibly may change the mean temperature of the earth by a tenth of a degree. A hundred times larger energy production would be required in order to change the natural energy fluxes by one percent and in such a case the global changes of the earth's temperature might reach about one degree C. Secondary effects in a form of increased evaporation, cloud formation and precipitation cannot be forecast without extensive model computations that have not been possible to carry out so far.

Man may, however, influence the global climate indirectly long before the energy production reaches those gigantic values that such a hundredfold increase represents. Already the temperature changes that Manabe and Weatherald have computed as a consequence of a doubling of the amount of carbon dioxide in the atmosphere would imply changes of the energy flux on a global scale that are about one percent of the natural ones. This would represent a very noticeable disturbance of the present radiation balance. Many secondary changes in the climatic system could be thought of as restoring the balance, above all changes in the hydrological cycle, i.e. increased evaporation and condensation, as has been already mentioned before. The possibility for a positive feed-back mechanism exists, i.e. an increase in the temperature might change the amount of carbon dioxide or water vapour in the air resulting in a better radiation economy and an increasing temperature as a consequence. Even if such a possibility cannot be ruled out in principle, it is less probable in a complicated system such as the one that the atmosphere, the oceans and the ice sheets represent.

The part of the existing oil and coal reserves on earth that can be utilized for energy production without expending too much effort on prospecting, pumping and mining in any case corresponds to a carbon dioxide amount in the atmosphere which is considerably larger than the one that is naturally there. It is technically possible to burn coal and oil in such large amounts that the content of carbon dioxide in the atmosphere would be doubled or more. At the present rate of using fossil fuels it would take 200 to 250 years before such a doubling would occur, but already a two percent increase annually in the burning of fossil fuels implies that the carbon dioxide content of the air would be doubled within about 100 years and a five percent rate of increase implies that the doubling time is merely 50 to 60 years (see Figure 14). In these computations it has been assumed that the role of the sea as a sink for the increasing carbon dioxide in the air remains unchanged. Keeling (25) has, however, pointed out that in the future probably a smaller part of the emission will find its way into the sea because of the disturbance of the chemical equilibirum that is brought about by this flux of carbon dioxide into the sea. If this is correct the time for a doubling of the carbon dioxide content of the atmosphere is even less than indicated above.

Even if these computations are uncertain this picture of the future is sufficiently disturbing to question seriously if the use of fossil fuels in the world should be permitted to increase significantly above the present level. It is probable that the long-term environmental effects determine the degree to which fossil fuel may be used as an energy source and not that too limited amounts of oil and coal are available on earth. It should also be pointed out that possibly secondary effects, such as melting of the ice in the polar sea, have not been considered in the model computations referred to above. A temperature increase in the north polar region by several degrees, as the Manabe and Weatherald computations show, would no doubt markedly

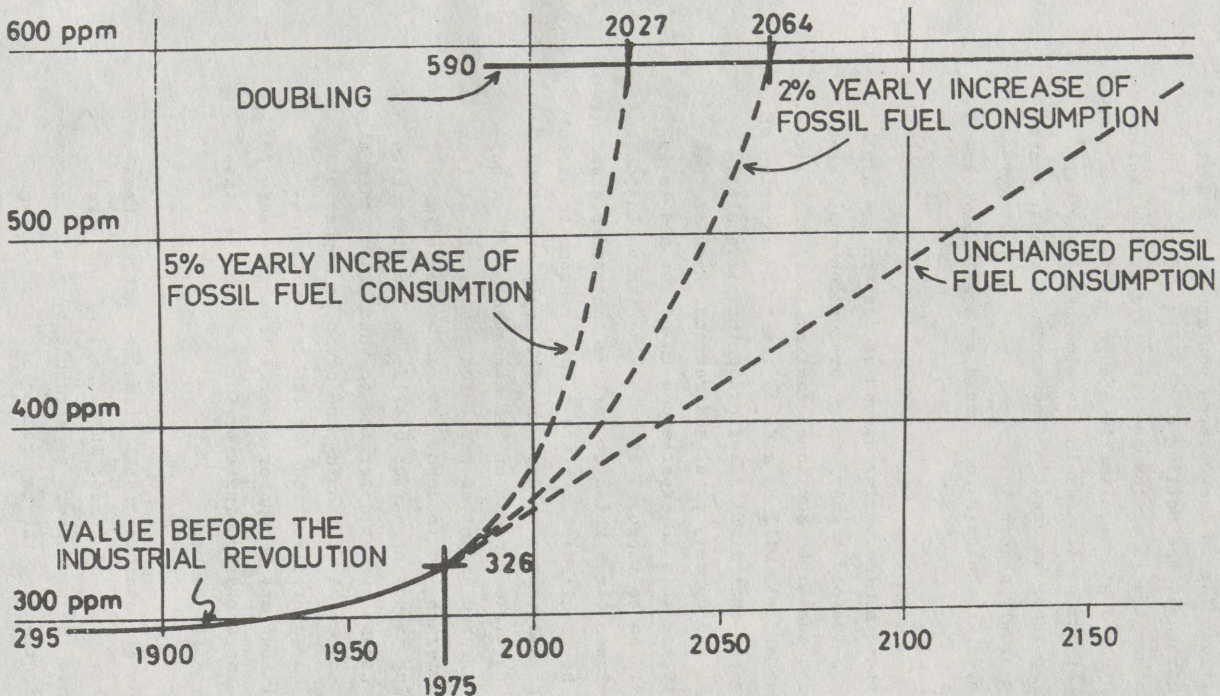


Figure 14. Computed changes in the amount carbon dioxide in the atmosphere assuming a) unchanged fossil fuel consumption, b) 2 % annual increase in the use of fossil fuel, c) 5 % annual increase in the use of fossil fuels. The computations have been made under the assumption of unchanging chemical conditions in the sea, which at a later stage probably is not a correct assumption.

change the conditions for an ice-covered sea around the north pole. On the other hand, the melting of the big ice sheet on Greenland and Antarctica is a slow process. It should be reiterated, however, that a global climatic change due to an increasing amount of carbon dioxide in the atmosphere may well be long-lasting, perhaps hundreds or thousands of years, since the sea can only slowly absorb this excess carbon dioxide from the atmosphere even if the emissions would be completely discontinued.

It is possible that the increasing amount of dust in the atmosphere caused by a tenfold higher energy production could also have global consequences. As mentioned earlier it is most likely, however, that efforts will be made to limit the emission of dust and other gases that might deteriorate the air quality within industrial and densely populated regions. Even if the local air quality, as this is experienced in cities and in industrial regions, can be improved by releasing the pollution into larger air volumes (from which it follows that smoke cleaning will not always be required) there are hardly reasons to expect that a tenfold higher energy production will imply a tenfold increase in the particle content of the atmosphere. It is possible that an increased amount of particles in the air at least partly might counteract the tendency towards warmer climate that an increasing amount of carbon dioxide in the atmosphere might cause. We cannot as yet determine to what extent this may be the case. In any event it should once again be emphasized that while the characteristic time for the return to pre-industrial conditions may be one or several thousand years for carbon dioxide, the corresponding time for dust in the atmosphere is merely a few weeks.

In the discussion of possible global climatic changes summarized above we have only discussed the effect of the direct heat emission into the atmosphere as a result of man's increasing energy production and the importance of carbon dioxide and particles in the atmosphere. There are, however, many other ways in which man may influence the climate and both the scientific literature and the newspapers contain many such theories. A closer study of the literature shows, however, that the scientists at present do not agree on the correctness of most of these. It is possible that some of them may be correct in principle, but massive research efforts and a long time will be required in order to clarify this and above all in order to estimate if they may be of quantitative importance. Against such a background it is important to emphasize that the statements that one finds in the press and elsewhere about clear interrelations between man's activities and climatic changes that lately have occurred cannot at present be accepted as sufficiently well documented. It is only by a global cooperation between scientists and countries that we can hope gradually to understand the interplay between the many mechanisms that are at work in the climatic system. But the very possibility that significant changes may take place within a time period of less than 100 years, maybe within 50 years, is an exceedingly important fact. Within another decade or two reality will most likely show how relevant these fears are. Even now due regard to such possibilities must be paid when planning our future energy supply, above all by retaining the utmost degree of flexibility.

8. Literature

(1) Inadvertant Climate Modification. Report of the Study of Man's Impact on Climate (SMIC). The Massachusetts Institute Press, Cambridge, Mass. USA, 1971.

(2) US National Academy of Sciences. Understanding climatic change, a programme for action. Report of the Panel on Climatic Variation to the US Committee for GARP, 1974.

(3) Report of the GARP Study Conference on "The Physical Basis of climate and climate modelling".World Meteorological Organization; International Council of Scientific Unions. Geneva 1975.

(4) Mitchell, J.M.: A preliminary evaluation of atmospheric pollution as a cause of the global temperature fluctuation of the past century. In Global effects of environmental pollution. Ed.F. Singer, 1970.

(5) Flohn, H.: History and intrasitivity of climate. Report from the International Study Conference on the physical basis of climate and climate modelling. ICSU/WMO, 1974.

(6) Bryson, R.A.: Climatic modification by air pollution, Polunin (Ed) The environmental future. London Macmillan XIV p. 134-174; 1972.

(7) Flohn, H.: Globale Energiebilanz und Klimaschwankungen. Reinisch Westfälische Akademie der Wissenschaften N 234, 1973. Westdeutscher Verlag.

(8) Schneider, S. and Dennett,R.D.: Climatic barriers to long term energy growth. Ambio, Vol 42, 1975.

(9) Manabe, S.: Cloudiness and the radiactive convective equilibirum. In "Global effects of environmental pollution".Ed.F. Singer, 1970.

(10) Ekdahl, C.A. and Keeling, C.D. In "Carbon and the Biosphere", US Atomic Energy Commission, 1973.

(11) Bolin, B. and Bishof, W.: Variations of the carbon dioxide content of the atmosphere in the northern hemisphere. Tellus, Vol 22, 1970.

(12) Manabe, S. and Wetherald, R.: The effects of doubling the CO_2 concentration on the climate of a general circulation model (GFDL/NOAA. Princeton NJ), 1974.

(13) Crutzen, P.: Estimates of possible variations in total ozone due to natural causes and human activities. Ambio, Vol 3, No 6, 1974.

(14) Mitchell, J.M.: A preliminary evaluation of atmospheric pollution as a cause of the global temperature fluctuation of the past century. In "Global effects of environmental pollution". Ed. F. Singer, 1970

(15) Rasool, S.I. and Schneider, S.H., Atmospheric carbon dioxide and aerosols: Effects of large increases on global climate Science, Vol 173, No 3992 p. 138, 1971.
Charlson, R.J. et al: Aerosol concentrations: Effects on planetary temperatures. Science, Vol 175, No 4017, p. 95, 1972.

(16) Newell, R.E.: Stratospheric temperature change from the Mt Agung volcanic eruption of 1963. J. Atm.Sc. Vol 27, 1970.

(17) Charney, J.: Dynamics of deserts and drought in the Sahel. Report to the Study Conference on the physical basis of climate and climate modelling WMO/ICSU, 1975.

(18) Kukla, G.J. and Kukla, H.J., Science 183, 1974.

(19) Budyko, M.I.: The future climate. EOS, American Geophysical Union. Vol 53, No 10, 1972.

(20) Calder, N.: The weather machine, BBC, 1974.

(21) A. McIntyre et al: The glacial north Atlantic 18000 years ago. A CLIMAP Reconstruction, Geological Society of America, Special Paper, 1974.

(22) Namias, J.: Macroscale variations in sea-surface temperatures in the North Pacific. J. Geoph. Res. Vol 75, No 3, 1970.

(23) Worthington, L.V.: Genesis and evolution of water masses. Meteorological Monographes, American Meteorological Society, Vol 8, No 30, 1968.

(24) Landsberg, H. and Machta, L.: Anthropogenic pollution of the atmosphere: Whereto? Ambio Vol 3, No 3-4, 1974.

(25) Keeling, C.D.: The carbon dioxide cycle: Reservoir models to depict the exchange of atmospheric carbon dioxide with the oceans and land plants. In "Chemistry of the lower atmosphere". Ed. S.I. Rasool, Plenum Press, New York-London, 1973

Energy and Society

Conceptual outline introducing
a future study.

Secretariat for Future Studies.
Sweden.

THE SECRETARIAT FOR
FUTURE STUDIES

December 10, 1975

ENERGY AND SOCIETY

Conceptual outline
introducing
a future study

"Problems worthy of attack
prove their worth by hitting
back"

Piet Hein

Contents

The purpose of this paper is to describe the aims of "Energy and Society", a recently commenced future study.

One of the tasks of future studies is to search for new ideas and test new concepts. It would therefore be a mistake to draw up strictly defined terms of reference for the work. On the other hand, the studies must deal with questions which have relevence for political problems and decision-making. Some guidelines are needed for the work as well as a project organization which will permit the testing of the relevence of the studies on a continuing basis.

The program has been prepared by the members of the project team after consultation with the Secretariat for Future Studies and the ministerial reference group (cf Appendix).

One reason for publishing a program for the study at this time is the great interest in the project demonstrated in various quarters. Since an important aim of the study is to broaden and deepen the public debate, we hope this paper will also be a useful contribution.

Energy and society: a future study of the relationship between the future structure of Swedish society and the need for energy

0. Preface

The secretariat for Future Studies intends to carry out a future study in the energy field.

The Secretariat for Future Studies is sponsor for three other future studies, viz:

- Sweden's International Conditions
- Working Life in the Future
- Resources and Raw Materials

Naturally, there are strong connections between these studies and the energy study. We shall also be cooperating on a number of substudies and projects. A brief presentation of the Secretariat, its working methods and the four future studies is given in the report, "Programme for Future Studies in Sweden" (1), which may be ordered from the Secretariat.

The object of this report is to discuss in greater detail the design of the energy study, the principal areas covered and the forms for its presentation.

Preparatory discussions and certain pilot studies have been taking place since the spring of 1974. Among those brought into these preliminaries have been the Swedish National Defence Research Institute and the Interdisciplinary Research Center at the University of Göteborg.

A great deal of investigative work has been carried out or started in the energy field principally in connection with the Government bill on energy policy in the spring of 1975. Special mention in this connection should go to the newly established Energy Research and Development Commission (under the Ministry of Industry) and to the Energy Research Institute which is to be linked with the Swedish Academy of Sciences. Universities and professional schools have also shown rapidly growing interest in energy problems. And many government agencies are now devoting great attention to the energy sphere.

All this, of course, is important in the design of our future study. It is to be seen as an adjunct to the above and not as a duplication of research effort. The present paper will elaborate on the special profile that we want our project to have.

The document roughly consists of two parts. The first part includes section 1-4 and contains a general discussion about future studies, why a future study is done in the energy field and a description of the research design. The second part (section 2) is not programme oriented and is primarily intended as an illustration of how we have been thinking thus far. We have included it partly because it contains a number of basic facts and statements we think are important and partly because it is a general ambition in future studies to show even "in between results". We are of course grateful for comments, criticism and ideas regarding the different sections.

This paper was written by the project team assigned to carry out the study, in collaboration with the Secretariat for Future Studies. Viewpoints and criticism have come from the members of the interministerial reference group, whose chairman is Mr. Erik Grafström, advisor to the Prime Minister on energy policy.

The project team and the Secretariat are alone responsible for the final wording of this report.

1. General remarks on future studies

Future studies are a new and untried activity in Sweden. It follows that the forms, the working methods or the drawing of boundary lines vis-a-vis other activities are not clearly crystallized. These will have to emerge as and when the experiences are gathered.

For that matter, too, it is not yet possible to say anything definite about what is feasible, about what contributions the future studies can render to the national life in Sweden. Here again time will have to show. On the other hand one can discern some expectations that various quarters are putting into future studies - expectations which taken together obviously cannot be satisfied wholly and completely.

One such expection is that someone must be held especially responsible for monitoring the long-term development: to study and call attention to the ultimate consequence of decisions that are taken today, and also to come up with his own proposals and alternatives on how the long-ranging consequences can be considered in policy making.

According to another expectation, future studies are supposed to cut across the sectoral boundaries in today's decision-making machinery. In our society the organizational structures for planning, decision-making and implementation are based on what is usually called "sectorized" spans of responsibility. Every ministry, government agency etc has its particular domain to look after. This is necessary in order to effectively administer the different activities. The responsibility for making sure that the various subdivisions really cover all essential problems rests with those who define the division of labour in the public sector, i.e. in the final analysis with Parliament and Cabinet. Moreover, intersectorial studies are being pursued in the Government Offices; cases in point are the Division for Long-range Economic Forecasting in the Ministry of Finance and the national physical planning.

Problems with long-term consequences often have the peculiarity that they cannot be dealt with within the framework of the spans of responsibility that primarily has been set for short- and medium-term problems (organizational theory literature indicates that this for the efficiency necessary division of work sometimes add to the occurence of long-term problems). In other words, the role of future studies would be to aim at assimilating a philosophy especially well suited to this type of problem.

Yet another hope is that the future studies will encourage the universities and professional schools in particular to do more of their research on an "interdisciplinary" basis. To be sure, the demand for more interdisciplinarity has amassed steamrolling force in recent years, and as such should probably be seen as more of a relatively inarticulate reaction against the oft-arbitrary boundaries set in the existing subject classification rather than as a fixed and finished mode of working. However, a programme of studies oriented to long-term problems should be able to foster an interdisciplinary mode of working, especially by setting good examples and offering encouragement but in part, too, by subcontracting for specific assignments.

Lastly, there is an expectation that future studies will help to broaden and deepen the democratic process, above all by presenting trends and alternatives in explicit and concrete scenarios. The intense debate on energy policy during the last year suggests the presence of keen interest in many quarters and suggests good prospects for an all-round discussion. It can be guessed that the debate is chiefly prevented from gathering momentum by the limited supply of basic facts, of pedagogical descriptions of what the problems look like and how different solutions can be realized. Here the mission for future studies will be to work as openly as possible and to furnish material to participants in the public debate - political parties, popular movements, educational associations and the mass media.

A question that one always confronts in a future study to a greater or lesser degree is what the "problem" actually looks like. The sectoral divisions of the civil service, the specialized bent of the sciences and the often near-term perspectives in the current debate influence our ways of posing problems and searching alternatives. Just as a society has a physical "legacy" in the form of buildings, roads and the like, one can speak of a "mental legacy" of notions about the real world. One function for a future study can be to subject such notions to critical scrutiny: to portray and analyze "mental images" other than the ones now prevalent.

The expectations are many and almost surely unrealistically high. Future studies work in a borderland that is narrowly confined, rough going and poorly charted all at once. Be that as it may, our remarks can still represent some direction for our ambitions.

Summing up, we can say that the future studies have three "faces": one turned towards the decision-makers at different levels, one turned towards researchers at different institutions, and one turned toward the public debate. The working method and the presentation forms we shall follow reflect these three faces and will be expounded on at greater length in section 4 below.

2. The energy debate and the decision of energy policy

Energy policy has become the subject of an extraordinarily intense debate in the Swedish community. Considered from the international aspect, this debate is probably unique. It has made more groups of people involved than in other countries and brought a diversity of problem formulations into its fold. More technical discussions about different energy supply systems - based on fossil fuels, nuclear power, reversable sources and so on - have been based on a broad discussion about employment, economic growth, the substance of welfare and its distribution, life styles, our dependence on the surrounding world, the connection between our standard of living and poverty in developing countries etc.

It follows that the debate on energy policy has been pervasive and so broad as to take on an element of vicarious debate.

Many of the most important questions have therefore been left without an answer. The connections between the development of the Swedish society and the future need for energy have been seen, apprehended and challanged, but have not been thorougly clarified.

That has also been one of the reasons for the direction imparted to the 1975 decision on energy policy. This decision has stressed the need to preserve freedom of action, together with measures deliberately aimed at bringing out even more inputs on which to rest coming decisions in this field. It has also emphasized that energy policy has been changed from an almost exclusive concern with supply problems to a much broader of energy supply and use; at the same time, the inclusion of a resource management policy has required a systematic expansion of the leadership and control of the public sector.

The Government bill also stressed the significance of the time perspective and the differences between short- and long-term. Our goal is to maintain the employment, welfare, macroeconomic equilibrium, etc but at the same time reduce the increase in use of energy. Slamming on the brakes too hard can accelerate such processes as structural change (in many industrial sectors the small firms with old plants use up comparatively more energy and are therefore first hit by e.g. price increases) and lead to different crises and disequilibria. Seen in a longer term the freedom of action is greater, but this will consequently be limited by the fact that changes which are intrinsically desirable must not be pushed so fast as to make these disequilibria surface. Hence there are limits to the pace of change that can be accepted at any one point in time. None the less, the desire to work consciously on behalf of development alternatives which go against the historic trends will tighten the demands for leadership from the Government.

The Government Bill also states that a new review of energy policy is to be made in 1978. This future study on energy will form one of the inputs for this review and, among other things, will be called upon to help make sure that as many as possible of the "broad" issues are treated.

3. Why a future study on energy?

The present study is only one of many projects which seek to produce inputs for future energy policy. Many studies have already been completed at home and abroad, and even more have been set in train during the past two years (see e.g. (2) for a run-through). Hence there are reasons for mentioning a few words about how we look at the role of the future study on energy and the boundary that marks it off from other studies.

A rough-and-ready characterization of the international research material indicates that it is preponderantly concerned with the problems of energy supply - different energy sources, environmental problems posed by energy production, methods and models for allocating resources in the expansion of such production, etc. The remaining material is chiefly about methods of energy conservation in the economy, such as different ways of insulating houses, producing automobiles that are using less petrol, installing less energy-intensive processes in industry, etc.

Only a very small part of the more systematic studies deals with the wide problems that have been brought up in the Swedish debate, namely energy's role in society and its significance for welfare, employmnet and so on.

This mirrors a bias in what we know about energy's role in society that also affects our "mental image" of the energy problem. Certainly there are quite a few sensible reasons for the present distribution of the research and investigative work.

It shows how the present allocation of responsibility for the management of energy resources in the society has been carried on.

The process of energy husbandry aims at keeping the equation

supply of energy = usage of energy

in balance (ex ante) at every point in time. Various methods are used to maintain this balance, among them pricing, licensing legislation and regulations on rates and charges. So far the government authorities have performed two roles in this connection: first, to make sure that these balancing mechanisms are upheld; and second, to assume responsibility for planning and controlling the supply of energy (the left-hand term in the equation above), especially the supply of electricity. In this sense energy policy has been supply-oriented..

This direction and delimitation has been natural in a time of stable (or steadily falling) energy prices, above all for oil since the early 1950s.

For various reasons, which are chiefly bound up with environmental effects, an increasing uncertainty both about the supply and cost of oil, the feasibility of developing alternatives to oil, the foreign dependence and the finite nature of natural resources, we have now entered a situation which makes it necessary to more actively promote saving of energy.

This means that the supply-oriented energy policy must be widened into one that is husbandry-oriented. The Government at different levels must take a clear responsibility also for actions on the demand side of the equation above and keep the rate of increase of energy use within reasonable bounds. In other words, we must consciously act upon and change those mechanisms which balance the equation above.

This shift of emphasis signifies that new trade-off problems and goal conflicts are cropping up on the political scene - problems and conflicts that used to be handled more or less automatically by the adjustment mechanisms which earlier existed.

Widening the sphere of decision-making for energy policy will make it necessary to broaden and deepen our knowledge of energy's role in society. We shall have to try to study how energy use depends on distributive effects, the structure and development of residential accomodations and the trend, extent and geographic spread of industrial production. Then it is important to illustrate the connections and the conflicts between the goals set for energy policy and other acts of public policy.

The impact of the needs to deepen our knowledge has been to shatter the frame encompassing the traditional energy forecasting work, even when this is conducted with the aid of more or less sophisticated econometric methods. It has also shattered the frame for what can be studied, with normal quality criteria, on the basis of available theory and empiricism. In other words, we find ourselves in a twilight zone between the established sciences and the unabashed speculations. It is this twilight zone that will come under the purview of our future study.

We think it is necessary to start the project by getting thorough information about the energy's significance for social progress and try to specify the complex features in the energy supply system. It is, for instance, obvious that it is not the energy usage per se - expressed in e.g. TWh - that is "the problem" but a number of not intended environmental effects, using up limited global resources, national dependence etc that are difficult to solve. It is the negative effects that should be reduced. Thus the energy policy means a consideration of negative and positive effects we can achieve by having an extensive quantity of energy.

One of the more basic factors behind the need for a broader energy policy, is that two time perspectives gradually are approaching each other.

The first time perspective is the time constant of <u>the present</u> system for energy production. The energy policy in the 1970's and 1980's is based on fossil fuels and uranium (the relative importance of water power is being reduced). With the present technology for extracting oil, reactors etc the estimated resources can form the base for a continuing global expansion in the role of energy usage during somewhere between 20-40 years. The uncertainty is of course great and depends on the increase rate in the energy usage. The increase in turn depends on the price etc. But it should be noticed that the Swedish Government is the only one that have spoken of "Zero-Energy--Growth". The competition for oil and uranium could possibly get tougher already in the 1990's.

The second time perspective is the time it will take to develop and fully introduce new alternatives - e.g. the breeder reactor - and markedly have an effect on the energy usage through e.g. urban and regional planning etc. We are for different reasons probably increasing the inertia of the systems, and the time horizon in the physical urban and regional planning is already getting close to the energy production's. The same is of course true for the time it takes to change institutional systems like organizations etc. To understand this inertia is fundamental for the possibility to obtain freedom of choice.

In the light of these facts we can formulate the purpose of the future study in the following points.

1. Collect information and knowledge about the different aspects of our future energy supply system that are restricting our freedom of choice. What could be the influence on our environment, the size of global resources of fossil fuels and uranium, organizational consequences of alternative energy supply systems etc.

2. Formulate, specify and illustrate conflicts between different societal goals such as secured employment, increased welfare, national independence and so on, and demands that (from 1 above) speaks for a restriction of the energy usage.

3. Point out conflicts and connections between 1) and 2) that we think are essential but don't have the capacity to discuss and try to initiate deeper studies and research in different fields.

4. Try to understand and explain the facts in the social change that determines the demand for energy in a longer time perspective and discuss how and to what extent these facts can be influenced as well.

A few things should be pointed out. Number one, that we to a large extent will be working with existing material and studies. It is not our intention to contribute to the development of different scientific institutions. Number two, we are of course going to work closely with other committees and project groups, especially the recently started Energy Research and Development Commission. Number three, that our study is a complement to what is being done elsewhere. Number four, that it is our aim to try to make a synthesis that is necessary to understand the long-term problem. Number five, finally, that we dont't know how far we can get in these syn-thesizing ambitions.

For a researcher it is often emotionally satisfying to penetrate one question and become an "expert". To ab-stain from this consciouly and instead try to "work on a broad front", see connections, make a synthesis etc is to expose oneself to the risk of not learning anything methodically and expose oneself to criticism from all the people how know much more within a spe-cific field. Unquestionably this is emotionally more trying. At the same time it is necessary to try - a vivid democratic debate about the future possibilities and risks is inconceivable if simplifications and summa-ries are not allowed (it goes without saying that the gap between simplifying and oversimplifying is narrow).

The question is therefore how this primarily should be done, that is what type of method should be used to achieve point four in the programme above. We intend to start by systematically studying the energy usage from different angles, more or less like looking at a house from the outside through different windows. The economist through his window distinguishing certain characteristics, a geographer through his, a social scientist through his and a political scientist through his.

The same goes for administrative persons. Different government agencies look at the same reality differently and they often draw different conclusions about the appropriate measures to take.

By systematically studying the management of energy resources from different angles we think we can build up a "frame of reference" that tells us what the problem (problems) looks like and get more precise hypotheses that tell us what prime mover underlies the development.

We have preliminary discussed the components that should be included in such a "frame of reference". This is set forth in section 5 below. However, before then we shall discuss how we have planned the study. With this disposition we hope to avoid that section 5 is read programatically - that is like a statement of what we intend to do. That is not the case, it is an attempt to try to "think aloud" in the initial stage of a study that wants to have a continuous dialogue with its readers.

4. Research design

Although the research design has yet to be specified in detail, this should follow as a natural consequence of the remarks made in previous sections.

The study will be called upon to promote understanding of the long-term questions. Other contributions will come from ongoing official investigations and further initiatives that the Government has taken, e.g. the heavy commitment to the recently formed commission, Energy Research and Development Commission. Seen overall, these activities ought to add new increments of knowledge about the long-term perspective by the time energy policy is due for its next review.

This future study has been given the name, "Energy and Society". In selecting that title we have wished to stress that our primary task will be to study energy's role in society, while no more than secondary weight will attach to the more restricted but more frequently broached matters concerned with the production of energy.

It is practical to speak of three phases in the work:

The orientation phase

It is our intention to make a survey and cover all the points in the programme. The result is intended to be a specification of the societal goals of great significance for our future use of energy. It will as well be the basis of a more rough estimation of the areas to be considered. Here we will also discuss our choice of methodology for the synthesis.

The analysis phase

Here we intend to do a thorough investigation of the questions selected in phase 1.

The synthesis phase

It is our intention to make a summary of possible alternatives for future development. The first phase is estimated to be completed during the spring of 1976. We will work simultaneously on phase 2 and 3 right up to the completion of the project until the turn of the year 1977/78.

Below we will give details about how we today look at these phases. Naturally phase I has the most clear-cut features.

The orientation phase is aiming at giving a specification of the problems. We have already started going through a number of questions that have been taken up in the Swedish energy debate and at the moment we are trying to specify these questions. A great deal of the actual work has been commissioned to different researchers, individually or as a team. Reports delivered can sometimes be published directly, sometimes they are going to be revised by the project group.

We have selected to work from the following angles.

The energy usage looked at from an economical-political perspective. Under this headline we will discuss three subheadings, namely the importance of the energy supply for economic growth, employment and the consequences of different alternatives on the production of goods and services. We have collected a fairly wide amount of background material and even investigated existing theories in this field. We are now putting together the material and we hope to publish two reports on the subject in the near future. We are here working with the Commission of Employment and the Energy Research and Development Commission.

The energy usage looked at from a socio-political perspective. Foreign studies clearly show that there are great differences between population groups even regarding the use of energy. We think it is important to study these differences more closely even in Sweden. Such studies can possibly be extended to include social anthropological and social phychological aspects. By those means we will try to find methods to describe the importance of different "life styles". As an example we can take a surbuban family with a single-family house and two cars compared to e.g. a city family living in an apartment without a car. Here we also should discuss needs (a question that is more or less taboo in today's science but is difficult to leave out).

An interesting question could be the factors that determine the interest and motivation to save energy and other resources in housing areas and at work. It seems natural to think that a high motivation must be based on participation and co-responsibility. Certain data indicates this. Today we are not prepared to specify how far we can get in this direction.

The energy usage looked at from an environmental perspective. There is no doubt that the environmental consequences of energy usage are restricting our future freedom of choice. Here it is essential to make a distinction between and take into consideration both the energy demand that is generated by a desire to improve our inner and outer environment (the energy cost for mechanizing heavy work, construct and maintain a sewage treatment plant etc) and the environmental effects originating from our high energy usage (accidification, cancerous substances in fossil fuels, the influence on the global climate of a continued use of fossil fuels etc). We have collected material about the first question, that is the energy requirements for steps to protect the outer and inner environment, and we hope to publish reports in these questions shortly. The influence of the energy usage on the global climate has been discussed in a report by Professor Bert Bohlin (12). Furthermore, we intend to make a summary of the material about the environmental effects of energy production. We also have commissioned a project to illustrate the conclusions that can be drawn for the energy husbandry by a consistent ecological approach to the energy questions. Such questions will also be discussed jointly by the projects and within the Secretariat for Future Studies.

The energy usage looked at from a geographical perspective. It is obvious that the spatial distribution of the production and the residential areas play an important role for the use of energy. This is not only expressed in the need for transportation but also in the need for floor space for different purposes (see also point X in section 5 below). Consequently we think it is essential (more essential than most other areas) to try to understand both what the links between the spatial distribution and the use of energy look like and even get information about the driving force behind the changes in the spatial distribution. The historical dimension is therefore essential. We are here working with the ethnogeographical institution at the University of Lund. It is too early to have an opinion about where this angle of approach can take us.

The energy usage looked at from an organizational perspective. A great number of complicated questions can be grouped into this title. It has e.g. been stated that the choice of energy supply system can have effects on the degree of centralization/decentralization even in other sections of the society. A somewhat related question is to what extent the organizational and institutional characteristics of today's and yesterday's energy supply systems will effect the alternative we choose for our future energy supply system. The literature about organizational behaviour that can be of interest in this connection is very extensive. At the moment we think this angle of approach is of vital importance for understanding the possibilities of implementing possible development alternatives. The issues are similar to those discussed in political science, financial history, sociology of law etc, but is not in the same way covered by existing commissions and government agencies. We have started collecting an extensive amount of material.

The energy usage looked at from a foreign policy perspective. The importance of energy supply systems in the world has increased in the international power struggle. From our point of view two aspects seem to be of interest, namely on the one hand to understand the developing countries' situation in this respect and on the other hand how the energy policy we have is effected by our dependence of the surrounding world. In order to understand the question of the developing countries we intend to read what is written today about the energy supply's importance for the development achievements in the developing countries and the conclusions we can draw from there regarding different designs of a Swedish energy policy. An interesting hypothesis is the consequences, a Swedish energy policy loyal to the developing countries, would have on our relations with the developed countries. On the whole it is necessary to try to sort out the concepts regarding the connections between Swedish energy policy and our international dependence. So far these questions have mostly been discussed in terms of supply of energy, raw materials (oil, uranium etc) the importance of oil imports on our balance of payments etc. It might be interesting to study our dependence on the surrounding world even on the other side of the equation of balance, e.g. to what extent energy saving measures conflict with international agreements etc. For instance, to what extent can Sweden have its own policy regarding the energy consumption for automobiles. The consequences of our extensive import and export belong here too of course.

It is not likely that we can undertake deeper studies of these questions, but we think that also a systematic discussion of these questions together with certain basic facts can be of value.

In this field it is natural for us to cooperate with the future study "Sweden in the World Society" and the "Energy Research and Development Commission".

All these subjects are very comprehensive. Our aim is limited to finding out <u>what is known today</u> within each domain about the energy policy's importance for political goals for the field in question. From these surveys it should be possible to estimate possible alternatives and then give priority to a few. We are also hoping that a number of problems we have indentified but not been able to consider can be forwarded to other institutions for deeper studies.

<u>The analysis phase</u> is aiming at deeper studies of the fields we have selected after the orientation phase. We have certain ideas about which those fields can be. A specific problem is to find or develop a method. Many

analyses of the energy usage patterns have been made already, in connection with different studies of the energy policy. Analyses of the usage within different industrial branches, means of transportation, residential forms etc have been stressed. That has been and is principally still enough for prognoses. We will try a different approach and try to consistently study the energy usage from the consumer's perspective.

We think this is necessary in order to be able to give development alternatives which at the same time are credible.

The synthesis phase. We think it is adequate to synthesize the analysis and try to outline future development alternatives based e.g. om different amounts of energy. As already mentioned is it necessary to find a method or an approach. The synthesis phase will therefore start with going through the alternatives used in studies of a similar nature.

For that purpose, of course, we must have some grasp of the different demands these trends will put on the energy production, both as regards the total amount of energy and its distribution by grades such as fuel and electricity. As concerns state-ot-the-art surveys in the energy production field, we think that by using already available domestic and foreign sources it can give us all the essential material we need.

Further, an important part of the third phase will be to study institutional and administrative prerequisites for the different development alternatives. We shall put a fairly good deal of work into trying to understand those demands on organization and administration which the different alternatives impose.

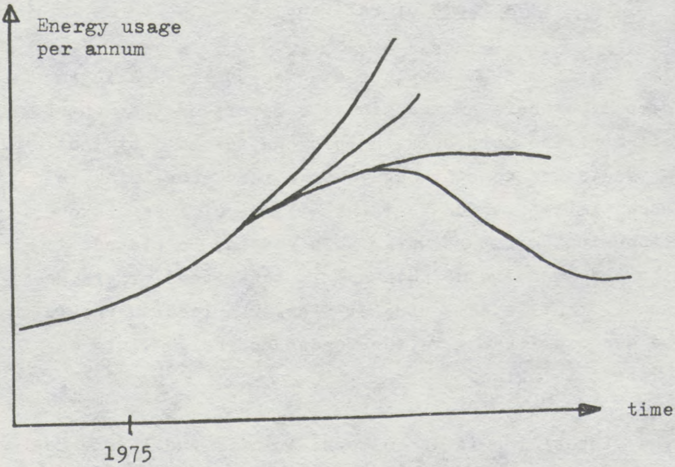
5. On outlooks and attempts - some building stones in a frame of reference

It is said that the future studies shall work in an open atmosphere and continously report on the mental efforts. The purpose with this chapter is just that - - to discuss a few thoughts we already now think is essential and which we think will be of great importance in the future work. This chapter is placed at the end since we do not want it to be read programmaticly, that is as a project plan. The reading should be associative - give the reader an insight into our present thinking.

The disposition is as follows: Point I and II are dealing with the energy policy problems in general. We are stressing the necessity for freedom of choice and the levelling between the energy supply's negative effects on our environment, depletion of natural resources, foreign dependence and so on and the advantage of having an abundant supply of energy. Points III-VII discuss different goal conflicts and the interaction between energy supply and the economy in a wide sense. Points VIII-XII finally consist of a number of observations which we to-day think can be of importance for a deeper analysis of the elements that determine the future increase in the energy usage.

Something about the energy policy problems (points I, II)

I. <u>This is more than a matter of energy alone</u>. As a nation we can choose a strategy for the energy use within limits which, though narrow in the short term, will become wider and wider the farther we look ahead (when the legacy gradually diminishes).

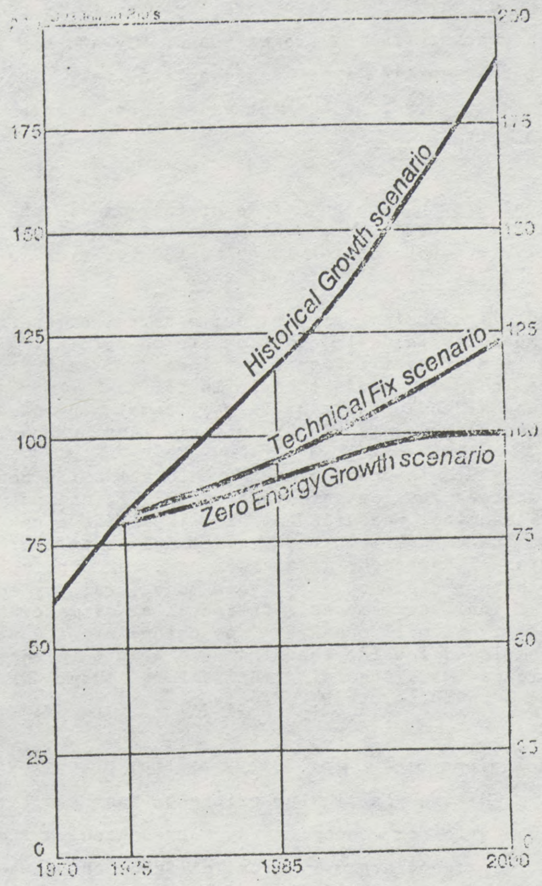


But what do the different alternatives signify? How do our efforts to meet political goals such as increased welfare, increased employment and increased social equality effect our "energy takeout"? The question of how energy and social change depend upon and condition one another is the fundamental one that must be elucidated.

Approaches to such studies exist. For instance, various reports and a summary have emanated from the Energy Policy Project sponsored by the Ford Foundation (3).

25

The following diagram is taken from the Ford study.



Ford scenarios require increased production of domestic oil.

We can observe th. ·· ese development alternatives diverge. Society m :t ake on different characteristics depending on whic ·d we choose to travel. The question is which characteristics are effected, why and how this happens, both qualitatively and quantitatively. The Ford study tries to describe the three development alternatives as follows:

Historical Growth denotes a rate of increase in energy usage by 3.5 % per annum. Such a rate of growth would require very heavy capital investment, give rise to enormous environmental effects, etc.

Technical Fix denotes carrying out a series of energy-saving measures which in addition are commercially profitable at prevailing energy prices. The rate of increase in energy usage then falls off to 2 % per annum but GNP and employment largely remain the same. Environmental problems will be visibly less serious.

Zero Energy Growth denotes taking, alongside the conservation measures that are taken under TF, not only further technical measures but also imparting a new twist to the consumption pattern. Examples: an increased production of services, greater emphasis on public transportation in preference to private modes, railway instead of truck, increased emphasis on recycling of materials. Thus relatively mild measures ("no change of life styles") can be employed towards reaching zero growth in energy usage around 1990. According to the Ford study, GNP and employment would hardly be effected.

The conclusions of the Ford study are not uncontroversial in the United States. Particular criticism has been levelled at the scenario for economic growth presented in the last alternative. There are very great differences between Sweden and the U.S. and one should be wary about slavishly translating the conclusions of this American study into Swedish conditions. None the less, the study does illustrate how different processes of special change can be described. At the same time attention can be called to the limited array of characteristics which the Ford study takes up, viz:

- energy usage
- economic growth
- employment
- capital requirements
- environmental problems
- production pattern

For Swedish conditions it would also be desirable to shed light on other characteristics, among them the working environment, the distribution of welfare and our dependence on other countries. One can say that the future study ought to illuminate our freedom of action. It is only by attacking the nettle of problems like these that we can avoid becoming captives of the energy system.

II. Energy is uninteresting "per se". Why is energy a problem? Is the problem one of energy? Or is it something else? Strictly speaking energy is an asset, a resource from which we benefit and have benefitted. Our present prosperity would not have been possible but for an abundant supply of energy. So even if this fact is self-evident, it must be pointed out that the advantages of holding down on energy use must be weighed against the advantages that stand to be gained from an abundant supply of energy.

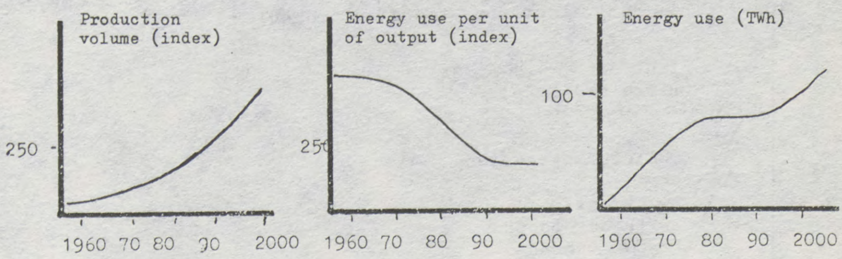
This line of reasoning becomes less self-evident once we take a closer look at different energy sources (oil, coal, nuclear power, waterpower, sun, wind, etc) for their pros and cons. Obviously, the consequences for environment, foreign dependence, depletion of finite natural resources etc will be quite different if we heat our homes with oil, electricity from nuclear power, electricity from hydropower, the sun (via solar panels), the wind (via wind power stations) and so on. Even the time perspective differ markedly. It is these consequences that have to be weighed against the good we can do with the energy source - in spite of all, the number of kilowatt hours we get out is of secondary importance. Hence we must be wary when we talk about such things as energy requirements, zero energy growth and low-energy or high-energy societies. After all, whether or not we are going to opt for zero growth and the level to which we should adhere will have to depend on which energy sources we elect to use and what their advantages and drawbacks are.

III. Production volume and specific consumption. How can a development alternative for energy usage be analyzed? The energy used up in any one industrial sector is determined by two factors:

- the volume of production in the specific industry, i.e. how much is produced
- the energy use per unit of output

The two left-hand diagrams, based on data compiled by the Royal Commission on Energy Forecasts (4), show how both factors are assumed to develop for the paper and pulp industry.

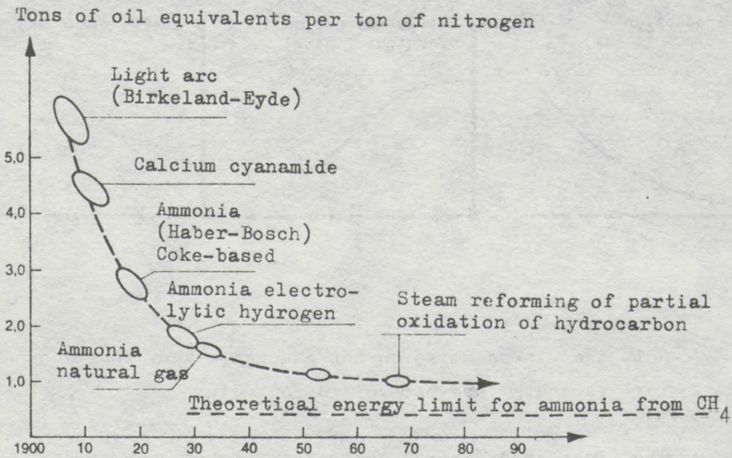
29



Note that the commission has assumed a very sharp downturn in energy use per unit of output.

The right-hand diagram shows the total energy used up in the pulp industry. Energy usage increases at a slowly tapering rate as new technology is adopted. But towards the end of the period it starts surging again, since the rate of increase in production volume remains unchanged while the specific usage is no longer diminishing.

Presumably, different technical measures can be taken to make the intermediate curve, i.e. the energy usage per unit of output, decrease faster. Energy usage for the industry as a whole then moves more slowly. But there is a limit which advancing technology cannot exceed, and that is the strictly physical quantum of energy needed to make the product in question. The diagram below shows this development over a longer time perspective for manufacture of fertilizers. It makes quite plain how the theoretical limit has been gradually approached.



Most branches of industry have a long way to go before they reach these limits - this is especially true of the energy-intensive industries such as iron and steel, pulp and paper, etc.

But there is no doubt that energy-saving investments seen over time will not suffice to push the rate of increase in energy usage down to zero and keep it there. The direction and extent of production itself must be discussed.

IV. Direction and extent of production and consumption. As a starting point for the discussion we can take the forecasts made by the Royal Commission on Energy Forecasts, EPU, (4) for industrial production. Set out in the table below is that industry-by-industry increase in production volume which corresponds to EPU's higher alternative, i.e. an increase in energy usage from 370 to 910 TWh (1970-2000).

Industry	Prod increase 1970-2000 (1970=100)
mining	550
pulp, paper	476
chemicals	870
primary metals	614
engineering	690
all industries	500
Passenger cars	197
single-family house	146
flats	116
shops and stores	113
schools	127
hospitals	124

This society can be described as a society where the industrial production has gone up steeply (five times), the number of automobiles has doubled, new single-family houses are being built at a rate three times that for multiple-family houses etc.

It stands to reason that such forecasts trigger off a great many questions. What are we going to do with nine times as many plastic products in the year 2000? Seven times as much metal product output? How will those societies function that are based on single-family dwellings and the private motorcar as the dominating way of transportation.

Even if such questions are unfamiliar and hard to answer, we must still try to start a discussion about them. One cannot discuss energy policy for the long term without having some opinion, whether explicitly stated or not, about what is going to be produced in the society.

But the discussion must not be simplistic. One of the factors that have to be taken into account is the employment. There is no reason to assume that labour productivity will not increase in the future even if there is reason to believe that the rate of increase is going to be slower. Fewer and fewer working hours will be needed to produce e.g. an automobile or a refrigerator in the future.

So if we want to preserve the work force in industry at a certain level, we must see to it that its output keeps increasing all along. With that industry's total energy usage will presumably increase as well. Thus here we have a clear-cut relationship between energy usage, industrial production and total number of employed in industry.

Imports and exports comprise another factor to consider. Sweden is far from being an isolated island - our economy is built around native raw materials, most notably timber and iron ore, and presumably the goods we export incorporate more energy than the goods we import. If we were to change the structure of the Swedish economy - - for instance, by producing more products with a higher value-added component - we would do no more than change the international division of labour. If we choose to import our aluminium from other countries instead of making it in our own smelters, this of course does not mean that we Swedes will be using up less energy overall.

Therefore we must not only look at Swedish production but also on Swedish consumption of goods and services. Influence must be brought to bear on both these areas if we are going to be able to control the total amount of energy we use up, whether that is done inside or outside the country's frontiers.

Let us now look at the total consumtion of goods and services. We use energy in two stages, direct and indirect. Direct use takes the form of petrol for the car, fuel for the house, electricity for the TV set and kitchen range, etc. The indirect stage is represented by the energy that goes into making the car and the TV set, building the house, producing and distributing the food etc.

The following breakdown of energy use holds for Great Britain and the United States as a very rough approximation:

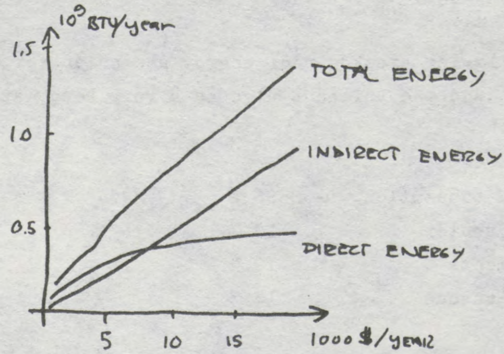
private conumption	66 %
public sector	10 %
investments	10 %
miscellaneous	14 %

Although no such proportions have yet been figured out for Sweden, it would appear that private consumption works out at a lower figure and public consumption at a somewhat higher figure. Then, too, Sweden is probably a net exporter of energy bound in goods (we have not included the import of energy raw materials).

If anything, tables like the one above tend to underestimate the role of private consumption. For instance, a not inessential part of what the public sector does is directly dependent on private consumption - thus roadbuilding is a direct consequence of private motoring.

V. Who consumes energy? It will not suffice to study what is consumed; we must also go into who does the consuming. There is a patent lack of figures and particulars under this head, but with the aid of data from the U.S. and Great Britain as well as certain fragments from Sweden we can nevertheless form a picture which ought to be accurate, at least in rough outline.

The following diagram is based on American statistics (5).



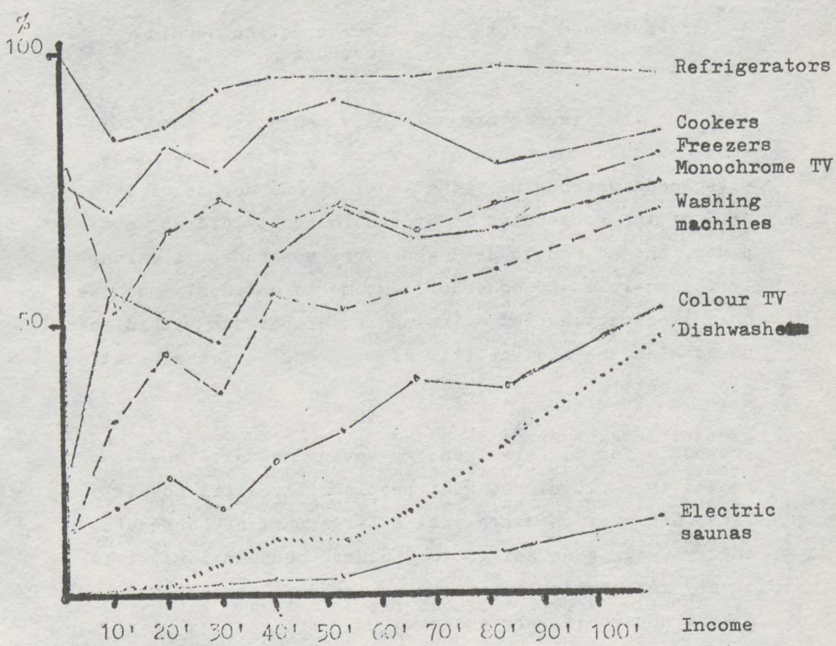
The bottom curve describes how the direct use of energy in households - that is expenses for electricity, oil, gas, gasoline etc - is due to income, the middle curve the indirect energy use, that is the energy it takes to produce the food, the car, the house etc.

The picture clearly shows how income enters. The greater the income of a person, the more energy he uses. Although this observation is ipso facto axiomatic, it can still serve as a point of departure for some ponderings.

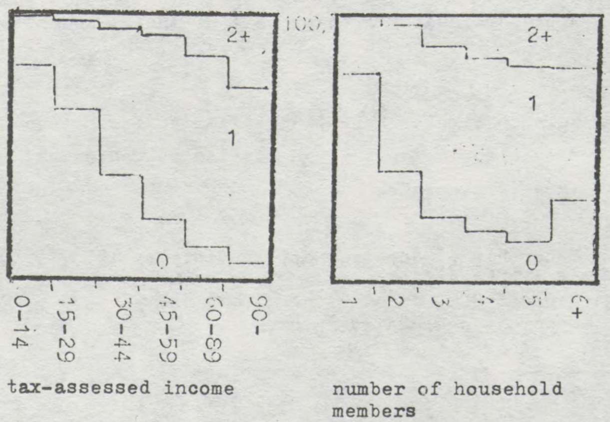
For example, the picture can illustrate what happens when the real income of households goes up in increments. In the act of buying more goods and services, they will at the same time increase the total energy usage. Another point: the lower-income households are most sensitive to increased energy prices: they spend a proportionally greater part of their incomes on direct energy.

No such figures have been estimated for Sweden. Even so, the following very rough diagram suggests that the picture is the same.

Ownership of domestic appliances, May 1973, in percent of all households.
Source: CDL
Income = aggregated income



Households in the Stockholm region owning none, one or more cars as a function of income and number of household members, 1971, in percent.
Source: TU 71, Stockholm County Council



Although the figures are not fully comparable they do show how much the household ownership of energy-intensive goods depends upon the level of income. As of 1974 45 % of the households in Stockholm county did not own a car, and as can be seen above car ownership is strongly income-related (household income is obviously not the only important aspect - the number of persons within the household, the availability of e.g. public transportation etc, also plays a role).

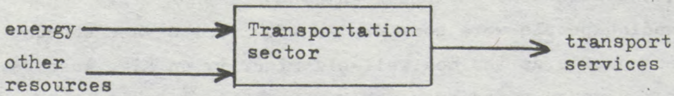
Proposals for different energy-saving measures must be rooted in a picture of what people's lives are actually like. One must be aware that a large part of household energy usage does not go to "luxury" consumption but is a very real matter of improving personal comfort and making household work easier.

At the same time it is evident that if a majority of the Swedish people were some day to acquire the same consumption habits as the now well-off minority on high incomes, energy usage would presumably skyrocket. If this is a prospect we refuse to accept, then we shall have to analyze <u>why</u> the consumption looks the way it does, try do study those determinants which make people acquire, say, two cars instead of one. We would also have to ponder on certain aspects of the consumption pattern which now matter little for energy usage but which might have great importance at some future time. This of course is when the greatest freedom of action is enjoyed today. The future trend of the leisure sector is a case in point. There is no doubt that sharply increased charter-flight services to overseas countries can play a great role, in the same way as a sharp increase in e.g. the number of large motorboats and secondary dwellings heated for year-round occupancy.

Serious analyses of questions like these inevitably lead to discussions on how people want to live, i.e. choice of life styles. Some people prefer to live in single-family houses outside Stockholm and to solve the transportation problems with two cars. Other people choose other solutions, making it all the more evident that future energy usage will depend on the extent to which these choices can be effected.

<u>VI. Energy is a rather small part in the total picture</u>.

There is no doubt that all these questions are pretty far removed from the energy studies that have been carried out so far. Perhaps we can illustrate this with a picture.



The transport sector uses substantial amounts of energy, in part directly for its operation, in part indirectly to provide the sector with goods and services of the kind that make it work. On the basis of traditional economic statistics it has been estimated that about 45 % of the American society's energy budget goes to the transport sector. In the ordinary statistics a rate of 25 % is given for direct energy use; the remaining 20 % is needed to refine oil, build cars, highways, etc. In other words: the transportation sector has a much larger impact on the energy demanded in society than what is shown by the direct use of energy.

If one wants to influence future energy use in the transport sector, two points of attack can in principle be selected:

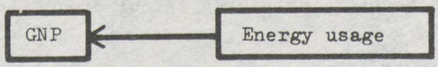
a) technical savings as represented by better car engines, smaller cars, aircraft which economize on fuel, etc.

b) measures which change the need for transport services, such as urban and regional planning, the organization of different activities, etc.

In a longer perspective the latter type of influence is probably the essential one. We can therefore foresee that the future study on energy will be dealing only in part with energy in a restricted sense.

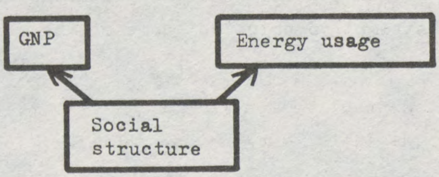
<u>VII. Energy and the economy</u>. We shall leave these questions and go over to the relationships between energy and the economy.

Economic growth (GNP) and energy usage (E) have historically evolved very much in parallel. This statistical correlation has led to assumptions that there is also a simple relation of cause and effect.



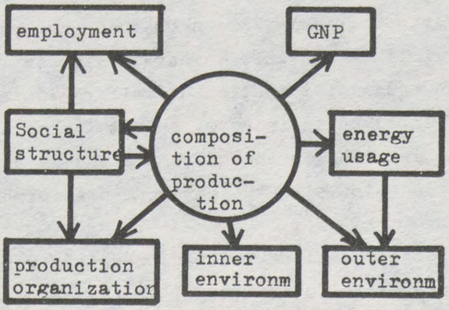
The assumption would in other words mean that we have to increase our supply of energy if we want to have a sustained economic growth.

We shall not go into the discussion, interesting enough in itself, of GNP as an index of prosperity and welfare but content ourselves with observing (see e.g. the final report (3) of the Ford study) that the most common view held by e.g. economists is that the relationship between energy usage and GNP is elastic and in any case stretchable up to a point. So a better description would be



Up to now the society has developed so that E and GNP have taken a parallel course over time. It is an open question whether there may not be other development strategies where these curves do not evolve in parallel. International comparisons which show that some countries use much less energy per capita than others for the same GNP per capita also suggest that the social structure is of great importance. It can be acted on and changed. By the same token it turns out that there are no simple connections between increasing labour productivity and energy usage per unit of output. At the same time as labour productivity has increased, the energy used up to produce each unit has dropped in most branches of industry. Roughly speaking, labour productivity has increased not only because new machines have been adopted but <u>also</u> because these machines have been more energy saving than the old ones they replaced. This underlines the importance of technological change. Put differently: there is no axiomatic conflict between the goal to save energy and the demand to increase labour productivity in the industrial sector.

It is also natural to look at other essential factors such as employment, income distribution, outer/inner environment etc as being additionally interesting characteristics of the social structure, with various connections to be found between them. The picture below is a speculative attempt to point out some of the connections.



It is therefore necessary that we understand different partial directions: between energy and inner environment, between energy and employment etc. After that we can discuss what interactions are likely to be the most dominating ones and that have to be looked upon in closer detail. The orientation phase of the study is intended to do just this.

But the picture can also illustrate a danger. There is a danger in studying isolated interdependences of for instance energy and employment. We have already found out that the energy demand of industries depends on the total volume produced which in turn depends among other things on the goal we have with regard to the number of employed in industries. The increase in labour productivity will mean a decrease in the number of employed in industries which can only be compensated by expanding the total volume produced in industry: thus perhaps also increasing the total amount of energy demanded by industry. In other words we have to try to look at several variables at the same time.

The interesting part is in other words not only how related demand of energy and number of employed are but also if it is possible to have a high employment and a more equal distribution of welfare and a reasonable amount of employed in industry and at the same time decrease the increase in energy demand and at the same time come to grips with the environmental problems.

This is probably an important and possibly weak point in the work with a future study. It is not possible to handle very many variables at the same time, and therefore the very necessary discussion of priorities has to be at the same time very thorough.

A few words on how to analyse the demand for energy

VIII. Different ways to look at energy demand. In order to close in on the questions raised in III-VII, we must make a thorough analysis of the energy use. Today, direct deliveries of energy roughly break down as follows:

industry	40 %
transportation	20 %
premises, etc	40 %

This distribution has been markedly stable over the years (it was roughly the same during the early 1950's).

A breakdown by selected industries is given in the following table (6).

Industry division	total energy usage	percent of industry's energy usage	percent of industry's workers	energy usage per worker
Pulp and paper	62 TWh	41 %	7 %	1 300 MWh
Primary metals	28	19	6	665
Clay and stone	13	9	4,5	429
of which cement and limestone	7	5	0,3	3 795
Manufacturing	13	9	41	47
Chemicals	11	8	6,4	264
All industries	150	100		233

Industrial sectors differ strikingly in their average energy use. This is, of course, a reflection of differences between industrial processes - seen roughly, we can say that the energy-intensive branch of industry is the processing industry, i.e. that segment which is called upon to make steel from iron ore, pulp from timber, cement from limestone, plastics from oil, etc. This industry's share of industry's total energy requirements comes to about 75 %, which means we can prepare a very rough new table on the total energy use employing a classification that differs in part from the one conventionally used.

1.	process industry	30 %
2.	Transportation and space heating	60-65 %
3.	Miscellaneous	5-10 %

The manufacturing industry's energy requirement is then divided into one part for space heating (roughly 50 %), which lies in item 2, and one segment which lies in mechanical working-up (welding, drilling, fastening, etc), here put in item 3.

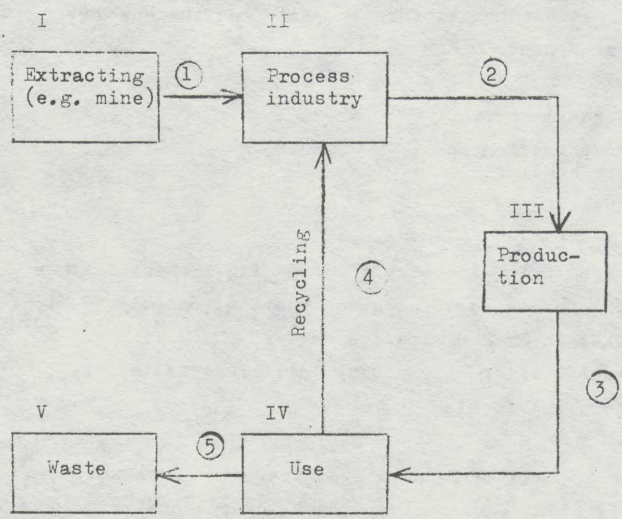
We can use this table as a starting point from which to find different angles of approach towards analyzing consumption.

One reason why the process industry uses up so much energy is the chemical conversion, say of iron into steel, required to satisfy the society's growing need for materials and commodities. So the first angle of approach is to study the flow of materials in society.

Item 2 in the table above is an amalgamation of energy usage for space heating and transportation. This item can be described as the amount of energy needed in order to uphold a certain geographic distribution of different activities. We shall call the second angle of approach society's spatial organization.

The big differences between items 1, 2 and 3 reflect differences of energy usages for the process industry, space heating and mechanical working up. We shall take that as our starting point for a third angle of approach, namely energy's role in society seen from a physical perspective.

XI. The flow of materials can be studied with reference to the rough picture shown below.



I ... V processes
1 ... 5 transportation

We accordingly mirror society's use of energy by studying the flow of materials. Further analyses show that the major contributions to total energy use lie in the processing stage and in the use of the finished products. It is interesting to note that the mechanical working-up (drilling, welding, lifting heavy goods, etc) in III draws rather small amounts of energy as compared with II and IV (8).

The argument can be examplified by looking at the amount of energy needed for producing one "American" car (7). 70 percent of the energy needed for producing the car is attributable to stage II, that is making steel of the ore. The rest is used in space heating, mechanical work like drilling, assembling etc.

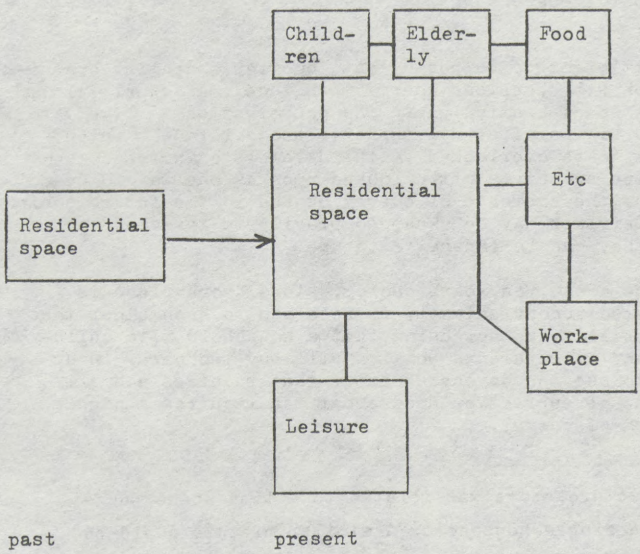
The amount of energy needed for producing the car can also be compared to the energy used in using the car. Then it is found that an "American" car uses roughly the same amount of energy per annum in driving (gasoline) as needed for the total production (stages I, II, III in the picture above).

In some cases stage I can also render large contributions, namely if the ores are very low grade. Cardinal importance therefore attaches to those properties of products which determine materials usage, length of life, recoverability and operating performance. These questions are discussed at some length in (7), a report which also shows some of the consequences of recycling materials. Nevertheless, it should be pointed out that the value of recycling will depend on how rapidly the materials requirement rises, on how long the materials are used and on the energy cost of collecting the scrap etc. In any case there is no doubt that the future society's energy requirement will to a great extent depend on how much material we use and, above all, on the magnitude of the rate of increase in materials usage. It is this factor that determines the total energy consumption in I and II above. A society that is lean on materials is also lean on energy.

But we have to look at the interaction between production and use. A rough conclusion we have drawn after having studied a number of energy analyses is that for durable products like domestic appliances, cars, buildings etc, the substantial energy use is attributable to their use by the end consumer. Frequently there is also a relationship between the amount of materials needed in production and the amount of energy needed in the use of a certain commodity. As for cars we mentioned that the amount of energy needed in driving the car increases when the car its heavier, that is less material in the car means less energy needed both for producing the car and for using the car. For houses etc the opposite relationship holds - more material (e.g. isolation) decreases the need for energy for space heating. See (7).

X. The spatial organization. We can assume that a large part of the increase in energy usage can be explained as follows. In every era of history households and individuals have had fairly stable needs for such things as shelter, food, clothing, looking after children, medical care, taking care of elderly and education. What has happened over the past few decades is the emergance of partly new ways to meet these needs. Functions which used to be wholly or chiefly performed in the home - and as such went unrecorded in the "money economy" - have been gradually specialized, engineered, complicated and frequently improved so that more and more of them are now being performed outside the home.

Seen as a change over time we can accordlingly draw the following picture. Needs which were formerly satisfied in a restricted floor area immediately adjoining the home are now being satisfied by specialized functions, each of which requires a certain amount of floor space plus transport facilities. The spatial organization has changed.



The increased specialization in the organizations of work and production - which has been necessary in order to increase productivity as this is measured - has led to a functional division of space, i.e. to growing needs for buildings and for transportation.

This spatial organization demands a certain amount of energy. This is roughly estimated to be between 60 and 65 percent of total energy demand. But this is only direct use of energy in space heating and transportation. Furthermore, energy is needed for building up and changing the spatial organization. If we add this it is not impossible that between 70-75 percent of the total use of energy can be directly related to the spatial organization. One can say this is a way to mirror the change from a barter economy to an industrial economy. It would not have been possible to increase the standard of living without these changes.

Now it might be supposed that tomorrow's spatial organization will use less energy than today; after all, it is in space heating where the conservation is likely to yield big payoffs. But there is another factor which tends to be overlooked in the debate: to increase the service sector is often looked upon as one way to decrease the increase of energy demand in the future society. Services may be cheap to provide in terms of energy but they <u>can</u> be expensive to use.

If the house, day-care center, store, work place is situated inconvieniently in relation to each other the probability is increasing that a household with children and both parents working will buy two cars. In order to use the day-care center that requires a small amount of energy you need a car the requires a high amount of energy.

The picture above was related to a time-space budget of one single household. A similar picture could be drawn for an industrial plant or any other work place.

The discussion suggests that there <u>might</u> be interesting couplings between not only land-use planning and energy (i.e. were buildings etc are placed in the space) but also in how we choose to organize activities like services, production of goods etc. Such discussions will force us down into rather deep studies of the meaning of concepts like productivity, specialization, labour market, full employment etc. This could be seen as examples of questions that are identified as being important in future studies, which probably cannot be handled here but have to be "sent further on" to for instance universities.

XI. The physical perspective. Concepts like production and consumption of energy are economic concepts. They have no meaning to a physicist or a chemist, to whom energy is not consumed but converted. Roughly speaking it is not energy that is the scarce resource but usable energy. The later is measured in the thermo-dynamic concept of free energy and which roughly speaking is a measure of how much mechanical work that can be done.

The difference between energy and free energy might be explained by looking at the oceans. There are enormous amounts of heat energy stored there but these amounts are stored as low temperature heat that cannot be used.

What is consumed in an economy is therefore not energy but free energy. And it is possible to evaluate different energy conversion processes on the basis of how efficient they are with respect to the use of free energy. It is therefore likely that different energy policy strategies ought to be evaluated not only in terms of how much energy that is consumed in the economic meaning but also in terms of how much free energy that is consumed within the thermo-dynamic sense. It is the latter that is the scarce resource.

The interest in these questions have risen very fast during the last year. In order to advance one has to describe the use of energy in physical terms, that is in the type of process the energy is used. Empirical studies are made difficult by the fact that energy statistics is based upon who is using energy and not on for what energy is used.

A rough classification would, however, show that the dominating parts are:

- high-temperature heat, above all for chemical conversion in process industries
- low-temperature heat, above all for space heating
- transportation

Mechanical work etc uses as we have already seen only a rather limited part of the total energy. If an increased mechanization of industry is necessary in order to have a better inner environment this does not necessarily mean that the impact on energy consumption would be great.

More penetrating analyses of the physical purposes for which energy is used can serve as one of several angles of approach to how different energy sources (oil, hydropower, nuclear power, sun, wind etc) can be converted into different energy forms (fuel, electricity etc) and then complement and supplement one another at the point of the end consumer in the home or in the factory. Electricity, for instance, is necessary for certain manufacturing processes (electronics, electrolytic methods), while its use for many other purposes is the result of the relative prices in the economy.

Hence a discussion of what the so-called alternative energy sources might contribute to our energy supply should not solely proceed from their innate potentials for superseding (say) nuclear power when it comes to producing electricity. The discussion should also proceed from the extent to which they can replace the electricity which is used to heat homes by harnessing other heating methods.

Indeed, a physical (thermodynamic) comparison between our way of using energy with our way of producing it shows that we often take rather long roundabout routes (see 8). Such an analysis can point to more rational solutions in terms of physics: something that will also prove to be economically beneficial in the long term.

XII. Energy husbandry seen in an organizational perspective. We had occasion to observe earlier that the pivotal weight of energy policy has shifted. This policy, which once was almost exclusively supply-oriented, has now taken on a stronger element of husbandry, i.e. conscious balancing of measures to increase the production of energy with measures to reduce its consumption.

In principle this is something new. Decisions which effect energy use are of course taken from a number of motives in which energy usually plays a fairly limited role. Increasing the level of ambition also means a change from a rather well-defined policy area to one that is decidedly more fragmented in terms of the organization, responsibilities etc.

This can be illustrated with an example taken from another area: the health and medical services. Organizationally speaking, caring for the sick are fairly well defined; lines of responsibility and governing authority are defined by different legal acts, professional norms etc. In contrast, the health services are decidedly more complicated and may require measures taken under the heads of urban and regional planning, social welfare, labour market policy, industrial health programmes, occupational safety, etc. Viewed from the central level in the societal structure, it is more complicated to influence those measures of different kinds which prevent any one need from arising than to create measures which are remedial or therapeutic. For a further discussion of these matters see (9, 10, 11).

It is our intention to study these institutional problems in fairly great depth. There are several reasons for so doing. Organizations and institutions happen to be among the most stable components in society. Their sluggish responses to change form a major part of our legacy, a fact that has to be understood to enable us to appreciate what freedom of action we have. It will therefore be central to analyze how the present energy-policy institutions have emerged, how the philosophies have superseded one another back and forth.

Another aspect of the same problem is the interdependence between the technology one would like to apply and the corresponding organizational requirements. Does a certain type of technology - e.g. nuclear power - demand a certain type of organization? Also the reversed relation is interesting: How do companies, authoroties and agencies choose new technologies: there are studies that show that profits etc plays a role, but perhaps not such a dominating one as is often assumed. New technology does not always save money, sometimes it also demands a different organization, different type of education, different type of cooperation with other organizations etc. It is not unlikely that particularly the so called alternative energy sources and the inertia in applying them depends more on these types of problems rather than on purely economical considerations.

This can give us some ideas on what type of institutional demands that are imposed by active policy of energy husbandry.

A concluding remark

This section has aimed at presenting some aspects of the long-term energy policy that we think are important. But it should be pointed out that this painting is not covering the whole picture, even if it is painted in broad strokes. There are other aspects that should be discussed before we make the final decision of priorities. However, we believe that we will cover these questions during the now on-going phase of orientation.

6. The work in the next few months

As mentioned in section 4 we have divided our work into three phases

- a phase of orientation
- a phase of deeper analysis
- a phase of synthesis

These phases do not follow one another consecutively in time but are of course over-lapping.

At present we are mainly working with the first phase, the content of which was also discussed above. A number of different conflicts of goals between the goal of energy husbandry and other social goals will be discussed in seperate reports during this phase. Our aim is to conclude this work during the spring. Work with the phase of synthesis has also begun, mainly in order to discuss different methodological ways for making a comprehensive discussion of the results. The link between orientation and synthesis is performed by a very much deeper analysis of the points I and II in section number 5, that is a more precise formulation of what the long-term energy policy problem looks like and could be formulated. We intend to present some more articulate thoughts on this topic as the conclusion of the phase of orientation.

Bibliography

1. Programme for Future Studies in Sweden. Secretariat for Future Studies. Sweden.

2. Energiforskning. Proposals from the Energy Program Commission. Ds I 1975:3.

3. "A Time to Choose". A report from the Energy Policy Project of the Ford Foundation. Ballinger 1974.

4. Energiprognosutredningen (EPU, the Royal Commission on Energy Forecasts: Energi 1985-2000. SOU 1974:64, 65.

5. Hannon: Energy conservation and the consumer. Science 189, 11 July 1975.

6. Lägesrapport från EPU (a state-of-the-art paper). Ds I 1973:2.

7. Energianalyser - en introduktion samt försök till strukturering. Thomas B Johansson and Måns Lönnroth. A report from the Future Study "Energy and Society". December, 1975.

8. Efficient Use of Energy: a physics perspective. American Physical Society, January 1975.

9. Strategisk planering och den offentliga sektorns struktur. Hans Esping and Måns Lönnroth. Paper read before symposium on long-term planning arranged by the Secretariat for Future Studies at Biskops-Arnö, June 1974. (Printed in Långsiktig planering och folkstyre, Ds Ju 1974:23).

10. Government by policy vs Government by Program. Daniel P. Moynihan. Public Interest, 1972.

11. New laboratories for old. David J. Rose. Daedalus Summer 1974.

12. Energy and Climate. A report from Professor Bert Bohlin to the Future Study "Energy and Society". September 1975.

Appendix

Organization of the project

Background

Following discussions in the Government Research Advisory Board and other bodies, the Prime Minister appointed a Working Party in June 1971 under the chairmanship of Mrs. Alva Myrdal, then Cabinet Minister, to deal with matters relating to future studies in Sweden.

On August 25, 1972, the Working Party handed in its report (SOU 1972:59), To Choose a Future, a Basis for Discussion and Deliberations on Future Studies in Sweden. Four special papers were appended to the report. On the Working Party's recommendation, a Secretariat for Future Studies was established on February 1, 1973, attached to the Cabinet Office. The Secretariat was mandated to pursue the inquiries on the basis of statements received and other comments on the report. The Secretariat has collected the comments to form the basis of subsequent discussions and, through contacts of various kinds, the subject matter and organization of future studies have been further illuminated and defined.

Adopting a Government Proposal, Parliament voted an appropriation of Skr 4 million to finance future studies for the 1974/75 fiscal year. Parliament allocated the same amount for fiscal 1975/76.

Of this amount Skr 2 million is earmarked to finance projects which are coordinated by the Secretariat for Future Studies in consultation with the ministries concerned. A decision was made to award the greater part of these funds to three projects.[1, 2]

Executive Committee for the Secretariat for Future Studies

In order to provide the parliamentary parties with the information and access that they have requested, a reference group consisting of six members was attached to the Secretariat in June 1974. In October 1975 the Government appointed an Executive Committee for the Secretariat for Future Studies. Members of the committee represent the five political parties in Parliament. Below are the names and party affiliations of the Executive Committee:

Inga Thorsson, M.P. (Soc.Dem.), Chairman
Kerstin Anér, M.P. (Liberal)
Gunnar W. Biörck, Professor (Conservative)
Birgitta Dahl, M.P. (Soc.Dem.)
Per J. Israelsson, M.P. (Communist)
S. Olof H. Johansson, M.P. (Centre)
Lars Ingelstam, Professor - Head of the Secretariat

---

1) The remainder of the appropriation (i.e. Skr 2 million) is earmarked for what is called "long-term motivated basic research" (the terminology is taken from Chapter 5 in "To Choose a Future"). According to an observation the Working Party made in its report, such research - - which must nearly always be interdisciplinary - should be planned in close association with the activities of the Research Councils and corresponding bodies. For this reason a Joint Committee for Long-Term Motivated Research detached from the Secretariat, has been appointed under the chairmanship of Professor Torsten Hägerstrand with parliamentarians, the research councils and others represented.

2) Parliament has directly voted requisite financial resources for the project, "Energy and Society".

Ministerial reference groups

In the initial stage of the project, the task of the ministerial group has been to identify tentatively, in partnership with the Secretariat for Future Studies, salient problem areas and to discuss the thrust of the project. The reference group for the study called "Energy and Society" consists of the following persons:

Erik Grafström Chairman	Cabinet Office
Knut Thyberg	Ministry for Foreign Affairs
Ulf Hjertonson	Ministry for Foreign Affairs
Karl Erik Strand	Ministry of Defence
Ingemar Nygren	Ministry of Health
Kjell Åke Lantz	Ministry of Transport and Communications
Odd Engström	Ministry of Finance
Olle Djerf	Ministry of Finance
Mac Murray	Ministry of Education and Cultural Affairs
Bernt Jonsson	Ministry of Education and Cultural Affairs
Bo Assarson	Ministry of Agriculture
Jörgen Holmquist	Ministry of Commerce
Lars Ettarp	Ministry of Labour
Kjell Svensson	Ministry of Housing and Physical Planning
Kerstin Lövgren	Ministry of Industry
Ingvar Hjelmqvist	Ministry of Local Government
Lars Ingelstam	Secretariat for Future Studies

The Secretariat for Future Studies

The Secretariat commissions the studies in accordance with the Government's directives. One member of the Secretariat's staff will serve as secretary of each reference group and as special liasion man for the project. If major departures from agreed-on programs and guidelines are envisaged, these should be discussed with the reference group or its chairman.

The project group

For each project several persons are engaged to do the actual work. As a rule one person is appointed to lead the project, and is responsible for ensuring that co-operation is effective, that agreed plans are adhered to, that the budget is planned and, in general, to bear the ultimate responsibility for seeing that the study is a cohesive and well-arranged product.

The autonomy and responsibility of the project groups must not preclude close and informal contacts with, among others, the Secretariat for Future Studies and members of the ministerial reference group.

For the most part, results from the studies should be presented in the form of reports for which the project group is jointly responsible. These reports are intended for widespread circulation, for instance by arranging a subscription scheme for materials produced by the different projects. Contacts have also been made with educational associations, popular movements, mass media etc., with a view these organizations being able to use project reports in their activities.

<u>Project group</u>

Lars Bergman

Margareta Grånäs

Thomas B Johansson

Måns Lönnroth
Project leader

Peter Steen

Address of the Project:

The Future Study Energy and Society
Fack

103 10 STOCKHOLM/Sweden

3 December 1976, Volume 194, Number 4269

SCIENCE

To: Frank Potter
From: Jerry Barney

Efficient Energy Use and Well-Being: The Swedish Example

Swedes use less than two-thirds as much energy per capita as Americans, at the same standard of living.

Lee Schipper and Allan J. Lichtenberg

It is often said that there is a direct relationship between per capita energy use and standard of living as measured by gross national product (GNP) (*1*). However, examination of the energy and GNP statistics for the most industrialized countries indicates a large spread in the ratio of energy use per unit of GNP (see Fig. 1). This article compares energy use in the United States, one of the countries with a high energy/GNP ratio, with that in Sweden, a country which in 1971 used approximately 60 percent as much energy as the United States to generate each dollar of GNP. Sweden was chosen not only because of its low energy/GNP ratio, but also because the GNP per capita is essentially the same in both countries. Moreover, much of the economic activity and many of the demographic features in Sweden are similar to those in the United States. Thus, evaluating the differences in energy utilization between these two countries may illuminate strategies for saving energy (*2*).

Studies of energy conservation in the United States indicate that the more important of these strategies, taken together, could reduce energy consumption 25 to 40 percent (*3–5*), while lowering pollution, reducing capital requirements for energy production, and generally raising employment. But the interrelationships among economic inputs (including energy) within an economy are complex. Thus, examination of an economy that is similar to ours but requires substantially less energy than our own may provide guidance in understanding the total effect of energy conservation.

Interest in energy use and conservation has stimulated a number of international comparisons (*6, 7*), as well as new evaluations of data from single countries (*8, 9*). A preliminary study concerned with a number of countries showed some of the differences reported here, but no conclusions were drawn (*10*). In a study of the United States and West Germany (*11*) comparisons were developed further, and methods for conserving energy in the United States were discussed; the conclusions reached are in qualitative agreement with those in this article. Two other comparisons of U.S. and Swedish energy consumption have been undertaken (*6, 7*), and we have been able to compare our data with theirs. Although there are many small discrepancies in data from different sources, in no cases are these discrepancies large enough to change our general conclusions.

Lee Schipper is a research assistant at the Lawrence Berkeley Laboratory and an energy specialist with the Energy and Resources Group, University of California, Berkeley 94720. Allan J. Lichtenberg is a professor of electrical engineering and computer sciences, and chairman of the Energy and Resources Group, University of California, Berkeley.

Factors Entering into International Energy-Use Comparisons

Many factors enter into the determination of the energy/GNP ratio. Among these are energy costs relative to other costs, government policies including taxes, subsidies, and regulations, and demographic and cultural variables. One meaningful measure of the effect of energy prices on consumption is the price elasticity of demand, defined as the ratio of the percentage change in demand to the percentage change in price, other factors being held constant. A study of the long-term elasticity for electricity in the United States, for example, gave values of −1.2 for residential use, −1.8 for industrial use, and −1.4 for commercial use (*12*). Recent studies indicate that the long-term elasticity for gasoline may be as great as −0.75 (*13*). The long-run effects of energy prices can be seen qualitatively in Fig. 1. The high energy/GNP countries are those that historically have had cheap energy (relative to other goods and services); the United States, Canada, Great Britain, and Norway are examples. The countries with lower energy/GNP ratios are those that have been relatively fuel-poor, especially since World War II. Although Sweden, for example, has had abundant hydropower, the country has been increasingly dependent on imported petroleum, particularly for nonelectric uses. Consequently, electricity has been inexpensive relative to fuel, with both price and per capita consumption very similar to that in the United States. Motor fuels, on the other hand, have been taxed heavily in Sweden, and per capita consumption of these refined petroleum products has been far below U.S. consumption. Similar taxes have been the rule in other oil-poor countries. Although oil for home heating has been relatively inexpensive in Sweden (comparable to U.S. oil prices) the large amounts demanded for long winter heating seasons acted in place of higher prices to stimulate conservation efforts (*14–18*).

Sweden's energy/GNP ratio was rising during the 1960's, probably because of

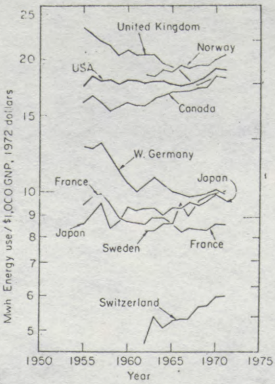


Fig. 1. The energy/GNP ratio for several countries over time, with hydroelectric power counted at 3 kwht/kwhe. From Linden (*1*). For a discussion of units, see (*2*).

changes in life-style similar to those which had taken place in the United States a decade or two earlier. These changes include greater living space and gasoline use per capita. The ratio has since stabilized and then fallen in the period of high energy prices after the oil embargo, as has the ratio in most other countries. The United Kingdom and West Germany had a falling energy/GNP ratio during the 1950's and early 1960's, probably due to a shift away from coal, which was their main cheap source of fuel, to more expensive substitutes.

One factor that can be important in determining the energy/GNP relationship is the relative industrialization or type of industry in a country. Certain products are particularly energy-intensive, including steel, aluminum, cement, paper, and plastics. The effect of changing the output mix is most noticeable in comparing Luxembourg, where the steel industry plays a dominant role in the economic structure, with Switzerland, where banking, insurance, timepieces, and other items of high value added per unit of energy expended predominate. Luxembourg has an energy/GNP ratio of 30 kilowatt-hours total per dollar compared to Switzerland's 6 kwht per dollar (*10*). The energy/GNP ratios of Great Britain and New Zealand were found to differ by a factor of 2 (*5*), which may be partly attributable to the degree of wealth based on agriculture in New Zealand. However, effects due to the agricultural sector are usually small among industrialized nations. For the countries in Fig. 1, agricultural sectors comprise between 3 and 5 percent of the total GNP; if any correlation exists, it is between energy use and the size of the services sector, which will be explored further below.

The effects of cultural and life-style differences on energy consumption are very difficult to quantify but are clearly very important. Cultural patterns, although not wholly controlled by the marketplace, may be tempered over long periods of time by prices and fuel availability. Some of the current pattern of intensive energy use in the United States and Canada can be traced to the availability of fuel wood during the 19th century (*19*). In 1850, for example, with a per capita energy consumption of 30.8 × 10^3 kwht, including wood, the United States used as much energy per capita as Switzerland does today.

We take the years 1970 to 1972 as our comparison period, because complete data are available and energy prices and use trends were relatively stable. Where appropriate, we use data from other years. In 1971, there was a mild recession in Sweden; total energy use was slightly higher in 1970, and our Swedish industry statistics were taken from that year. Because of variations in exchange rates, relative GNP's can change independent of changes in real wealth. Unless otherwise noted we employ the exchange rate of 5.18 Swedish crowns (Skr) per dollar, which applied until late 1971. The rate was as low as 3.9 Skr per dollar in 1973 and has since stabilized at 4.3 Skr per dollar in 1975 and 1976. It is generally believed that the old exchange rate undervalued the Swedish crown relative to the dollar.

In comparing energy/GNP ratios, additional problems arise. Comparing the size and content of the GNP has received considerable attention (*20*). In our study we give indications of the structure of the economy in Sweden and in the United States, highlighting the differences and similarities, comparing various physical standards of well-being. Accounting for differences in climate, geographic factors, population distribution,

Table 1. Basic economic and social indicators for the United States and Sweden (1971). Data for the United States are from (*24*), data for Sweden from (*22, 23*) and fact sheets distributed by the Swedish Institute, New York.

Indicator	United States	Sweden
Physical characteristics		
Population (million)	207	8.1
People per square mile	57	47
Climate-heating [degree-days per year (68°F)]*	5,500	9,200
Economic activity		
GNP (dollars per capita)	5,051	4,438
Energy consumption (kilowatt-hours per capita)	96,000	52,450
Steel (kilograms per capita)	620	680
Cement (kilograms per capita)	342	430
Fertilizer (kilograms per capita)	105	67
Paper (kilograms per capita)	224	540
Food (per day)		
Energy (kilocalorie per capita)	3,300	2,850
Protein (grams per capita)	99	80
Cereals (grams per capita)	176	168
Meat (grams per capita)	310	142
Health and education		
Doctors per 1000 persons	1.5	1.35
Dentists per 1000 persons	0.49	0.72
Hospital beds per 1000 persons	7.8	15
Infant deaths per 1000 births	19	11.1
Teachers per 1000 students	34	60
Newspaper copies per 1000 persons	301	534
Books published per 1000 persons	0.39	0.94
Conveniences		
Telephones per capita	0.59	0.56
Television sets per capita	0.45	0.32
Automobiles per capita	0.45	0.3
Automobile passenger miles per capita (1970)	7,900	5,050
Refrigerators (percent of households)	100	93
Freezers (percent of households)	28	46
Clothes washers (percent of households)	76	41
Vacuum cleaners (percent of households)	88	89

*We use 68°F for the United States and Sweden and have adjusted figures for the United States accordingly (*27*).

and so on, is also important; we have made comments on this problem where applicable. The method of counting the contributions of hydropower and of combined electricity and heat generation can be significant in international comparisons, and is discussed below. We find that no matter how one counts hydropower the difference in energy use between Sweden and the United States is large, especially since the largest contrasts appear in transportation, space heating, and process heat applications. The use of noncommercial sources of energy, usually considered only when discussing less-developed countries, is important to our comparison. The paper industry in Sweden, which accounts for fully 15 percent of the total consumption of energy there, actually generates 60 percent of its fuel internally from waste forest products. Together with other waste products, including urban wastes, these noncommercial fuels account for 9 percent of Sweden's total fuel use in 1971 (*21*) compared to 1 percent for the United States. Finally, a troublesome statistical problem is inconsistency between different information sources. For example, the fuel used by agricultural and construction equipment could be counted in transportation or industry, depending on how figures are kept. Similarly, self-generated electricity, district heating, by-product fuels (such as coke gas), noncommercial fuels, consumption of energy by energy producers, and so forth must be carefully sorted out. We believe we have resolved these various problems to the point that the remaining errors are only a few percent.

Sweden and the United States: Physical and Economic Comparison

In Table 1 we compare physical characteristics, economic activity, and various measures of well-being in the United States and Sweden (*22–24*). Although the populations differ by a factor of 25, the population densities are similar, as is the distribution into densely populated urban centers and sparsely populated rural regions. Movement to the suburbs, fostered by the automobile, started earlier and is more advanced in the United States, although there are signs of such a trend in Sweden (*25, 26*). The natural distances over which goods must move are larger in the United States, although in Sweden much of the lumber, iron ore, and electric power flows from the sparsely populated far north to the more crowded south. The climate in Sweden is more severe; the number of degree-days, weighted by population distribution, is close to 9200 in Sweden, comparable to the value in North Dakota, whereas the weighted U.S. average is approximately 5500 degree-days (*27*).

Table 1 indicates that in 1971 the United States had a GNP per capita 10 percent higher than Sweden's at the then current exchange rates. However, for each dollar of GNP Sweden required

Table 2. Per capita energy consumption in the United States and Sweden in 1971. Data for the United States are from (*28–30*); we included 1,000 kwh per capita in wood wastes (*30a*); the totals in the kwh and kwht columns do not agree because of differences in counting hydropower. The Swedish data are from (*16, 21, 31*), with feedstocks estimated from (*32–34*); we included 4,000 kwh per capita in wood wastes; hydropower was counted at 3,413 Btu/kwhe in the kwh column. All kwht values were calculated by distributing utility losses to end consumers; consumption of electricity within electrical sectors was counted in "Industry." The kwht column for the United States includes hydropower at 10,460 Btu/kwhe; that for Sweden counts all electricity at 10,400 Btu/kwhe. The actual "heat rate" for thermal and back-pressure plants in Sweden is 8,870 Btu/kwhe, including distribution losses; the rate for production only is 7,780 Btu/kwhe. Cogenerated electricity in the paper industry is excluded from the kwht columns.

Consumption	United States			Sweden		
	kwh	kwhe	kwht	kwh	kwhe	kwht
Transportation	24,025	25	24,075	7,350	200	7,775
Commercial	9,600	2,150	14,250	7,375	1,500	10,625
Residential	13,500	2,300	18,450	11,125	1,400	14,150
Industry	28,900	3,300	36,000	20,400	4,200	29,450
Feedstocks	5,600		5,600	2,500		2,500
Utility losses (actual)*	14,200			3,700		
Actual consumption†	95,825	7,775	98,375	52,450	7,300	64,500
Energy embodied in foreign trade‡	1,800§		1,800	−4,600‖		−4,600
Net consumption¶	97,625	7,775	100,175	48,150	7,300	59,900

*Hydropower was counted at 3,413 Btu/kwhe. Other losses are according to actual consumption. †Actual consumption refers to fuels and electricity, including petroleum refining losses and other captive fuels. ‡Embodied energy includes the process energy of refined fuels but not the energy available when the fuel is burned. §The import-export energy balance for the United States is from (*35*). ‖The import-export energy balance for Sweden is from (*16*). ¶Exports of coal, crude oil, or refined products are excluded from this balance.

Table 3. Passenger transportation data for the United States (*36–38*) and Sweden (*33, 40, 41*). Division of modes into urban (within areas of population 30,000) and intercity [from (*41*)] does not exactly correspond to our classification by local and intercity; PM, passenger mile.

Passenger mode	United States (1972)			Sweden (1970)		
	D_j' (PM per capita)	E_j' (kwh/PM)	T_j (kwh per capita)	D_j' (PM per capita)	E_j' (kwh/PM)	T_j (kwh per capita)
Automobile*						
< 30 miles	4,850	1.72	8,330	1,825		
> 30 miles	4,200	1.02	4,300	3,225		
Totals	9,050	1.41	12,630	5,050	0.74	3,760
(Totals for 1970)	(7,900)	(1.41)	(11,200)			
Bus†						
Local (< 30 miles)	112	0.50	56	460	0.41	200
Intercity (> 30 miles)	122	0.30	42	25		
Rail‡						
Local (< 30 miles)	64	0.21 (0.63)§	13.7	85	0.16 (0.48)§	15
Intercity (> 30 miles)	21.3	0.87	18.6	356	0.25 (0.75)§	90
Total land	9,370	1.36	12,760	5,975	0.68	4,065
Air domestic	490	3	1,500.	46	1.12(?)	275(?)
Air international‖	243(?)	1.38(?)	335	200		
Other passenger and military			1,500		?	200
Total passenger	10,103		16,095	6,221		4,540

*Hirst (*36*) gives 1969 load factors that imply an overall load factor (ratio of passenger miles to vehicle miles) for automobiles of 1.7, which seems unreasonably low. A load factor of 2.2 is implied in (*37, 38*), and a load factor of 1.9, which we adopt, is assumed in (*42*). There was a similar discrepancy in the Swedish data, most references giving an implied overall load factor of 2, with one giving 1.7. We adopt 2, since the driving in Sweden is dominated by family driving to a greater degree than that in the United States. †The U.S. bus fleet is 75 percent diesel; the Swedish bus fleet is 10 percent electric, the remainder either diesel or gasoline. ‡The U.S. local rail service is electric; intercity rail service is 75 percent diesel, the rest electric. In Sweden 90 percent of rail service is electric, the rest diesel. §Electricity figures are net values, and the E_j's in parentheses reflect a theoretical 3 kwht/kwhe. ‖The figures for international fuel and passenger miles are uncertain.

only 68 percent as much energy as the United States. Correcting for the energy embodied in foreign trade (see below) reduces the 1971 Swedish figure to 61 percent. Despite the difference in energy use, the total per capita production of basic industrial commodities is comparable in Sweden and the United States.

Basic well-being is difficult to compare quantitatively. As seen in Table 1, food intake is similar, with Americans eating considerably more meat (about twice the Swedish per capita consumption), which, per gram of protein, is more energy-intensive than most other foods. In health and education, Sweden leads the United States in almost all categories. When the comprehensive health and social security system in Sweden is examined this difference is even more striking.

The large number of automobiles and TV's in the United States is accounted for mainly by multi-unit ownership by families. Transportation convenience is, in fact, comparable, because public transportation is more readily available in Sweden, and domestic distances are generally smaller (*25, 26*). Swedes have more second homes (500,000 in all) per capita than Americans, and most of the population enjoys 4 weeks of paid vacation each year. Thus we conclude that the living standards are comparable quantitatively in Sweden and the United States, but the mix is substantially different, with somewhat less energy-intensive economic activities and life-styles in Sweden.

Table 4. Automobile data for the United States and Sweden (1970). (Conversions used: 1 U.S. gallon = 33.75 kwh; 1 mile = 1.6 km.)

Parameter	United States	References	Sweden	References
Persons per vehicle	2.25	(*42*)	3.4	(*16*)
Licensed drivers per capita	0.5	(*38*)	0.4	(*16*)
Passenger miles per capita	7,900	(*42*)	5,050	(*40*)
Vehicle miles per capita	4,160	(*37*)	2,560	(*46*)
Miles per vehicle*	9,360	(*37*)	8,900	(*46*)
Load factor	1.9	(*42*)	2.0	(*40*)
Average weight (kg)	1,700	(*43*)	1,100	(*44*)
Miles per gallon†				
Actual	13.7	(*37, 43*)	24	(*43–45*)
Theoretical	12.5		20	
Kilowatt-hours per passenger mile	1.4		0.73	
Kilowatt-hours per capita	11,200		3,710	

*The surprising similarity between the U.S. and Swedish values suggests that in Sweden second cars are replaced by mass transit, and a significant number of families have no car at all. †The U.S. theoretical value is estimated from the weight-fuel economic statistics of the Environmental Protection Agency (*43*); the actual value is determined by dividing actual miles driven by fuel consumed. The Swedish theoretical value from Ullén (*44b*) matches the actual value for Sweden.

Table 5. Goods transportation data for the United States and Sweden. The U.S. data are from (*30, 30b, 39*). Swedish data are from (*16, 40*), with the breakdown for truck by distance based on the 1973 distribution.

Transport	United States (1972)			Sweden (1970)		
	D_J (ton-mile per capita)	E_J (kwh per ton-mile)	T_J (kwh per capita)	D_J (ton-mile per capita)	E_J (kwh per ton-mile)	T_J (kwh per capita)
Truck						
Local (0 to 30 miles)	360	1.95	700	339	0.58	200
Intercity (>30 miles)	2069	0.63	1430	1284	0.86	1100
Total truck	2429	0.88	2130	1623	0.8	1300
Rail	4132	0.19	800	1350	0.06 (0.18)*	80
Domestic air	20	7.5	150			
Water						
Domestic			420	704	0.3	190
International†			480			1600
Total goods	6585		3980	3670		3170
Nonrevenue goods transport (agriculture, forestry, construction, and so forth)			1850			470
Pipeline			200‡			
Other			120‡			930
Totals	6585		6150			4570

*The value in parentheses reflects a conversion factor of 3 kwht/kwhe. †Excluded from totals in Table 2. ‡These are 1971 data.

Comparison of Energy Use

In Table 2 we compare energy use in the United States and Sweden (*16, 21, 28–35*). Sweden uses less energy per capita in all sectors, the largest difference being in the transportation sector. There are considerable differences in basic materials processing in the industrial sector and electricity use in the residential and commercial sectors.

A useful formula that summarizes the uses of energy (T_J's) is: energy use = $\Sigma_J E_J D_J = \Sigma_J E'_J D'_J = \Sigma T_J$, where the D_J's are the dollar demands for goods and services and the E_J's are the energy intensities of those demands; or, in physical terms, the D'_J's are the quantities of goods and services and the E'_J's the energy intensities associated with those quantities.

When data are disaggregated in this way, both the relative mix of modes (D_J or D'_J) and the efficiency of those modes $(E_J)^{-1}$ or $(E'_J)^{-1}$ can be compared among countries. Energy use in the economy can be lowered by shifting economic activity to less energy-intensive sectors (D_J) or by increasing the efficiency (lower E_J) of production of a given D_J. We use this formalism in the specific comparison of U.S.-Swedish energy use. The differences in E_J's between countries indicate possibilities for energy conservation through technical change, without requiring changes in life-style.

Transportation. Table 3 shows basic passenger transportation data for Sweden and the United States (*33, 36–42*). Major differences exist in all modes. In addition to the striking differences in automobile D', E', and T, we note that Swedish passenger transportation is more heavily concentrated in rail (including subway) and bus modes, at the expense of the automobile and the airplane. All Swedish E'_J's are lower than the corresponding U.S. values. This is due in part to higher load factors and the extensive use of air and bus charters.

In Table 4 we consider the automobile in more detail (*37, 38, 40, 42–46*). We see that the Swedish D' is only 62 percent of the U.S. figure, and E' is only 60 percent of the U.S. figure. The biggest contributor to efficiency is the lower weight of Swedish cars (1100 compared to 1700 kilograms). The weight distributions are given in Fig. 2 (*43–45*). Interpolation of Environmental Protection Agency (EPA) measurements of fuel consumption as a function of inertial weight suggests that weight alone accounts for a 30 percent difference in energy consumption per mile (*43*). The lack of power extras, automatic transmissions, and air conditioners in Swedish cars reduces fuel demand further, as does the lower ratio of engine displacement to car weight.

In addition to these technical differences there are differences in automobile utilization that have significant consequences. For trips of 10 kilometers or less, for which automobile fuel consumption per mile is nearly double average fuel consumption (*47*), the Swedes use private cars and public transit in the ratio 55/45 (percentage of trips) (*45*). In the United States, by contrast, the ratio is 90/10 (*38*). This traffic accounts for 65 percent of all automobile trips in the United States, resulting in lower average driving cycle efficiencies. Thus it becomes apparent why actual miles per gallon in Sweden are higher than predicted by interpolation of EPA measurements (*43*): the driving cycle demands less energy. Surprisingly, load factors in both countries average approximately 2. This is probably because the smaller size of families in Sweden compensates for that country's higher ratio of family to commuter use.

Speed limits further reduce Swedish automobile energy use. The Swedish speed limit during our period of comparison was as high as 110 km/hour (68 mile/hour) on only about 10 percent of the largest highways. In the United States highway speed limits were commonly 65 mile/hour or more in 1971.

It has been noted (*25, 26*) that the use of alternatives to the automobile in Sweden has gradually eroded. Nevertheless, the automobile's share of all passenger miles has stabilized at 82 percent in Sweden (*33*); the U.S. figure is 92 percent (*38*). The availability and use of mass transportation in local and long-distance travel is an important factor in the optimization of the use of the auto discussed above (*25, 26*). In Stockholm, Gothenburg, and Malmö, where more than 25 percent of Sweden's population resides, mass transit, motor bikes, and pedal bikes account for 75 percent of all commuting (*41*). The figure for the entire country is 46 percent. Mass transit provides half of this, mostly in the cities named above. Most of the cities of more than 50,000 people in Sweden have bus systems and economic incentives, including subsidies, to encourage their use by riders going into the city center. In Gothenburg, for example, one can obtain a round-trip ticket for the price of a single fare by using the streetcars and buses at off-peak daytime hours; in Stockholm and other cities a 70-Skr pass allows unlimited transportation on all rail and bus lines. Buses are often as close as 4 minutes apart during peak hours, and rapid rail and buses provide direct service to places as much as 40 km from the city centers. Thus, to the city or suburban dweller in Sweden, mass transit presents a viable and economic alternative to the use of an automobile, and development of suburbs and new towns around rail and bus stations reflects the popularity of mass transportation. For longer trips, alternatives to automobile transport in Sweden are also available. Intercity buses, semicharter buses, and trains carry 20 percent of the passenger miles in trips over 50 km. Swedish Railways offers hourly departures between Malmö, Gothenburg, and Stockholm during day and early evening hours, traveling at average speeds of 80 to 100 km/hour.

The tax system has strongly affected use of the automobile in Sweden. In 1971, the gasoline tax of 50 cents per gallon raised the price by 250 percent to 70 cents per gallon (*23, 48*). Automobile excise taxes and yearly fees rise in proportion to vehicle weight according to the formula shown in Fig. 3. These fuel and weight taxes influence owners to purchase light cars, as the small proportion of cars heavier than 1700 kg (the U.S. average) shows (Fig. 2). In addition, the excise taxes raise the cost of a new car in Sweden (compared to the United States), providing an incentive to keep an older car in running condition.

Table 6. Per capita residential and commercial energy use in the United States (*3, 30b, 49, 49a*) and Sweden (*16, 41, 53, 54*) in 1972.

Use	United States	Sweden
Residential		
Direct fuel (kwh)		
Heating	9,660	8,200
Water heating	1,950	3,300
Gas appliances	630	125
Second homes		300
Electricity (kwhe)		
Refrigerator and stove	610	530
Lighting	335	105
Air conditioning	300	
Other appliances	590	475
Heating	280	400*
Water heating	500	
District heating saving		−1,300†
Total net use (kwh)	14,855	12,135
Electric conversion loss at U.S. rate‡	5,230	3,020
Total gross use (kwht) (with actual losses)‡	20,085	15,135 (12,820)
Commercial		
Floor space (m^2)	10	13§
Direct fuel (kwh)		
Space heat	5,625	4,800
Water heat	790	
Air conditioning	200	
Electricity (kwhe)		
Air conditioning	205	
Lighting	1,250	625
Electric heat and other	310	1,075
Total net use (kwh)	8,380	6,500
Electric conversion loss‡	3,530	3,200
Total gross use (kwh) (with actual losses)‡		(7,280)

*Includes hot water in all-electric homes, and second homes. †Assigned to residential sector for convenience. ‡Losses are counted at the U.S. rate of 2 kwht/kwhe for uniform comparison, as in Table 2. Actual Swedish losses (0.46 kwht/kwhe) are reflected in the totals in parentheses. §This value is obtained from the volume of commercial office space by assuming a 4-m room height.

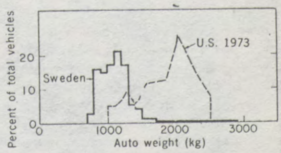


Fig. 2. Distribution of automobiles by weight. 1974. Swedish data are for 1974 and are from (*44*); U.S. data are for 1973 and were estimated from (*43a*).

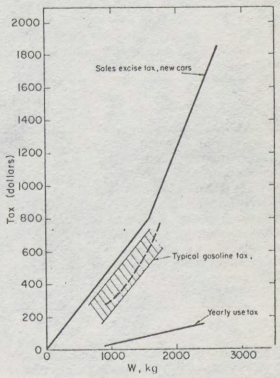


Fig. 3. Taxes on automobiles and gasoline in Sweden in 1974 (based on the old exchange rate of 5.18 Skr/$). Sales excise tax was computed from $45 per 100 kg to 1600 kg and $58 per 50-kg additional weight. The shaded area and dashed line give an estimate of gasoline tax as a function of weight, using 14¢/liter for a typical 20,000 km/year. The yearly use tax was computed from $32 + $8.40 [weight (kg)-900]/100. Data are from (*23, 44a, 48*).

The average car in Sweden has a lifetime of about 14 years compared to a U.S. average of less than 10 years.

Nontax disincentives have also been employed to discourage use of automobile transit in Sweden. In Stockholm there is no 24-hour free street parking in the greater downtown area, and parking fines begin at $12.50. Both Stockholm and Gothenburg have set up systems of barriers, one-way streets, mass transit-only lanes or passageways, and pedestrian-only streets that further discourage use of cars.

For freight transport, as shown in Table 5, the largest difference in per capita energy use is associated with distances through which goods are moved (*16, 30, 30b, 39, 40*). A lesser, though still important, factor is the energy intensity of freight movement. Although a complete study of efficiency is yet to be made, some important factors can be identified. Long-haul trucks are more energy-intensive in Sweden than in the United States, but short-haul freight is much less energy-intensive. Small station wagons and four-cylinder microbuses or diesel minitrucks are used extensively for short hauls in Sweden, in contrast to the heavier pickup or panel trucks used in the United States, so that mode and vehicle are more closely matched to the demands of the task. Much of the difference in freight miles would be accounted for by shipments of Swedish exports of raw materials through other countries, exports that far outweigh (literally) imports. However, these freight miles are not distinguished in our study. Also, coal and other fuels are transported over much greater distances in the United States than in Sweden.

Energy used in foreign passenger travel, particularly in European countries, where this constitutes a significant fraction of what corresponds to domestic travel in the United States, may distort comparative energy use analysis. This is particularly true of air travel. Nearly every passenger flight connecting Sweden with anywhere stops in Copenhagen, where most of the fuel for the trip is put aboard. Thus, Danish fuel intensity per air passenger mile is abnormally high (*8*), while that for Sweden is low (*16*). It is also difficult to credit passenger miles when foreign visitors travel to or within a country. Because of these uncertainties, we have refrained from drawing conclusions from the great differences in E' for air passenger travel in Table 3.

Residential and commercial energy use. A comparison of energy use in the residential and commercial sectors is given in Table 6 (*3, 16, 30b, 41, 49–51b*). Although the per capita consumption is significantly lower in most categories, a full appreciation of the differences is only obtained by examining the D'_j's and E'_j's separately.

Space heating, consuming more than one-half of the total residential energy (Table 7), shows very large differences in efficiency when account is taken of the differing climates and the actual energy use per unit area of residential or commercial space. The larger number of degree-days in Sweden is compensated for by considerably lower heating intensity (kilowatt-hours per square meter per degree-day). A study of insulation in Swedish homes and apartments showed that heat loss through walls declined steadily to a typical U value of 0.06 British thermal unit per hour per square foot per degree Fahrenheit (*16*). One can almost guess the year of construction of a residence in Sweden by the U values; the scatter from the average value for any year of building being very low (*16*). This indicates that factors such as building codes have acted to permit only energy-efficient (and economic) construction in housing (*52*). In contrast, U values in the United States have been set mainly by a weak Federal Housing Administration (FHA) minimum property standard, which before 1971 was 0.12 Btu $hour^{-1}$ ft^{-2} $°F^{-1}$ for ceilings and 0.19 for walls (*50*). The factor of 2 difference between U.S. and Swedish U values is nearly equal to the average ratio of heating intensities. Swedish houses also have correspondingly less infiltration and heat loss through glass because of the use of double glazing (*17*).

Although the lower heat loss in Swedish houses is in part a response to the more severe climate, this is not the primary reason, as seen by comparing heating intensities in terms of degree-days in various regions in the United States and Sweden (Table 8). Although there is little overlap between the U.S. and Swedish degree-day values, the plots of intensity (kilowatt-hours per square meter per degree-day) against degree-days would clearly lie on different curves for Sweden and the United States. Also, the Swedish values are nearly independent of degree-days, reflecting the use of similar standards in their four climate zones (*52*).

In Sweden, the mix of single-family dwellings and apartments (multiple-family dwellings), 42 and 58 percent, respectively, is considerably different from that in the United States, where in 1970 the corresponding figures were 71 and 29 percent. However, this does not account for much of the difference in heating efficiency, as the kilowatt-hours per square meter was only slightly lower in Swedish apartments than in single-family dwellings, and the kilowatt-hours per capita was also very similar, because of the higher number of people per house in

Table 7. Residential space energy consumption (fossil fuels only). Data for the United States are from (*14, 15, 24, 51*); values are for single-family dwellings, except the kwh per capita value, which includes all dwellings. Swedish data are from (*16, 17*); MFD = multiple-family dwelling, SFD = single-family dwelling.

Parameter	United States	Sweden		
		MFD	SFD	Average
Persons per housing unit	3.3	2.1	3	
Rooms per housing unit	5.1	3.2	4.5	
Persons per room	0.66			0.66
Average area (m²)	115	70	110	
Degree-days (68°F)	5,500			9,200
Kilowatt-hours per housing unit	34,000	16,350	28,750	
Kilowatt-hours per square meter	300	235	260	
Kilowatt-hours per degree-day	6.2	1.77	3.10	
Kilowatt-hours per square meter per degree-day	0.054	0.025	0.028	
Kilowatt-hours per capita	9,150			8,200

Table 8. Heating intensities by climatic regions for the United States (*14, 15*) and Sweden (*17*). In the Swedish data (*17*), curves for electrically heated homes were adjusted upward to reflect oil furnace efficiencies and construction.

Parameter	United States			Sweden		
	California	Pennsylvania	Minnesota	Malmö	Stockholm	Norrbotten
Degree-days (68°F)	1,900	5,500	8,500	7,700	9,200	13,000
Kilowatt-hours per square meter per degree-day	0.11	0.063	0.049	0.028	0.027	0.026

single-family dwellings. In apartments, common metering of all units in a building removed the incentive to conserve, raising both space heat and hot water use (*41*).

Use of electric resistance heating in Sweden was increasing rapidly (*53*), as was U.S. use (*49*), until the embargo of 1973 caused a reevaluation of the overall effectiveness of such systems. In 1972, 7 percent of Swedish homes (15 percent of single-family dwellings) were heated electrically, similar to the 8 percent in the United States, but much less than the approximately 20 percent in Norway, where hydroelectricity is the largest single contributor to the total energy supply. The average heat losses in Swedish all-electric homes are two-thirds of those in oil-heated homes (*17*).

In the commercial sector, overall energy use per square meter of space may be as much as 30 percent lower in Sweden than in the United States (*16*), even before the difference in heating degree-days is considered. The heating intensity, when measured in kilowatt-hours per square meter per degree-day, is approximately 2.5 times lower in Sweden. We attribute this mainly to the same differences in insulation, ventilation, and construction standards that applied to the residential sector, but the energy consumed in the commercial sector is reduced further by more realistic lighting standards, which also lower the need for cooling. (Unlike many large buildings in the United States, Swedish office buildings do not generally require air conditioning in winter to remove the heat produced by high lighting levels.)

In Table 6 the important residential and commercial uses of electricity are compared. Higher U.S. energy use arises primarily from a combination of factors: significantly more use of large appliances like dryers and large "frost-free" refrigerators, excess lighting, and more small appliances (*53, 54*). Air conditioning is conspicuously absent from Swedish electricity use, but accounts in the United States for only 12 percent of electricity used in the residential and the commercial sectors and only 3 percent of total energy use. The per capita total energy use for space cooling in the United States is roughly equal to the total consumption for space heating of factories in Sweden, a factor unimportant in the United States (*30a, 54*).

Water heating, another major energy user, requires typically 6,200 kwht per household in apartments (central water heating) and 10,500 kwht per household for single-family dwellings in Sweden, while the corresponding U.S. figures are 9,600 and 11,500 kwht. Much of the hot water in Sweden is prepared in centralized systems, eliminating some of the losses typical of American single-unit water heaters. On the other hand, the larger systems are not easily metered individually; in studies of energy use in apartments in Sweden (*16, 41*) it was noted that occupants paying individually for heat, hot water, and electricity use at least 15 percent less than those paying indirectly by sharing the cost in the rent.

An important mechanism for supplying space heat in Sweden is district heating, in which central stations either produce heat alone, or cogenerate heat and electricity. District heating supplies 19 percent of the total residential heat needs in Sweden (*16*). The energy balance for Swedish thermal power plants shows that 24 percent of the kilowatt-hour input appears as warm water or steam, primarily for heating of homes and buildings, and 29 percent as electricity (*21, 55a*). Figure 4 illustrates the combined electricity-heat balance for the United States and Sweden for 1971. In Malmö, a city of 250,000, combined electricity-heat stations provide heat for more than 50 percent of the homes (*55b*). The overall effect of these systems, after the slightly lowered production of electricity is taken into account, is a net saving of fuel of 1300 kwh per capita, which is 2 percent of the total energy consumption in Sweden. These savings are somewhat offset by the high demand for heat and hot water in unmetered

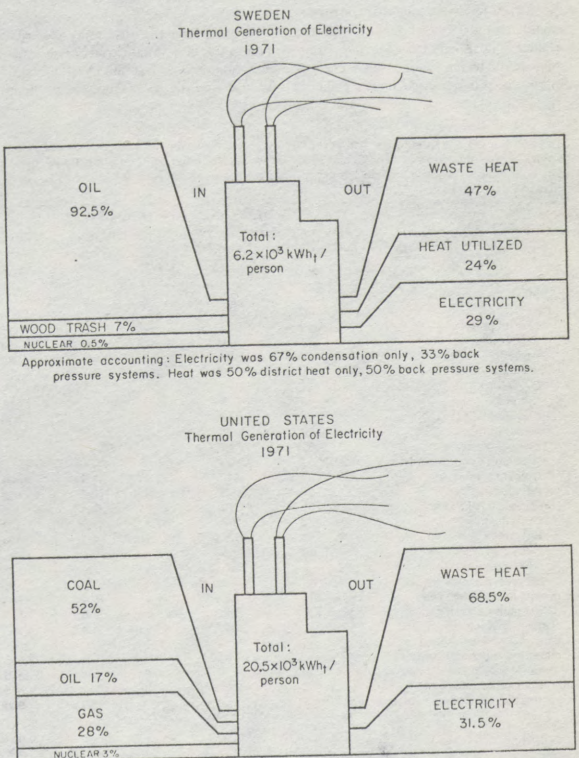


Fig. 4. Use of fuel to produce electricity in Sweden and the United States in 1971. The Swedish data exclude some process heat supplied to paper and mining industries (500 kwh per capita). The U.S. data exclude a small amount of co- and self-generation in industry. Data are from (*16, 21, 29, 55a*).

apartments in Sweden compared to single-family dwellings.

Industrial energy use. In both Sweden and the United States the largest use of energy in industry is for basic materials processing. In Sweden this energy use is highly concentrated, five sectors accounting for 85 percent of the net use (*16, 21, 30–35, 56–64*).

In Table 9 we see that larger fractions of Sweden's manufacturing value added and energy use are concentrated in the five energy-intensive sectors. Additionally, the energy use in each sector and the value added are more concentrated toward materials processing—organic chemicals versus drugs, paper mills versus paper products, and so forth. Thus the mix of output in Swedish industry is more energy-intensive than in U.S. industry. This is reflected in the E_j for the total of the energy-intensive industries, which is slightly higher in Sweden than in the United States, as is the aggregate E_j for all manufacturing. While some energy-intensive products, such as plastics, chemicals, and aluminum, are made in greater per capita quantities in the United States, steel, cement, paper, and pulp are made in greater per capita amounts in Sweden. Much of Sweden's energy-intensive raw output is exported.

However, these measures of intensity can be misleading. As Table 10 shows, the process energy intensity (E') is significantly lower in Sweden for virtually every product, usually because of reduced process heat requirements. We note that similar differences in process energy intensities were found in the study of West Germany (*11*). These findings suggest that Sweden's industry is more energy-efficient than our own. More important, though, these findings stress the inaccuracy of measuring energy use, or efficiency, by aggregate ratios of energy use to value added or GNP, as done in (*1*).

Swedish industries use more electricity as a fraction of industrial energy consumption, or as a fraction of all electricity used in the whole economy, than their American counterparts. This effect can be understood by noting that historically nearly all of Sweden's electricity has been generated from hydropower, the predominant domestic energy resource; industries could be expected to utilize this resource, which has been less costly than steam-based electricity. Since electricity prices are similar, we attribute the higher electric intensity of Swedish industry to the lower ratio of the price of electricity to the price of fuels, as compared to that in the United States, where most electricity is steam-based. These costs and the quantities used are summarized in Table 11.

Other factors in Sweden tend to reduce specific industrial energy consumption compared to that in the United States. Sixty percent of all fuel used in the paper industry (which consumed 15 percent of all energy in Sweden) is provided internally by barks and liquors, as opposed to 35 percent in the United States (*21*); but a third of the electricity used by that industry (and smaller frac-

Table 9. Energy use in industry—an economic overview. Data for the United States are from (*30, 56, 57*), data for Sweden from (*16, 33–35*). Values of kwh include kwhe. The E_j and T_j values are net; for gross kwht, multiply by [(2 kwhe/kwh) + 1], where the kwh and kwhe are from T_j. The U.S. figures for kwhe include self-generation, but these are not included in the E_j's. The U.S. E_j's are for 1971; value added from (*56*) was inflated to 1971 dollars.

Industrial sectors	D_j Value added ($/capita)		E_j (kwh/$)		T_j U.S. (1971)		T_j Sweden (1970)	
	U.S.	Sweden	U.S. (1971)	Sweden (1970)	kwh	kwhe	kwh	kwhe
Manufacturing								
Paper*	62	101	44	75	3,200	290	7,625	1,300
Market pulp	2	34			125	25	3,680	500
Paper mills	24	60			2,500	230	3,895	800
Percent of sector†	40%	84%			82%	88%	99%	100%
Chemicals	156	62	25	18	3,930	575	1,135	540
Organic	16	7			1,575	110	80	250
Inorganic		9			1,220	250	110	100
Plastics and fibers	24	18			630	80	305	80
Agricultural	8	7			115	15	120	55
Percent of sector	31%	49%			90%	79%	54%	90%
(Feedstocks consumed)‡					(4,600)		(1,600)	
Petroleum products	30	11.5	142.9	81.7	4,000	145	940	30
Refining§	25	8	152.0	112.5	3,800	135	900	23
Stone, glass, and clay	51	50	36.3	32.5	1,850	120	1,625	150
Primary metals	110	103	51.8	37.7	5,700	710	3,880	910
Basic steel	46	74			4,390	190	3,065	500
Alloys	10	3			80	35	280	160
Nonferrous	8	6			640	300	370	225
Percent of sector	57%	81%			90%	74%	96%	97%
Total energy-intensive‖	421	328	44.4	46.4	18,680	1,840	15,205	2,930
Other manufacturing	1,320	808	3.4	2.0	4,525	1,050	1,600	710
Total manufacturing	1,741	1,137	13.3	14.8	23,205	2,750	16,805	3,640
Energy harvest (excluding refining and electrical utilities)					2,500	230	500	280
Mining					570	100	570	180
Agriculture and forestry					1,825	55	510	200
Construction (excluding vehicles)					900	16	650	85
Total industry (excluding feed stocks)					29,020	3,290	19,035	4,385

*Includes wood wastes. †The value added is given for groups that are more energy-intensive than the average. Percent of sector gives the percentage of the sector contained therein. It can be seen that Sweden's value added is more concentrated in these sectors. ‡Feedstocks for Sweden are estimated from (*31–33*). These are excluded from totals. §Includes captive consumption not counted in most Swedish studies, but found in (*31, 32*). Feedstocks are subtracted from refining losses in (*31*). Here 500 kwh per capita of nonfuel petroleum (lubricants and so forth) is omitted, but it is counted in Table 2. The Swedish refining 7 could be as low as 700. ‖Excludes self-generation for electricity totals, except 400 kwh of self-generation in paper and pulp industries in Sweden.

tions elsewhere) is cogenerated with steam production (*16, 21, 55a*), thus reducing fuel needs. Cogeneration has also achieved considerable energy savings in Germany (*11*), and is considered to be economic for the United States (*65*), where half of the electricity consumed in the paper industry is self-generated, but only a small amount is cogenerated.

Like process industries, assembly industries in Sweden tend to show a lower use of fuel per unit of product (or value added) than those in the United States. This is in spite of greater space heating requirements in Sweden, which in some cases surpass requirements for electric drive and lights. A total of 20 percent of Sweden's industrial energy use is for space heating. In the entire Volvo concern, encompassing several large assembly plants, 1974 energy use was estimated at 0.6×10^9 kwh for space heat and hot water, a similar amount for process heat, and an equal amount for electricity, of which one-third went for lighting and office use. [Volvo was able to cut its total energy use 25 percent after the oil embargo through "leak plugging" (*62a*).] If Swedish industrial fuel use were adjusted to take into account the difference in climate, it would be 10 percent lower.

The relatively more modern equipment in Swedish industry—Sweden's capital stock has grown significantly faster than ours as the Swedish GNP approached ours—certainly contributes to the higher efficiency. Both U.S. and Swedish industry have improved energy efficiency through technological change since World War II, in spite of generally falling energy prices (*56*). A comparison of data collected by Meyers *et al.* (*56*) with Swedish data (kilowatt-hours per ton or per dollar) suggests that the energy intensity of Swedish industry today would lie 10 to 15 years hence on the projected curves of Meyers *et al.* for U.S. industry. Significantly absent from Swedish industrial energy use were (and are) "interruptable" gas at bargain prices and cheap coal, two fuels that have been important to many U.S. industries and whose low price and availability fostered higher energy use in the past. The importance of relatively higher prices for energy in Sweden as a major factor in its relative energy efficiency was emphasized in a series of studies by Carlsson (*61*); see also (*16*), vol. 2, appendix 3.

Both official Swedish government forecasts (*16*) and the views of individuals in industry (*61–63*) reflect the belief that

Table 10. Materials and energy consumption data for the United States and Sweden. Data are for 1970 and 1971; U.S. data are from (*5, 7, 11, 24, 30a, 56, 59*). Swedish data from (*7, 16, 23, 32, 33, 60*). Electricity was included (net) in E_j. The T_j value for Sweden reflects 3 kwht/kwhe.

Material	D_j' (kg/capita)		E_j' (kwh/kg)		E_j' (kwhe/kg)		T_j (kwh/capita)		T_j^* (kwht/capita)	
	United States	Sweden	United States	Sweden	United States	Sweden	United States	Sweden	United States	Sweden
Basic steel*	580	650	7	4.8	0.5	1.0	4000	3100	4640	4420
Aluminum†	17	9	17.7	17.7	17.0	17.0	300	160	880	465
Oil refined‡	2900	1400	1.4	0.7	0.05	0.05	4060	900	4350	940
Market pulp‡	~ 1	550	9	6.7	1	1		3685		4900
Paper, including pulping§	260	550	9.5	6.6	1.5	1.5	2470	3630	2860	4730
Cement	342	460	2.0	1.6	0.1	0.1	685	735	755	830
Organic chemicals‖	234	89	6.7	4.0			1575	355	1800	855
Inorganic chemicals‖	100	87	12.2	4.4			1220	390	1720	600
Plastics and fibers‖	51	43	12.3	5.0			630	215	790	375
Fertilizer‖	105	67	1.0	1.8			115	115	145	230
Feedstocks (energy)‖	480	215	11.63	11.63			5600	2500		

*We did not include the energy content of scrap, estimated at an average of 500 kwh/ton for the United States and 1000 kwh/ton for Sweden, averaged over all steel. †Counts only the smelting of Al_2O_3 to Al. Refining of bauxite takes place in the United States but not in Sweden. ‡The U.S. oil refining E_j is from (*56, 59*). Swedish losses are estimated from (*31*) and (*33*). The last source gives a very low figure of 0.65 kwh/kg, but estimates based on the known flow of oil through refineries indicate 1.0 kwh/kg. We do not account for differences in refinery output mix. §Pulp and paper values include the energy in wood wastes and liquors. This amounts to 1000 kwh per capita for the United States (*30a, 59*), and about 4000 kwh per capita for Sweden (*16, 21*). Sweden uses more wood waste for fuel per ton of output, and uses fewer external fuels as well. Swedish electricity was one-third cogenerated, and U.S. electricity about half that. ‖Values of *E* for chemicals are difficult to obtain and to compare. Feedstocks used, including road oils, were converted to kilograms by using the approximate relation 1 kg (oil equivalent) = 11.63 kwh. Energy consumed by uranium enrichment in the United States is counted in industrial chemicals (*57*).

Table 11. Energy intensities and costs in industry. The U.S. data (for 1971) are from (*56, 57, 60*), Swedish data (for 1970) from (*16*). Price figures are for purchased fuels only. Electricity data are for purchased electricity, except for the Swedish paper industry. Subscripts e and f mean electricity and fuel.

Industry	T_j (kwh/capita)		*E* (kwh/$)		*P* (¢/kwh)		P_e/P_f	
	United States	Sweden	United States	Sweden	United States	Sweden	United States	Sweden
Five energy-intensive industries (excluding feedstocks)*								
Fuel	16,840	12,275	40	37.4	0.15	0.20	5.4	3.75
Electricity	1,840	2,930	4.4	8.9	0.81	0.75		
Other manufacturing†								
Fuel	3,475	900	2.6	1.1	0.19	0.36	6.3	3.1
Electricity	1,050	710	0.8	0.9	1.2	1.1		
Total manufacturing								
Fuel	20,315	13,175	11.7	11.6	0.16	0.22	6.25	3.7
Electricity	2,890	3,640	1.7	3.2	1.0	0.82		

*Energy-intensive industries include paper [Standard Industrial Classification (SIC) 26, Svensk Näringsgrenindelning (SNI) 341], chemicals (SIC 29, SNI 353 and 354), stone glass and clay (SIC 32, SNI 36), and primary metals (SIC 33, SNI 37). †"Other" industries include SIC 20 to 25, 27, 30, 31, and 34 to 39, and SNI 31 to 33, 342, 355, 356, 38, and 39.

optimization to counter ever-increasing fuel prices will further reduce specific energy requirements of Swedish industry toward the end of the century, as many have also predicted for the United States (*3, 4, 56*). Since Sweden traditionally has paid a high industrial wage, the saving of energy has come about not by direct substitution of labor for energy, but through the substitution of energy management (*62*) and capital [Carlsson in (*16*), vol. 2, appendix 3] for energy.

Other factors in resource use in Sweden contribute to both lower demand per product and lower demand for energy-intensive products themselves. It was noted above that Swedish cars outlast American cars, weigh less, and use materials that themselves require less energy than their American counterparts. Furthermore, Swedish consumers have maintained the widespread use of returnable bottles. Other utilization patterns (relative sizes of D_j) are interesting; in the late 1960's plastic bags became popular, only to be replaced by paper again as the cost of plastic, made from imported petroleum, rose compared to the cost of paper, made largely from domestic sources. We can generally conclude that cultural and institutional factors combine with economic and technical factors to effect energy savings in the industrial sector in Sweden relative to the United States. This is mainly done by increasing efficiency (lowering the E_j's); but changing the mix of products (mix of D_j's) actually consumed in Sweden toward lower energy intensity is also significant in some areas.

Imports and exports of goods. Since imports and exports comprise an important part of economic activity it is important to evaluate the energy embodied in nonenergy trade, as well as the process energy embodied in refined fuels, such as gasoline. We consider direct energy to be that applied by the producer of a good or service, and indirect energy that required to produce the materials and services used by the producer. For the United States, Herendeen and Bullard (*35*) found that while nonenergy imports and exports contained equal amounts of energy, the imports of refined oil embodied more energy than exports of coal and refined oil products (excluding the heat of combustion of these fuels). A similar balance for Sweden was evaluated by the Energi Prognos Kommitéen (*16*). The results, summarized in Table 2, show that Sweden's energy use per capita is overestimated due to an export surplus of embodied energy; the United States has a small import surplus. In contrast, Denmark's per capita energy use is considerably underestimated, as shown by Elbaek (*8b*), who found that the energy balance of trade amounted to an import of 20 percent of the energy consumed in Denmark. By contrast, West Germany has a large export surplus (*11*). Note that in every case the energy embodied in import of fuel is much larger than any of these figures. We conclude that an accounting of the energy embodied in foreign trade widens the difference in energy use between Sweden and the United States.

Electricity production and district heating. Sweden is rich in hydropower, an energy source that accounted for approximately 14 percent of all energy and 75 percent of all electricity produced in 1972. In Swedish statistics the electricity is counted at 85 percent First Law efficiency. Since most of Sweden's hydroelectric resources are in the far north, transmission line losses are greater than in the United States, per net kilowatt-hour sold.

About 35 percent of Sweden's fuel-based electricity came from combined heat-electricity systems, which produce more useful kilowatt-hours per kilowatt-hour total consumed than do purely electrical-thermal plants (*16, 55a*). In 1971 Sweden consumed fuel amounting to about 4.11 Mwh per capita to produce 1.77 Mwh per capita of electricity, for a "heat" rate of 2.32 kwht/kwhe. This is illustrated in Fig. 4, in which 0.8 Mwh per capita heat-only production is included. If the heat and electricity had been generated separately, about 1.3 Mwh per capita additional fuel would have been required if the heat was then produced in central plants, and about 1.5 Mwh per capita more if it was produced in smaller boilers. Only the half of the combined heat-electricity and heat-only systems that are in or near cities, to supply residential and commercial heat, are included in Fig. 4. The other half, located in industries, primarily paper, doubles the energy savings given above. Central heat-only plants provide heat for 600,000 dwellings, at 85 percent fuel to home (First Law) efficiency, compared to 65 percent for boilers in apartments. This

Table 12. Typical energy prices in the United States and Sweden. The exchange rate used is $1 = 5.18 Skr (1960 to 1970) and 4.30 Skr (1974). The U.S. data are from (*15, 24, 57*); Chern (*58*) gives the following prices (¢/kwh) for U.S. industry as a whole in 1971; gas, 0.13; coal, 0.12; oil, 0.23; electricity, 0.98; and other, 0.25. Compare with Swedish prices. The Swedish data are from (*16, 23, 48*) and a 1975 press release from the Swedish embassy.

Energy type	United States				Sweden			
	1960	1970	1974	1970 (¢/kwh)	1960	1970	1974	(1970) (¢/kwh)
Oil products (¢/gallon)								
Gasoline*	30	35	45	1.04	53	61	116	1.82
Diesel	23	28	35	0.83	42	48.8	90	1.45
Heating oil								
Small customers	15	18	35	0.50	13.3	13.2	40.6	0.37
Large customers	10.5	12	25	0.33				
Heavy oil	7	8	23	0.23	7	8.5	22.5	0.24
Gas (¢/MM Btu)								
Residential	82	87	113	0.29		550	680†	1.9
Industrial								
Firm Service	51	50		0.17				
Interruptable service	33	34		0.11				
Coal, industrial ($/ton)‡	10	13	25	0.14		18		0.2
Electricity (¢/kwh)								
Base	2.75	2.75		2.75	3.14‖	2.12‖	2.3§‖	
Base and space heating	1.75	2.0		1.5		~1.5	2.0§	
Industrial	1	1	1.5	0.4–2.1		0.93	1.8§	0.6–2.2

*Swedish gasoline taxes: 42¢ per gallon in 1970, about 68¢ per gallon in 1974. The U.S. prices include a tax of 10 to 13¢ per gallon. †Data for 1973. ‡Coal price excludes captive and utility coal. §Data for 1975. ‖Swedish figures are based on 1700 kwh/year (1960), 3000 kwh/year (1970), and 2000 kwh/year (1974).

saves 5100 kwh per dwelling or 375 kwh per capita. Another 25 kwh per capita is saved by district heating of buildings, for a total savings of about 400 kwh per capita from heat centrals. These savings must be added to those obtained by use of district heat from combined generation. The use of back pressure and heat-only centrals, in Sweden, leads to a heat rate of about [illegible]. Applying this thermal heat rate to hydropower in Sweden leads to a value of kwht which is 12 percent greater than the net kwh. This is in contrast to the 20 percent increase in Table 2 that was obtained by applying the U.S. heat rate to Swedish hydropower.

An additional factor that should be taken into account when comparing electricity use is that, stimulated by the low ratio of the price of electricity to the price of fuel, Swedish industry tended to use electricity for a wider range of tasks. Had electricity been 85 percent thermally generated, as in the United States, it would have been more expensive, and therefore used more sparingly (*66*).

Analysis of Differences in Energy Use; Conclusions

In Table 12 we show explicitly some important energy prices for Sweden and the United States. The largest price differences occur in road fuels, even before the higher taxes on automobiles in Sweden are considered. Electricity, on the other hand, has been relatively inexpensive (compared to fuel) in Sweden, because in the past a large share of electricity has been hydropower (*66*). In 1971 electricity use in Sweden (7400 kwh per capita) was close to that in the United States (7700 kwh per capita), but more of this total was used in the industrial sector in Sweden and more in the residential and commercial sector in the United States. Other fuels in Sweden lie between these two extremes, being slightly more expensive in Sweden (before 1973) and used more efficiently there as well. Since the price of oil used for home heating in Sweden was comparable to U.S. values (until 1973), the length of the heating season, as well as institutional factors mentioned above, must account for the efficient use of that fuel for space comfort. Significantly, Sweden had no natural gas or domestic coal, two fuels whose low prices certainly encouraged intensive use in the United States.

Higher energy prices alone, however, do not account for the more efficient energy use in Sweden. In this article and elsewhere (*4*) it has been stressed that, while a particular set of energy prices determines a mix of energy and other economic factors that allows production for the least cost, institutional and social factors determine how close individual consumers, firms, and society as a whole come to this most economic energy use. In the United States, for example, mortgage policies and market considerations constrain developers to minimize first costs, rather than life-cycle costs, constraints that do not appear to be applicable to construction in Sweden. Also, building codes have imposed energy-conserving construction more uniformly in Sweden, and the Swedish government has given priority to energy conservation in housing loans (*52*). Energy conservation in passenger transport in Sweden has also been strongly influenced by government policy, in this case mainly through the market mechanism, by various taxes and incentives. These factors also have important synergistic effects. Good intracity transport, and high costs of operating an automobile, tend to keep the population more concentrated. In addition to maintaining the viability of the public transport system itself, this situation also affects housing and living patterns in energy-saving ways. With increased population densities apartment living is more common, potentially effecting energy savings through fewer external walls, better insulation, and more efficient heating systems. Shopping also becomes easier, with more neighborhood stores; trips are shorter, often on foot; and smaller storage facilities are

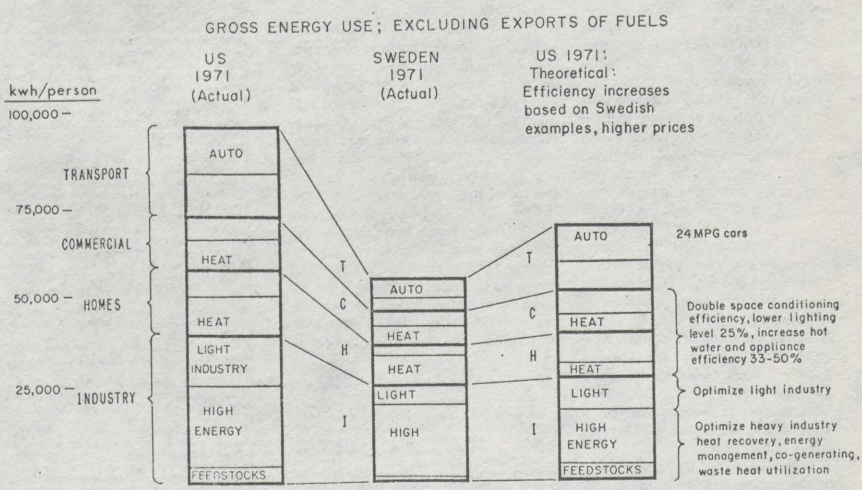


Fig. 5. Summary of U.S. and Swedish energy use in 1971, and theoretical U.S. energy use based on Swedish intensities in industry, space conditioning, and automobiles (miles per gallon). For theoretical U.S. use it is also assumed that appliance use and lighting levels decrease by 33 percent. Freight, airlines, and energy extraction are ignored, but higher air-conditioning and lighting efficiency are factored in. Life-style factors (such as numbers of appliances and passenger miles) were not considered. Values in the column at the left are kwh per capita. Compare with (*3*—*5*).

required, resulting in smaller refrigerators with consequent electricity savings.

In a recent study of energy use in the United States, Hannon (67) suggested that lowering the energy requirement for an economy by changing life-styles and the mix of consumer goods (the D_j's) would be difficult, because consumer expenditures would generate energy requirements no matter how they were directed. We have shown here that in Sweden the D_j's are shifted toward less energy-intensive activities, and the E_j's toward higher efficiency. For both effects, dollars saved by saving energy in one activity and respent on another do not, on the average, generate as much energy use as expenditures for a more energy-intensive mix of D_j's, or activities with less efficient E_j's, would have done. All energy intensities are reduced through higher efficiencies (conservation), and shifts from more to less energy-intensive activities are made at the same dollar level. Sweden, like other European countries, developed these energy economies to offset its higher energy prices and balance of payments problem resulting from importing energy. This resulted in a higher standard of living for a particular level of energy consumption. This suggests the answer to the dilemma posed by Hannon: in the face of energy scarcity and consequent rising energy prices, consumers in the United States would seek to maintain their standard of living by optimizing energy use both through increased energy efficiency and through shifting to less energy-intensive activity.

Future work should further elucidate both the underlying causes of and the mechanisms for achieving higher energy use efficiency in Sweden. At this point we offer some tentative conclusions about energy use based on our comparison of Sweden and the United States.

1) For a particular GNP, the efficiency of energy use, demographic factors, and the mix of goods and services share in determining the energy requirements of an economy.

2) Some of the main factors that have accounted for the reduced energy use in Sweden are smaller automobiles, more use of mass transit, more insulation and tighter construction, more efficient industrial processes, and the use of cogeneration and district heating.

3) Higher efficiency (lower E values) accounts for the largest portion of the lower energy use in Sweden arising from these factors.

4) Counting hydropower at 3 kwht/kwhe, as is done in U.S. accounting, results in a ratio of Swedish to U.S. energy consumption of 0.6, while using a one-to-one accounting results in a ratio of 0.5. The difference, although significant, does not account for the dramatically lower Swedish energy use.

5) The most important variable affecting energy use and energy efficiency is the relative price of energy with respect to other resources. However, institutional and social factors are also important.

6) It is necessary to consider individual energy intensities (E_j's) as well as levels of activity (D_j's) in order to understand energy uses and needs. Consideration of only total energy use (ΣT_j) or the energy/GNP ratio (*1, 28, 68*) obscures dramatic differences in intensity (or efficiency) and economic structure. Similarly, forecasts of energy "needs" in which the aggregated quantities are used also overlook vital details and trends in the components of E and D, components that may be more or less sensitive to changes in energy prices.

Although we have seen that energy use in Sweden is generally more efficient than that in the United States, both countries can improve energy use effectiveness by optimizing to the higher energy prices that have developed since the period we examined. Our comparison indicates that many energy conservation measures are available to the United States, as energy prices continue to rise. The Swedish economy performs well as a (relatively) energy-efficient economy, suggesting that more efficient energy use will not interfere with the function of the American economy. While we hesitate to give an exact figure, we suggest that Swedish methods of energy conservation, including smaller cars, better structures, and more efficient use of process heat, would result in a savings of 30 percent of the total energy used in the United States (Fig. 5). Thus, international energy use comparisons, far from suggesting an inevitable coupling between level of economic activity and energy use, actually suggest ways in which more well-being can be wrought from every Btu of fuel and kilowatt-hour of electricity consumed in a given country (*69*).

References and Notes

1. H. R. Linden, *Testimony Before the President's Energy Resources Council* (10 December 1974), or *Resource, Economic and Historic Considerations Related to Issue of Energy Policy* (1975). Both are available from the Institute for Gas Technology, Chicago, Ill.
2. Except where popular use dictates American units (for example, miles per gallon or degree-days Fahrenheit), we use kilowatt-hours as our standard unit: kwh means fuel or electricity used in end consumption; kwhe refers to electricity only; and kwht refers to total consumption of energy with electric conversion losses included at the rate of approximately 2 kwh lost per kwhe produced. All tons are metric.
3. M. Ross and R. Williams, *Assessing the Potential for Fuel Conservation* (Institute for Public Policy Analysis Report 75-02, State University of New York, Albany, 1975); available from M. Ross, Department of Physics, University of Michigan, Ann Arbor; *Technol. Rev.*, in press.
4. L. Schipper, *Energy Commun.* 2 (No. 4), 33[illegible] (1976); in *Annual Reviews of Energy*, J. Hollander and M. Simmons, Eds. (Annual Reviews, Palo Alto, Calif., 1976), vol. 1, pp. 455–517.
5. A. Makhijani and A. Lichtenberg, *Environment* 14 (No. 5), 10 (1971).
6. "World alternative energy strategies project" (S. Carhart and P. Craig, personal communication) and "Energy consumption and economic activity and comparative patterns in nine industrial countries," Resources for the Future, Inc., Washington, D.C. (J. Darmstadter, J. Dunkerley, J. Allerman, in preparation).
7. A. Doernberg, "Comparative analysis of energy use in Sweden and the United States," *Brookhaven Natl. Lab. Rep. BNL-20539* (1975).

8a. Industri Department, *Danmarks Energi Forsyning i Fremtiden* (Denmark's Energy Supply in the Future) (Copenhagen, 1974).

8b. See also B. Elbaek, *Energi—Energi—Energi Kris* (Munksgaard, Copenhagen, 1975).

9. Ministry of Industry, *Energiforsyningen i Norge på Fremtiden* (Energy in Norway in the Future) (Oslo, 1974). See also H. Parr, P. Hofseth, K. Byrne, J. Riekeles, *Energi Miljo og Samfunn* (Energy, Environment, and Society) (Norges Naturvernforbund, Oslo, 1974).
10. J. D. Parent, *Some Comments on Energy Consumption and GNP* (Institute for Gas Technology, Chicago, Ill, May 1974; revised October 1974).
11. R. Goen and R. White, *Comparison of Energy Consumption Between West Germany and the United States* (Government Printing Office, Washington, D.C., 1975).
12. T. D. Mount, L. D. Chapman, T. J. Tyrrell, "Electricity demand in the United States: An economic analysis," *Oak Ridge Natl. Lab. Rep. ORNL-NSF-EP-49* (1973).
13. W. J. Mead, private communication.
14. Foster Associates, *Energy Prices 1960–1970* (Ballinger, Cambridge, Mass., 1974).
15. Federal Energy Administration and American Gas Association, *A Pilot Project in Homeowner Energy Conservation* (Government Printing Office, Washington, D.C., 1974).
16. Energi Prognos Kommiteen, Ministry of Industry, Stockholm, *Energi, 1985–2000 (Energi Prognos Utredningen [EPU])* (Allmänna Förlaget, Stockholm, 1974).
17. K. Munther, *Energi-Förbrukning i Småhus* (Energy Use in Single Family Dwellings) (Statens Institut för Byggnadsforskning Report 58, Svensk Byggtjänst, Stockholm, 1974).
18. In this and other examples Swedish usage is adjusted to reflect 60 percent fossil-fueled heating (First Law) efficiency.
19. S. H. Schurr and B. C. Netschert, *Energy in the American Economy, 1850–1970* [Johns Hopkins Press (for Resources for the Future), Baltimore, Md., 1960].
20. I. Kravis, *A System of International Comparisons of Gross Product and Purchasing Power* (Johns Hopkins Press, Baltimore, Md., 1975).
21. *Effektivare Energi Användning* (More Efficient Energy Use) (Report 181, Ingenjörs Vetenskaps Akademi, Stockholm, 1975).
22. *Some Facts About Sweden* (Skandinaviska Enskilda Banken, Stockholm, 1974–1975). We use 5.18 Skr = $1. In 1974 the applicable rate would be approximately 4.30 Skr = $1.
23. *Statistiska Årsboken* (Statistical Abstracts of Sweden) (Statistiska Centralbyrån, Stockholm, 1972–1975), with English summaries.
24. Department of Commerce, *1975 U.S. Statistical Abstract* (Government Printing Office, Washington, D.C., 1975).
25. K. Hultgren, *Människan och Bilsamhället* (People and the Automobile Society) (Norstedt, Stockholm, 1974).
26. L. Anell, A. Hedborg, M. Lönnroth, L. Ingelstam, *Skall vi Asfaltera Sverige?* (Should We Pave Over Sweden?) (Norstedt, Stockholm, 1971).
27. We use 68°F as a base temperature for both countries, and we ignore appliance heat loads and so forth. This understates heating differences because appliance use is somewhat greater in the United States, while insolation in Sweden is small compared to nearly all of the United States in the winter. Peak cold temperatures are not as low in Sweden as in our North Central, Rocky Mountain, and New England states, but average temperatures are comparable, and the Swedish winter is longer.

28. W. Dupree and J. West, *United States Energy Through the Year 2000* (Government Printing Office, Washington, D.C., 1972, updated 1975).
29. E. Cook, *Study of Energy Futures* (Environmental Design Research Associates, Chapel Hill, N.C., 1975).
30. R. Knecht and C. Bullard, *Direct Use of Energy in the U.S. Economy* (Technical Memo No. 43, Center for Advanced Computation, University of Illinois, Urbana, 1975).
30a. Stanford Research Institute, *Patterns of Energy Consumption in the U.S.—1968* (Government Printing Office, Washington, D.C., 1972).
30b. M. Beeler, *Source Book for Energy Assessment* (Brookhaven National Laboratory, Upton, N.Y., 1975).
31. *Verksamheten* (Activities) (Ångpanneforeningen, Stockholm, 1971-1976).
32. *SOS Industri 1970–73* (Sweden's Official Statistics—Industry 1970–73) (Statistiska Central Byrån, Stockholm, 1972-1975).
33. Energi Program Kommitteen (EPK), *Energiforskning*, vol. A, *Energin och Naringslivet* (Energy R & D: vol. A, Energy and the Economy) (Allmanna Forlaget, Stockholm, 1974).
34. The latest energy use data for Sweden are published as part of the Energy Conservation Bill in the Parliament: *Energy-Hushållning* (Energy Husbandry) (Ministry of Industry, Stockholm, February 1975). See also *Energiförsörjningen 1975–1980*, Rapport av Statens Industriverk (Allmanna Forlaget, Stockholm, 1976).
35. R. Herendeen and C. Bullard, *Energy Syst.*, in press.
36. E. Hirst, "Energy intensiveness of passenger and freight traffic, 1950-1970," *Oak Ridge Natl. Lab. Rep. ORNL-NSF-EP-41* (1973).
37. Federal Highway Administration, *Estimated Motor Vehicle Travel in the United States* (Washington, D.C., 1970–1975).
38. Federal Highway Administration, *Nationwide Personal Transportation Survey* (Government Printing Office, Washington, D.C., 1970).
39. Federal Energy Administration, *Project Independence: Energy Conservation: Transportation* (Government Printing Office, Washington, D.C, 1974).
40. Ministry of Communications, *Regionalu Trafikplanering* (Regional Traffic Plan) (Stockholm, 1972); *Transporter i Sverige* (Transportation in Sweden) (Report Dsk 1975: 4, Stockholm, 1974); Swedish Institute, *Fact Sheet of Swedish Transportation* (Swedish Information Service, New York, 1973).
41. Energi Beredskaps Utredningen (EBU), *Energi: Beredskap i Kristid* (Energy: Preparedness During Crisis) (Allmanna Forlaget, Stockholm, 1975).
42. Motor Vehicle Manufacturers Association, *Automobile Facts and Figures* (Detroit, 1975); *Motor Vehicles and Energy* (Detroit, 1974).
43. K. Austin and K. Hellman, *Passenger Car Fuel Economy* (SAE Paper 730790, Society of Automotive Engineers, New York, 1973).
44a. *Motor Traffic in Sweden* (AB Bilstatistik, Stockholm, 1974 1975).
44b. See also J. Ullen, *Bilfakta* (Auto Facts) (Jan Ullen AB, Stockholm, 1975), vol. 28.
45. Energi Program Kommitteen, *Energiforskning*: vol. C, *Transport och Samfardsel* (Energy R & D: vol. C, Transportation) (Almanna Forlaget, Stockholm, 1974).
46. Statens Vägverk, *Personbilarnas Arliga Korlangd* (Yearly Private Car Vehicle-Miles) (Stockholm, 1971).
47. K. Austin and K. Hellman, *Passenger Car Fuel Economy as Influenced by Trip Length* (SAE Paper 750004, Society of Automotive Engineers, New York, 1975).
48. Svenska Esso, *Oljeåret 1974* (Oil Year 1974) (Stockholm, 1975).
49. A. Makhijani and A. J. Lichtenberg, *An Assessment of Residential Energy Use in the U.S.A.* (ERL M-310, Univ. of California Engineering Research Laboratory, Berkeley, 1973).
50. J. Moyers, "The value of thermal insulation in residential construction," *Oak Ridge Natl. Lab. Rep. ORNL-NSF-EP-9* (1972).
51a. Federal Energy Administration, *Residential and Commercial Energy Use Patterns, 1970–90* (Government Printing Office, Washington, D.C., 1974).
51b. See also S. Dole, *Energy Use and Conservation in the Residential Sector: A Regional Analysis* (R-1641-NSF, Rand Corporation, Santa Monica, Calif., 1976).
52. Indeed, the mortgage law of 1957 gave priority to home builders or buyers who intended to insulate beyond the building code minimums. A newer program (1975) provides greater subsidies, direct grants, and local testing programs, with total outlays of over $350 million over 3 years.
53. Centrala Driftledningen, *Sveriges Elkonsumtion, 1975–1985* (Sweden's Electricity Use, 1975–1985) (Stockholm, 1972).
54. Energi Program Kommittéen, *Energiforskning*: vol. D., *Uppvärmning och Lokal Komfort* (Energy R & D: vol. D, Heating and Space Comfort) (Almänna Förlaget, Stockholm, 1974).
55a. Swedish District Heating Association, *Combined Heat and Power, 1975* (Värmeverksförening, Stockholm, 1976).
55b. R. Johnson and L. Bell, *Malmö's Powerplants* (Industriverket, Malmö, Sweden, 1973).
56. J. Meyers *et al.*, *Energy Consumption in Manufacturing* (Ballinger, Cambridge, Mass., 1975).
57. Department of Commerce, *Census of Manufacturers* (Energy Data for 1971) (Government Printing Office, Washington, D.C., 1972).
58. W. Chern, "Electricity demand by manufacturing industries in the U.S.," *Oak Ridge Natl. Lab. Rep. ORNL-NSF-EP-87* (1975).
59. E. Gyftopolous, L. Lazaridis, T. Widmer, *Potential Fuel Effectiveness in Industry* (Ballinger, Cambridge, Mass., 1975).
60. S. I. Kaplan, "Energy demand patterns of eleven major industries," *Oak Ridge Natl. Lab. Rep. ORNL-TM-4610* (1974).
61. B. Carlsson, in *IUIs Langtidsbedömning 1976* (Industrins Utrednings Institut, Stockholm, 1976), p. 270; lecture at Industrial Energy Day, Stockholm, May 1976.
62a. Swedish Federation of Industries, *Energy Conservation in Swedish Industry* (Industriförbundets Förlag, Stockholm, 1974).
62b. A. Iveroth and B. Helmerson, *Industrin och Energi* (Industry and Energy) (Industriförbundets Förlag, Stockholm, 1974).
63. Statens Industriverk, *Tätorternas och den Tunga Industrins Energi Försörjning* (Energy Supply to Industry and Built-Up Areas) (Liber Förlag, Stockholm, 1976).
64. U. Norhammer *et al.*, *Samlat Energikunnande* (Collected Energy Skills) (Ångpanneföreningen, Stockholm, 1975).
65. Dow Chemical Co.; Environmental Research Institute; Greenspann-Townsend, Inc.; Cravath, Swaine, and Moore, Inc., *Energy Industrial Center* (National Science Foundation, Washington, D.C., 1975).
66. In Sweden, government-owned power stations, including hydroelectric facilities, produced 50 percent of the total electricity. These stations were financed at commercial interest rates, in contrast to most government-owned power in the United States.
67. B. Hannon, *Science* **189**, 95 (1975).
68. F. Felix, *Electr. World* **184** (No. 9), 64 (1975).
69. J. Holdren, *Bull. At. Sci.* **31**, 26 (December 1975).

70. This research was supported in part by the Lawrence Berkeley Laboratory, University of California, under ERDA contract W-7405-Eng-48. We also acknowledge the support of the Energy and Resources Group, University of California. One of us (L.S.) has also received grants from the Society for the Advancement of Scandinavian Studies and the Swedish Information Service, San Francisco. We acknowledge the helpful suggestions of J. Holdren, R. Herendeen, C. Bullard, and B. Carlsson. Måns Lönnroth (of the Secretariat for Future Studies, Stockholm) provided invaluable help in coordinating our research efforts in Sweden. This work is based on report LBL-4430 from the Lawrence Berkeley Laboratory.

Life Events, Stress, and Illness

Judith G. Rabkin and Elmer L. Struening

Studies relating social factors and life events to illness appear with remarkable regularity in the major psychological, psychiatric, psychosomatic, and sociological journals, and to a lesser extent in those of clinical medicine and epidemiology. While some of these publications derive from the cumulative efforts of investigators who have worked in this field for many years, concern has been expressed that many recent studies repeat both the findings and the flaws of earlier ones, delaying a hierarchical growth and development of knowledge in the field. Accordingly, there is a need for critical evaluation of this literature, taking in issues of method as well as content. In this article our goals are (i) to review selectively the research literature on the relations of life events, stress, and the onset of illness; (ii) to delineate trends in its development; (iii) to evaluate the conceptual and methodological approaches employed; (iv) to identify major variables mediating the impact of stressful events on individuals and groups; and (v) to recommend more comprehensive approaches to substantive issues.

Despite historical recognition of the predisposing role of social factors in the onset of illness, it is only during the last 40 years that scientists have attempted to study these phenomena systematically. In 1936 Hans Selye articulated his concept of stress as the "general adaptation syndrome," a set of nonspecific physiological reactions to various noxious environmental agents (*1*). This formulation was largely responsible for popularizing the concept of stress in the scientific

Dr. Rabkin is research scientist in and Dr. Struening is director of the Epidemiology of Mental Disorders Research Unit, New York State Department of Mental Hygiene, Psychiatric Institute, 722 West 168 Street, New York 10032. This article is adapted from a paper presented at the annual meeting of the American Association for the Advancement of Science, New York, 27 January 1975.

[From Energy Research Reports, Vol. 2, No. 8, Aug. 1976]

How Sweden Holds Her Energy Use Near Half the U.S. Per Capita Level

Sweden might be expected to consume more energy per capita than the United States, because her climate is more demanding and her exports more energy-intensive. But with virtually the same per-capita gross national product Sweden consumes only 55 percent as much energy per capita. There are lessons to be learned here: in the use of energy-efficient technology; in the creation of social, economic and political environments that foster such technology; and in liberation from the notion that unemployment must accompany a slowing or halt in the rise in energy consumption.

It's instructive to compare reactions to the oil embargo of 1973, which hit Sweden even harder than America, because Sweden is more dependent on imported fuel. Sweden, already far more efficient in energy use, emphasized further conservation. The U.S. intensified its subsidies and tax encouragements for developing energy supplies, a clearly more expensive way to bridge the gap between supply and demand [*ER June 1975, p. 6*]. In Sweden, prices and taxes on oil products rose above their already-high levels; the U.S. retained controls on the prices of most fuels. Sweden continued to revise electricity rates so heavy consumers pay a fair share of the long-run incremental costs [*ER May 1975 p. 1*], while the U.S. made little progress away from prices that are far from representative of the cost of producing electricity.

With support from the U.S. Energy Research and Development Administration, we at the Lawrence Berkeley Laboratory examined the major energy-consuming sectors of the Swedish economy. We found many contrasts with U.S. practices. Here are a few.

ENCOURAGING EFFICIENCY IN TRANSPORTATION

In transportation, a mix of efficient automobiles and mass transit similar to Sweden's would save the U.S. the equivalent of nearly two million barrels of oil each day. Swedish automobiles, far lighter than American versions, average 24 miles per gallon. Mass transit accounts for 40 percent of urban travel in Sweden, and trains handle 40 percent of intercity travel; there are 33 percent fewer cars per capita than in America.

Such figures are understandable in a nation with high gasoline taxes—totaling 60 cents per gallon—a new-car tax that rises with weight, and an annual tax that also depends on an auto's weight. These taxes encourage proper maintenance and tuning for efficient operation.

In buildings, Sweden's energy efficiency is equally striking. The heating season is twice as demanding as that in the U.S., but both residential and commercial buildings there consume only half as much fuel per square foot of floor space. Similar economies in the U.S. would save the equivalent of four million barrels of oil per day.

Low fuel consumption in residences has been attributed erroneously to the higher fraction of Swedes living in apartments. Because most of those apartments receive heat and hot water without being billed directly, each apartment dweller consumes as much energy as a person living in a single-family dwelling. Apartment living usually requires less energy for transportation, however, because long commutes are seldom necessary.

SUBSTITUTING CAPITAL AND LABOR FOR ENERGY

Energy savings in buildings stem from the fact that Swedish engineers, unlike American, never designed buildings to require heat in summer and cooling in winter [*ER August 1975, p. 5*]. Insulation, insulating glass, better ventilation and generally tighter construction practices have meant not only lower heating bills, but also higher employment and investment in the construction industry.

As Swedish builders substitute capital for energy, so do industries in the form of heat-recovery equipment, Because hydro-power makes electricity slightly less expensive there, industries do use that resource more than do their U.S. counterparts; even without ample hydropower, U.S. industries could save four million barrels of oil per day if they recovered heat to the same extent as in Sweden. And the high level of employment in Sweden shows that the often-mentioned link between energy consumption and jobs is a weak one at best.

If Swedish transportation, building and manufacturing techniques were adopted in the U.S., the total savings would be more than 10 million barrels of oil per day. But adoption of such measures requires a delicate interaction between government and other institutions.

HOW COOPERATION STIMULATES CONSERVATION

Tough building codes in Sweden are complemented by low-interest bank loans available for investments in conservation. Mass transit has been heavily subsidized to keep the auto where it belongs: on medium-distance trips. Industry and utilities have worked closely with the government to find ways to save energy, but the publicly owned power companies in Sweden are not government-subsidized, being financed instead at commercial interest rates; this cost stimulates efficient use. Another energy saver is the extensive use of waste heat; communities and industries recycle it from 33 percent of Sweden's thermal electric supply.

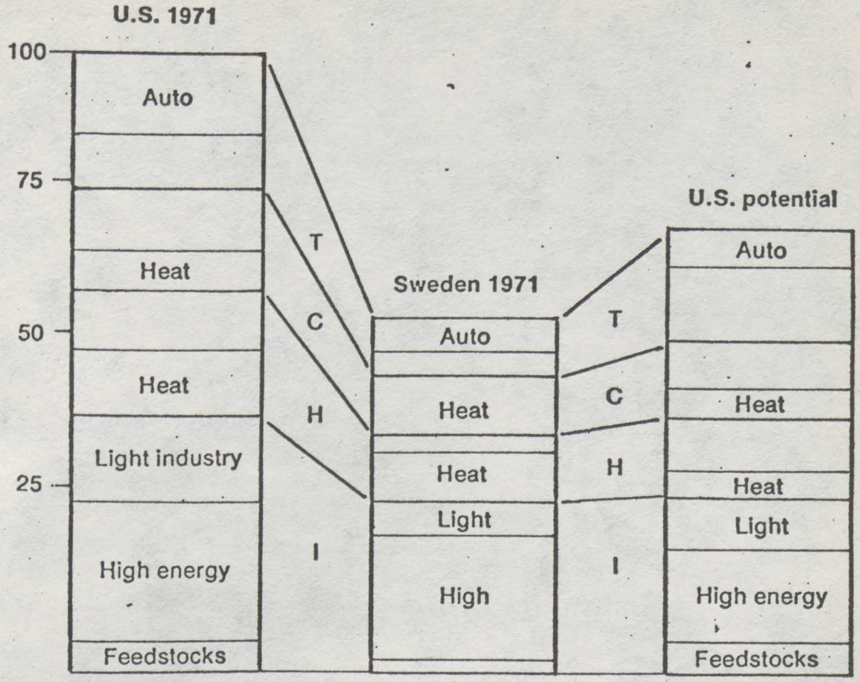
Such cooperation isn't easy to achieve among such disparate groups as bankers, manufacturers and public officials on national and local levels. We have seen, however, that a country's real energy needs are flexible and can be modified by economic and institutional actions.

(Lee Schipper, the author, is a member of the energy-and-resources group at the University of California in Berkeley and of the energy-and-environment division of the Lawrence Berkeley Laboratory.)

FURTHER READING

Efficient Energy Use: The Swedish Example, Lawrence Berkeley Laboratory Rpt. LBL–4430, 53 pp.

Sector-by-sector comparison of U.S. and Swedish energy consumption and analysis of differences.



Energy consumed in 1971 — in thousands of thermal kilowatt-hours per person — is shown for the United States and Sweden alongside the potential for reducing U.S. consumption by such measures as more-stringent building codes and cogeneration of electricity and heat. Consumption is divided into four categories: transportation **T**, *commercial* **C**, *home* **H** *and industrial* **I**

Reprinted from
ANNUAL REVIEW OF ENERGY
Volume 1, 1976

RAISING THE PRODUCTIVITY OF ENERGY UTILIZATION

×11017

Lee Schipper
Energy and Environment Division, Lawrence Berkeley Laboratory,
University of California, Berkeley, California 94720

INTRODUCTION

Energy planners in the late 1960s, projecting growth in energy use on the basis of past experience, compared the expected future demand for energy with possible supplies and generally concluded that a gap (Figure 1) would appear between demand and supply from domestic energy sources. It was suggested that the gap be filled by a variety of solutions: expanded oil imports; accelerated use of nuclear power or

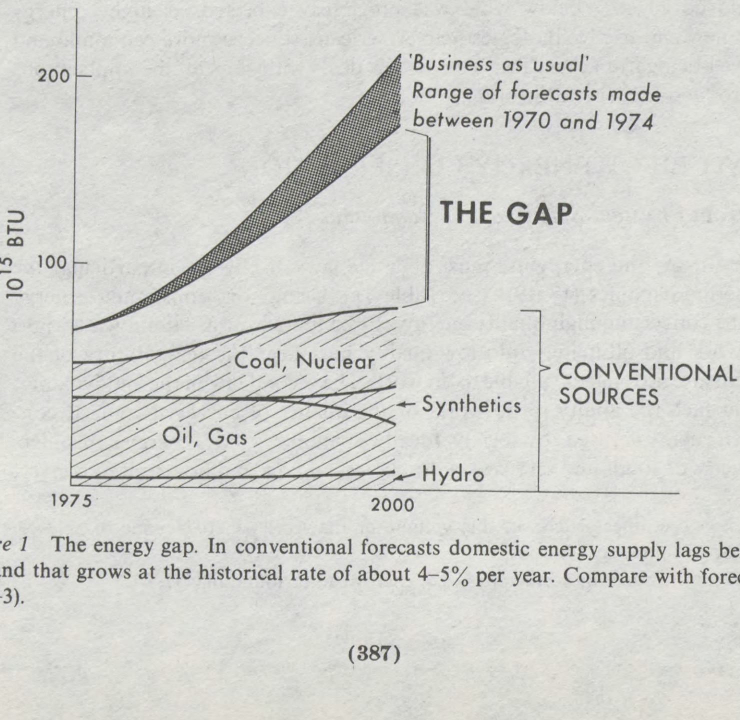


Figure 1 The energy gap. In conventional forecasts domestic energy supply lags behind demand that grows at the historical rate of about 4–5% per year. Compare with forecasts in (1–3).

coal; enhanced harvesting of domestic oil and gas; or development of synthetic fuels, solar energy, geothermal energy, or some other new form of fuel, heat, or work.[1] Today all of these supply options are still potentially important, but they are far more expensive than the oil, gas, and electricity that were available in the late 1960s. This suggests that a more productive use of energy can more economically supply much of the well-being that otherwise would be made available by using more energy. This higher efficiency, or higher productivity, of energy use is called *energy conservation.*

Until recently conservation was virtually ignored or dismissed in work dealing with energy (2, 3). A typical view was expressed in the prognosis of the Chase Manhattan Bank (5, p. 52), which asserted that

> analysis of the uses of energy reveals little scope for major reduction without harm to the nation's economy and its standard of living. The great bulk of the energy is utilized for essential purposes—as much as two thirds is for business related reasons. And most of the remaining third serves essential private needs. Conceivably, the use of energy for such recreational purposes as vacation travel and the viewing of television might be reduced—but not without widespread economic and political repercussions. There are some minor uses of energy that could be regarded as strictly non-essential—but their elimination would not permit any significant savings.

More informed studies of energy use contradict this analysis. Especially misleading is the subjective phrase "essential purposes," which obscures the whole question of efficiency. Careful analysis of energy use has revealed an enormous potential for energy conservation (6–15). The most recent forecasts from the Energy Research and Development Administration (ERDA) (16) suggest that US energy needs in the 1990s could be 20–40% below what was previously expected, as higher energy prices and new end-use technologies help Americans squeeze more economic and personal well-being from every Btu. This review deals with some of the implications of more productive energy utilization.

THE NATURE OF ENERGY CONSERVATION

Insights from Physical Sciences and Economics

All energy systems and energy use must obey the laws of physics, in particular the laws of thermodynamics (17–19)[2] (see Table 1). "Using" or "consuming" energy really means converting high-quality energy, stored in fuels or as falling water, into heat and work and ultimately into low-quality heat near the temperature of the environment and no longer available to do work. The second law of thermodynamics assures that fuel, the ability to do work, or the quality of energy, is indeed consumed when energy is "used" by society. Ideally economics guides energy consumers (and producers of goods and services) in the choices of how and how well to convert

[1] For reviews see other articles in this volume or the April 19, 1974 issue of *Science.* For "alternative" source see (4).

[2] An excellent introduction to the physics of energy can be found in (19).

Table 1 · The laws of thermodynamics[a]

First Law of Thermodynamics

Energy can be neither created nor destroyed, but it can change form. ("You can't get something for nothing, you can only break even.")

Second Law of Thermodynamics

It is impossible to convert a given quantity of heat completely into work. In any macroscopic process involving energy conversion, some energy is always degraded in quality, so that ability to do work is lessened. ("You can't break even, you can only lose.")

Quality of energy describes the degree to which energy can be converted into work, which is the application of force through a distance. The quality of thermal energy increases with the temperature *difference* between the body of heat and the background environment. Work, electricity, and gravitational energy are of the highest quality; chemical energy stored in fuels is also of high quality, although not the highest. The first law merely states that the total quantity of energy in a closed system is conserved. The second law, however, asserts that the quality of energy can be consumed in physical processes.

[a] See (17) or chapter by C. A. Berg in this volume.

energy use into goods and services or other forms of utility that increase human welfare. It is widely recognized, however, that energy use is a complicated social phenomenon, the full understanding of which demands interdisciplinary analysis far beyond ordinary economics or physical science (20, 21).[3]

Energy is used in the economy, along with other resources, to produce goods, services, transportation, environmental conditions (heating, cooling), or other life-support systems, and conveniences. Economic resources (factors of production) include capital (with design and know-how), labor, land, energy, and the environment, which absorbs pollution. These factors are compared and evaluated for economic decisions by attaching prices, or dollar values, to them as well as to the output produced by their use. Because energy is but one input to processes, minimizing energy use alone does not always equate with minimizing total costs. What has aroused the scientific community, however, is the fact that careful energy conservation does reduce total costs. This suggests the following definition of energy conservation:

> the strategy of adjusting and optimizing energy-using systems and procedures so as to reduce energy requirements per unit of output (or "well-being") while holding constant or reducing total costs or providing the output from these systems.

Conservation techniques will (*a*) improve the delivery of energy and reduce the specific energy requirements of processes or systems, or (*b*) modify the tasks or goals of energy use. Improving the efficiency of air conditioners reduces the energy required to pump each unit of heat out of a room, while redesigning the house can reduce the amount of heat that needs to be pumped out in the first place.

[3] An excellent introduction to economics of resources and pollution can be found in (22).

From an economic point of view, conservation strategies substitute other economic resources for energy. The most important of these is capital. Conservation can be viewed as an investment, with a certain rate of return.

Conserving has always been identified by economists as the practice of saving something that might be more valuable in the future (22, 23). Furthermore, conservation as increased efficiency allows energy to be saved at no sacrifice in the goals of energy use. Since most consumers have a definite time preference toward the present, few will automatically save for the future without rewards. The rewards for conserving energy are the economic savings that conservation strategies yield.

There are other rewards for conserving energy not measured by direct monetary savings. Some benefits are difficult to perceive by the saver as, for example, lower future prices for fuels in the United States and abroad, fuels saved for use by future generations, lessened dependence on foreign sources of fuel, lessened environmental burdens, and other "hidden benefits" (14). I believe, however, that the largest stimulus to more efficient energy utilization will occur in reponse to direct economic incentives and governmental policies designed to aid those incentives.

Some discussions of conservation implicitly or explicitly equate conservation with sacrifice of desired life-styles, acceptance of lower standards of living, or denial of

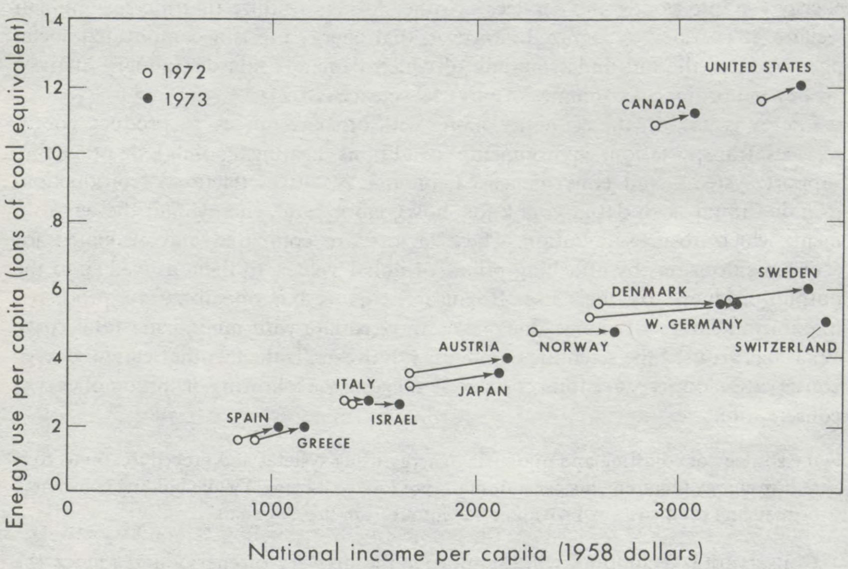


Figure 2 Per capita energy use and national income of some important industrial and emerging nations, 1972 and 1973. Note the wide variation in energy use among the nations with highest per capita income, measured in 1958 US dollars at current exchange rates. 1972 and 1973 data were compiled by A. Rosenfeld, Lawrence Berkeley Laboratory, from US and UN statistical abstracts. Data for Switzerland are based on author's estimate. National income is closely related to GNP.

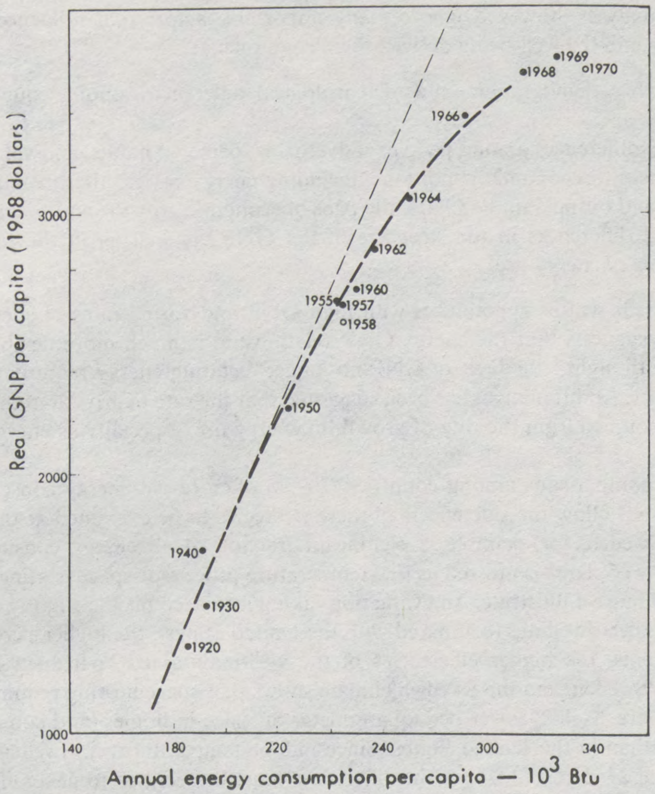


Figure 3 Growth of energy use and GNP in the United States. Source: (27).

economic opportunity to low-income groups (24, 25).[4] It will be argued here repeatedly that the strategies that bring about the largest savings in energy use need have few or none of the above effects. The difference between shortages, either short-term or long-term, and true reduction of specific energy needs brought about by more effective utilization must be borne in mind when energy policies are discussed.

Energy Use and Standard of Living

For many years it has been common practice to investigate the relation between energy use and gross national product (GNP) (26), often referred to as affluence or standard of living (Figure 2). Such relationships help to distinguish between wealthy and underdeveloped countries. Historical data also show correlations between the rise in GNP and the rise in energy use in a single country (27, 28) (Figure 3).

[4] See the general discussion of future demand in (24). Cook & Vassell (25) largely ignore conservation techniques.

These analyses, however, ignore many important factors that influence actual energy use and the well-being derived therefrom, such as

1. geographic, demographic, and meteorological differences among countries or regions;
2. cultural differences among peoples: advertising, personal habits, and values;
3. differences in economic conditions, including energy prices; the breakdown of inputs and outputs in the GNP; the pace of economic growth; and pollution;
4. physical differences in the structure of the GNP, as well as in the technical efficiency of energy use.

The present scatter of countries with high GNP and varied rates of energy use (Figure 2) suggests that the energy-GNP relationship is much more flexible than previously thought,[5] the level of GNP no longer dictating energy requirements of the economy. Additionally it has been suggested that the rate of growth in the GNP can be uncoupled from the rate of growth in energy use, especially as energy costs rise (29).

Careful comparisons among countries (30–34) often reveal energy conservation strategies and allow the side effects of these strategies to be examined at the same time. In Sweden, for example, a significant fraction of all energy consumed in thermal power plants is utilized as low-temperature process or space heating, as the details of Figure 4 illustrate. An evaluation taking into account the slightly smaller size of Swedish dwellings (compared with the United States), the higher percentage of apartments, the higher efficiencies of the well-maintained apartment heating systems in Sweden, and the Swedish climate shows that space heating requirements in Sweden are 30–40% lower per square meter of space in homes (and commercial buildings) than in the United States. Since indoor temperatures in Sweden are in the range of 23–24°C (73–75°F), the differences must be ascribed to generally more energy-efficient structures in Sweden (33, 35).

In the transportation sector Swedish automobiles are considerably lighter than those in the United States, averaging around 1100 kg. A larger fraction of short intra-city trips in Sweden are made via mass transit. More passenger trips in Sweden are made by train, with higher load factors, than in the United States, or by chartered jet, again with higher load factors than commercial aviation in the United States. Swedes travel nearly as much as Americans but with far less energy (33, 35).

In the industrial sector Sweden also uses less energy for each ton of steel, paper, cement, and most other industrial products, including allowance for the difference in heat rates. Sweden's import/export statistics indicate that 9–10% of all energy consumed in Sweden is embodied in exported products, while imports of refined petroleum products embody about 5% of Sweden's total energy consumption, this energy being consumed by refineries outside Sweden (33, 35, 36).

On balance Sweden requires about half as much energy per dollar of GNP as the United States. Some of this is certainly due to the large share of hydropower in

[5] See review by Craig, Darmstadter & Rattien in this volume.

the Swedish energy economy and the larger fraction of Sweden's GNP that goes to services, particularly social welfare. But most of the difference arises out of the strikingly more efficient ways in which Swedes convert fuel into comfort, transportation, and industrial output. Similar conclusions were reached in a study of West Germany (32).

Energy use per dollar of GNP has changed with time in the United States, reflecting changes in the goals of energy use as well as in efficiencies. And there are variations from place to place within the United States today in the amount of insulation in buildings (6, 9, 13), the use of public transportation (37–39), weight and other factors in automobiles, and the prices of fuels and electricity (40, 41). The differences in energy consumed for heating can be striking. Table 2 gives natural

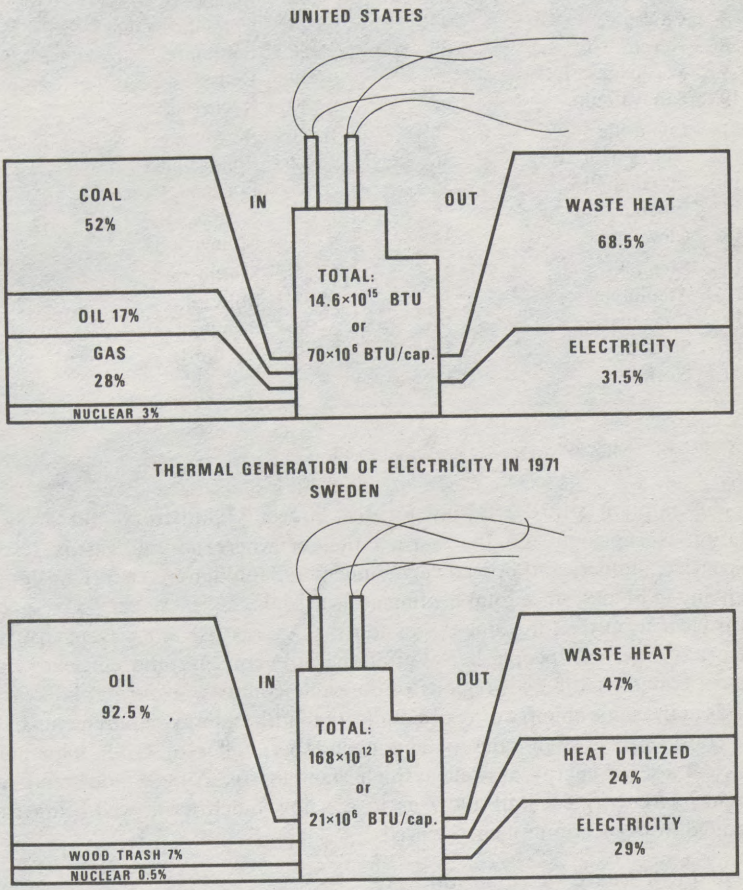


Figure 4 Comparison of utilization of output from thermal electric power plants in Sweden and the United States in 1971. Source: (14, 33).

Table 2 Residential energy consumption of the largest metropolitan areas in the United States[a]

Rank	Metropolitan Area	Thousands of Btu per Degree-Day	Rank	Metropolitan Area	Thousands of Btu per Degree-Day
1.	San Diego	72	21.	Detroit	33
2.	Los Angeles	63	22.	Dallas-Ft. Worth	31
3.	New Orleans	60	23.	Providence	31
4.	Phoenix	55	24.	Oklahoma City	31
5.	Houston	55	25.	Dayton, Ohio	30
6.	New York City	55	26.	Buffalo	29
7.	Chicago	44	27.	Columbus, Ohio	27
8.	Newark	39	28.	Baltimore	26
9.	Washington DC	37	29.	Denver	26
10.	San Antonio	37	30.	Rochester	25
11.	Louisville	36	31.	Boston	25
12.	San Francisco	36	32.	Philadelphia	25
13.	Indianapolis	36	33.	Portland, Oregon	24
14.	Pittsburgh	36	34.	Kansas City	24
15.	Cleveland	36	35.	Minneapolis	24
16.	Memphis	35	36.	Seattle	23
17.	Atlanta	34	37.	Milwaukee	20
18.	Cincinnati	34	38.	Birmingham	20
19.	St. Louis	33	39.	Hartford	17
20.	Norfolk	33[b]			

[a] Source: (42).
[b] Median consumption.

gas consumption per degree-day for the largest US metropolitan areas. The variation is enormous; in the warm cities, or where natural gas is relatively inexpensive, builders and homeowners understandably ignore energy in designing and living in homes, since total heating costs are low.

It is clear from the foregoing discussion that energy use alone is an insufficient measure of how well people live. Variations in energy use and efficiency among different countries, different regions of the same country, or during different time periods in the same country or region indicate that the energy requirements of tasks vary considerably. High rates of energy use per dollar of GNP may indicate inefficient use of energy as well as high standard of living. Understanding the efficiency of energy use will allow us to see how much more well-being can be generated from each unit of energy used.

Efficiency of Energy Utilization

PHYSICAL EFFICIENCY Physical measures of efficiency are important indicators of the potential for conservation. Traditionally the first law of thermodynamics (see

Table 1) has been used to express efficiency as

$$\frac{\text{(energy provided or transferred in desired form and place)}}{\text{(energy input to system)}}.$$

First-law efficiencies follow the flow of work and heat in systems, accounting for all uses and losses at the boundaries in and out of the system. Figure 5 shows first-law efficiencies for air conditioners (43). Motors (44) and other devices (45) have been carefully studied. First-law efficiencies are numerically less than one, except in the case of refrigerators, air conditioners, or heat pumps, where the amount of heat moved is usually greater than the amount of work (usually electricity) consumed. The "spaghetti bowl" chart, drawn first by Cook (Figure 6), shows an approximate first-law accounting of US energy use in 1971 [see also (45) and for other "bowls" from a variety of years, see (46)].

It is important to note, however, that first-law efficiencies can be misleading. As suggested by the study done by the American Physical Society (45), the second law of thermodynamics gives a more relevant measure of physical efficiency in cases

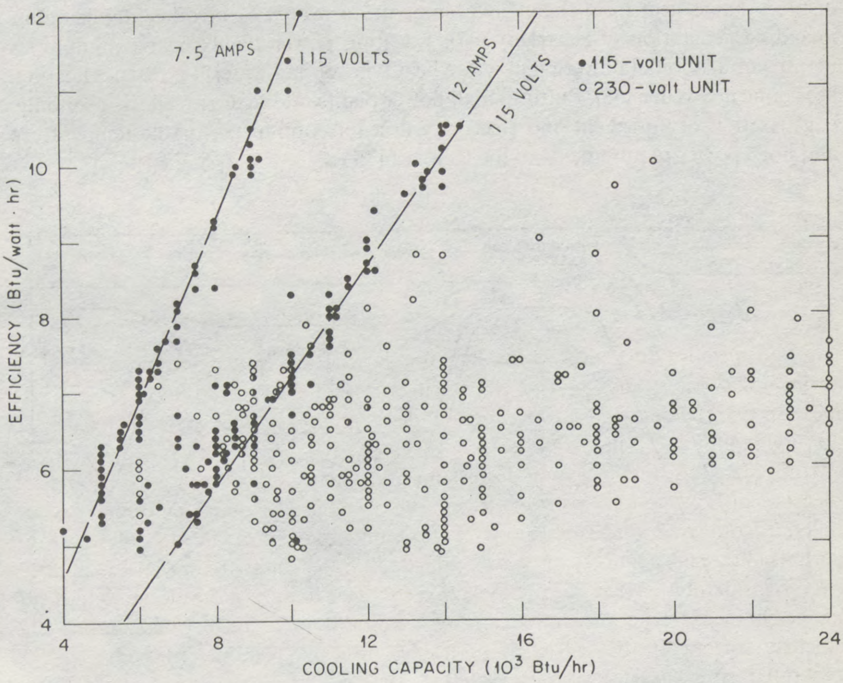


Figure 5 First-law efficiency of air conditioners. Vertical axis gives heat removed per unit of energy consumed; horizontal axis, the size of the unit. Note the wide variations in efficiency. The models that lie near the two straight lines are those constrained to operate on either 7.5-amp or 12-amp circuits. Source: (43).

where temperature changes are involved, by comparing the energy (as work or heat) theoretically required to perform a task with that actually used. Note that 60% of all fuel is consumed in order to change the temperature of environments or substances and that 85% of electricity and nearly all of transportation is provided by heat engines. Second-law efficiency is measured by

$$\frac{\text{(theoretical minimum energy required by second law)}}{\text{(energy actually consumed)}}.$$

Theoretical energy requirements of tasks are based on properties of materials, environments, and heat engines that convert heat to work and vice versa. The amount of work needed to pump heat across the small temperature differences common to most household or building situations and industrial tasks is small compared with the amount of work that could be extracted from combustion of the fuels that are used in these applications—hence the low efficiencies in Table 3. By contrast, modern power plants or industries using high-temperature heat utilize a larger fraction of the ability to do work that is stored in fuel. An ever greater efficiency can be obtained by modification of industrial procedures to allow use of the exhaust heat from these high-temperature processes in other applications, including generation of electricity (47). Locating power plants near communities permits utilization of power plant waste heat (via cooling water) for district heating, as is done in Sweden (33). Putting small power plants into factories allows economic cogeneration of both heat and electricity in a mix optimized for the temperature and horsepower requirements of the factory (47).

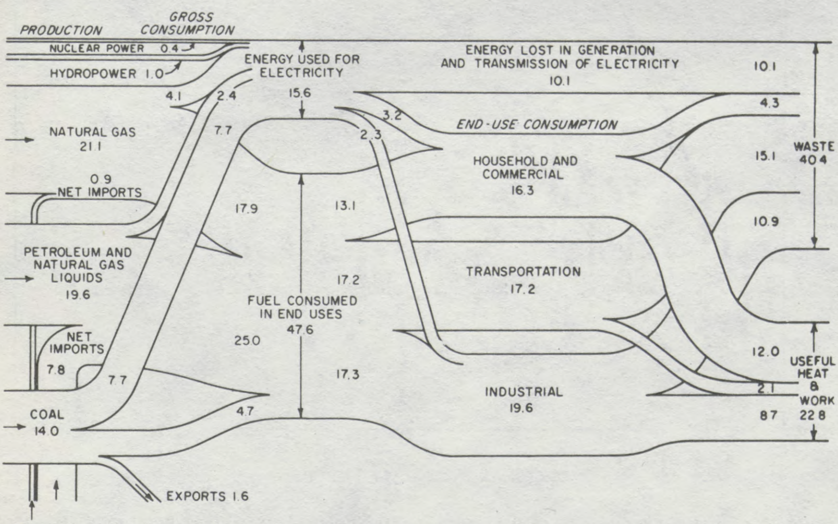


Figure 6 First-law efficiencies of energy use in the United States in 1971. Estimates by E. Cook (21). In Cook's earlier "spaghetti bowls," drawn for a variety of scenarios in (45), overall first-law efficiency was assumed to be higher, around 50%.

Table 3 American Physical Society estimates of efficiency of energy use[a]

Use	Relative Thermodynamic Quality	Percent of US Fuel Consumption (1968)	Estimated Overall Second-Law Efficiency
Space heating	lowest	18	0.06
Water heating	low	4	0.03
Cooking	low	1.3	—
Air conditioning	lowest	2.5	0.05
Refrigeration	lowest	2	0.04
Industrial uses			
Process steam	low	17	0.25
Direct heat	high	11	0.3
Electric drive[b]	(work) high	8	0.3
Electrolytic processes	high	1.2	—
Transportation	(work) highest		
Automobile		13	0.1
Truck		5	0.1
Bus		0.2	—
Train		1	—
Airplane		2	—
Military and other		4	—
Feedstock		5	—
Other		5	—
Total		100	

[a] Source: (45).
[b] *Work* is defined as *infinite-temperature* energy by the APS study.

Some processes are best understood by examining both first- and second-law efficiency. Improving heat-transfer properties from flame to boiler in a power plant, which is a first-law procedure, also increases temperature differences that the plant utilizes and therefore improves second-law efficiency (45). Often, too, redefinition of the tasks involved in energy use allows a higher physical efficiency. Use of recycled scrap lowers process heat and electricity requirements for most metals. Heat pumps might utilize groundwater, the temperature of which varies little during the year, instead of outdoor air, as a heat source for space heating. The temperature differences between the source and the indoor space is then reduced, so less work is required (45). While physical analysis of efficiency gives an important measure of possibilities for energy conservation, the tasks in question should also be evaluated.

DESIGN AND MAINTENANCE EFFICIENCY Sometimes it is useful to measure efficiency by relating the energy requirements of a task to the physical or economic output of that task. Design intensity is expressed this way, employing units such as Btu/passenger mile (for passenger transportation, see Figure 7), Btu/degree-day (for

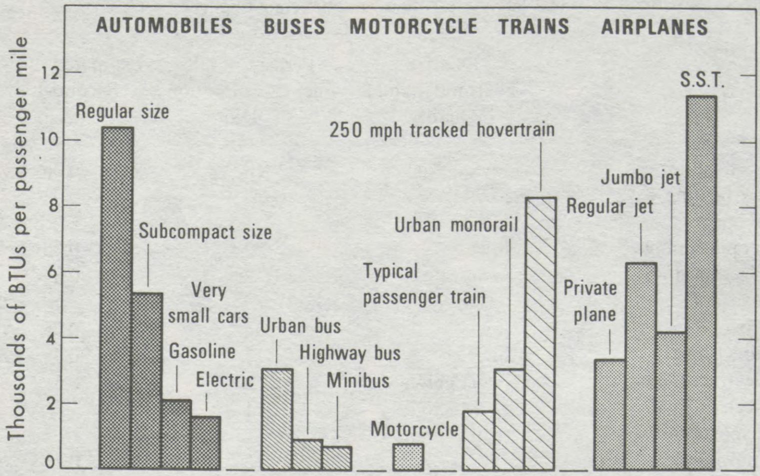


Figure 7 Design intensities of some modes of transportation, in Btu per passenger mile, using common load factors. Data from R. Rice, presented in (7). Note the wide variation in design intensities, which are far lower than possible in most cases because of low load factors.

space heating), or Btu/ton (for industrial output). Design efficiencies are the inverses of these intensities. But whether a task is carried out at its rated design efficiency usually depends on how well the system or process used is maintained. Maintenance efficiency compares rated design efficiency with operating design efficiency. The design efficiency may also depend on other factors; the seasonal dependence of the design efficiency of space heating systems (48) is a good example.

Some systems, such as mass transit and automobiles, are designed to provide far more output (passenger miles) per unit of energy consumed than is usually used (Figure 7). Uninsulated, poorly designed structures require more energy than insulated, carefully built ones (a design efficiency), and poorly maintained heating systems deliver less comfort, per unit of energy used, than well-maintained systems (a maintenance efficiency). By modifying systems, energy conservation procedures improve design efficiency, even before physical efficiencies are changed.

ECONOMIC EFFICIENCY Economic efficiency is measured by comparing the total cost of using energy in various systems at various levels of physical efficiency. "Cost" is usually, but not always, measured as the total direct cost of providing useful output or services from energy, measured over the lifetime of the system. Cost includes purchase price, interest or opportunity cost on the investment involved, taxes, and maintenance costs (49).[6] Thus economic efficiency considers both the cost of the energy and the cost of the energy system. Ideally, although rarely in practice, economic efficiency includes environmental or other external costs associated with

[6] See also the Appendix in (43) for sample calculations.

energy systems (22, 23), as well as the cost of the risk of the fuel or system being unavailable in the future and the prospects for changes in fuel costs. That system which provides the desired output for the lowest cost is the most efficient. Unless otherwise indicated, this review uses the economic definition of efficiency in terms of life-cycle direct costs, although compelling reasons have been suggested (22, 23) for including environmental costs and other non-market costs or exigencies such as the reduction of oil imports or threats to national security.

Economic efficiency can also be identified with total resource productivity. For many years economists usually concentrated their studies on labor productivity, since resource costs were stable. Now, however, energy costs have risen faster than labor costs, and in some cases energy, rather than labor unions, has gone on strike, as in the case of the 1973–1974 oil embargo. If energy prices continue to lead all other factors in inflation, including wages, then it can be expected that energy users will accelerate efforts to increase the economic and physical efficiency of energy use. Part of the reason for the relatively high efficiency of energy use in Sweden can probably be ascribed to the high cost of energy there. It has been noted, however, that over the past 25 years the physical and economic efficiency of energy use in US industry has increased in spite of falling real energy prices (29). In this sense energy conservation leads to a more productive use of resources.

Physical or monetary values are not always sufficient for analyzing energy use because people often make decisions on the basis of variables such as exertion, luxury, convenience, time, risk, pleasure, or nuisance. Urban design, employment, and life-style are other social aspects of energy use that influence energy choices. For example, I use taxis when I am in Washington DC (but rarely elsewhere) because the value of time there is usually worth the expense of taxis and the loss of exercise. Important values like these must enter into energy planning and considerations of conservation strategies. The object of conservation is not to deny ourselves conveniences, preferences, necessities, or other aspects of life-styles, but instead to make these activities more economically efficient. The next sections discuss how this might come about through energy conservation.

ENERGY USE AND CONSERVATION

Kinds of Energy Use

One way to display kinds of energy use is the traditional breakdown of energy use by economic sector and task shown in Figure 8, which can be compared to Figure 6, in which the flow of fuels from source to economic sector was illustrated. Another possible description of energy use is by task and quality, as the American Physical Society study (45) suggested (Table 3).

Often it is desirable to learn the energy requirements of individual economic or physical activities. Energy analysis allows these requirements to be evaluated through accounts of purchases of energy by firms, by using input-output techniques (50–52), or measurement of fuel consumption in production processes (53–55) (Table 4). Energy-intensive activities are those for which the specific energy requirements per unit of physical or economic output are significantly higher than for the

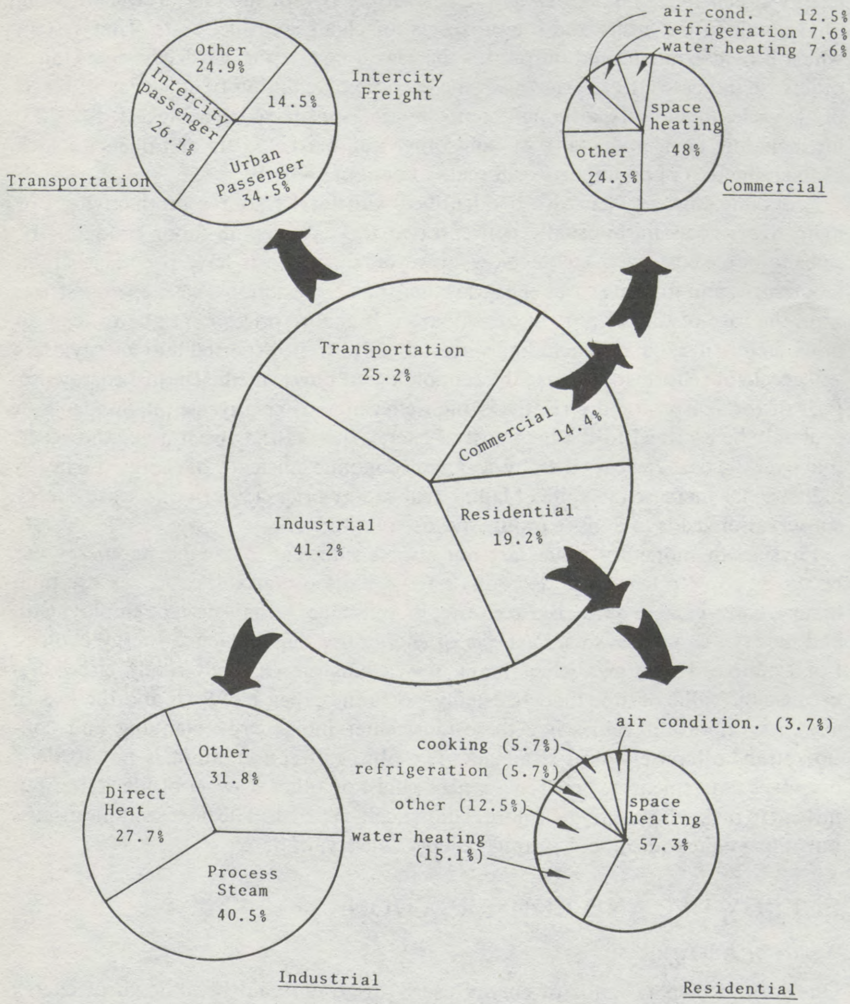


Figure 8 How does the United States use its energy? Schematic pie representation of energy uses in the United States. From Oak Ridge Associated Universities, 1974, *Citizens Energy Workshop Handbook*, Oak Ridge, Tenn. Compare with Table 3 and Figure 6.

Table 4 The energy cost of some common goods and services[a] and the energy costs associated with the production and recycling of metals[b]

1967 Example Energy Intensities[c]		Summary of the Energy Requirements for the Production and Recycle of Metals[c]		
Product	(10^3 Btu/$)	Metal	Main Source	Equivalent Coal Energy (kW-hr/ton)[d]
Primary aluminum	388	Magnesium	sea water	90,821[103,739]
Fertilizers	174		mg scrap recycle	1,395[1,875]
Airlines	192			
Glass	103	Aluminum	bauxite 50% alumina	51,379[63,892]
Motor vehicles	67		aluminum scrap recycle	1,300–2,000
Cheese	73			
Apparel	50	Iron	high-grade hematite	4,270[4,289]
Hospitals	51		iron laterites	6,268[6,327]
Computing machinery	36		iron and steel scrap recycle	1,240[1,666]
Banking	18			
US average		Copper	1% sulfide ore	13,532[15,193]
Including energy	80		0.3% sulfide ore	24,759[29,766]
Non-energy goods	52		98% scrap recycle	635[853]

[a] Source: (52). These are direct plus indirect energy requirements.
[b] Source: (87). These are direct requirements only.
[c] Electricity has been counted at 40% conversion from fuel to electricity.
[d] Figures in brackets count electricity at 29% conversion efficiency.

Table 5 Energy cost of energy: efficiency of the US economy in delivering energy, 1967[a]

Sector	Efficiency (%)
Coal	99.3
Refined petroleum	82.8
Electricity	26.3
Natural gas	90.9

[a] Source: (52). Percentage of total Btu's harvested by the energy industries that are delivered to the US economy.

economy as a whole. Energy analysis also shows how much energy must be consumed to build and run energy production technologies (Table 5). Such analysis is particularly important for nuclear power programs or advanced fossil fuel conversion schemes (56–60b).[7] Energy analysis provides a reminder that investing dollars in almost everything requires investing energy.

Energy analysis can also be used to predict the energy cost of implementing conservation strategies, but consideration of the economics involved suggests that the periods for energy payoff will be short (61). Let us examine why this so. Expenditures for energy require between 2×10^5 and 10×10^5 Btu per dollar. The same dollars spent on conservation investments or other non-energy purchases require only about $6–8 \times 10^4$ Btu per dollar (50–52). Even if the present value of the energy saved from a strategy is somewhat less than the cost of the strategy, energy will be saved. However, in the case of energy technologies that are materials-intensive, such as solar photovoltaic and central-station solar power plants, large energy investments may be required, and these should be carefully evaluated.

These objective descriptions about energy use and cost avoid important judgements about the tasks involved. Must cars weigh 6000 lbs? Must a refrigerator be so poorly insulated as to "require" an electric resistance heater in its skin to drive off condensation? Questions like these suggest that while physical science and economics answer many of the technical questions about efficiencies of energy use alternatives, political and sociological analysis is required to explain why energy use patterns have developed (20, 21). Understanding the quantitative aspects of energy use is, however, essential in order to be able to evaluate energy conservation strategies. These strategies are discussed next.

Conservation Strategies and Their Applications

In Table 6 a classification of conservation strategies is suggested. The most important strategies for existing systems are leak plugging, management, and mode mixing, and for future systems, input juggling, thrifty technology, and output

[7] The matter of net energy during periods of growth in the nuclear program has not been settled.

Table 6 Kinds of energy conservation[a]

IN EXISTING SYSTEMS

Leak Plugging

Reducing heat and cooling losses in life-support systems, adjusting energy systems that are not running at design efficiency, and eliminating unutilized or underutilized energy by retrofit in all energy systems. Examples include insulation in buildings, heat recovery in industry. Leak plugging techniques are generally implemented once, at little initial cost, and then remain passively effective.

Mode Mixing

Changing the mix of transportation to utilize modes requiring less energy per passenger- or ton-mile.

Energy Management

Turning off lights, heat, or cooling; changing thermostat settings; improving maintenance; driving more slowly; car-pooling; increasing load factors in public transportation. Involves small but important changes in energy use. May cause minor changes in life-style and habits. Energy management, unlike leak plugging, must be actively pursued by individuals or firms. Capital costs are usually small. Also called belt tightening.

IN NEW SYSTEM

Thrifty Technology

Introduction of innovative technology not in common usage in any energy system to increase the useful output of the system per unit of energy consumed. Examples include gas heat pumps for space and industrial heat, electric ignition of gas water heaters, or new propulsion systems in transportation.

Input Juggling

Change in the mix of existing economic or physical inputs to a given kind of output. Substitutions can be among energy forms or among economic variables such as labor, capital, design (a form of capital), and machines. Solar energy substitutes capital and labor for heating; returnable bottles substitute labor for the extra energy and materials requirements of throwaways. Some leak plugging also substitutes investment capital, design, and, indirectly, labor for energy expenditures.

Output Juggling

Changes in life-style, consumer preferences, investment practices, or shifts from manufacturing to services in the economy, which lead directly and indirectly to lower (or higher) energy requirements. Shifting to throwaway containers raises energy requirements per unit of beverages. Gardening at home instead of taking a Sunday drive lowers energy use. Smaller cars, changing urban housing patterns, increased vacationing closer to home are all examples of output juggling.

[a] Modified from (14).

juggling. If strategies like these are applied to important end uses of energy, savings of 10–50% of specific energy requirements result (Table 7). Applying all of these savings to the 1975 US energy economy would have the effect of reducing total

Table 7 Applying some energy conservation strategies: possible savings[a]

Area of Strategy	Potential Savings[b]	Notes	References
Homes, Buildings			
Space heating	5–8%	Insulation; heat pumps cut electric heating needs by 50%; gas heat pump is a possibility	51, 62–67
Air conditioners	>1%	Save peak power, fewer brownouts; insulation, design, window improvements reduce heat load	43, 62, 65, 66, 68, 79
Home appliances	2%	Fluorescent lights, better motors, and insulation in refrigerators; insulation in water heaters, electric igniters replace pilot lights	44, 69–73
Design of buildings	5%	Includes redefining lighting levels and tasks; total energy systems, conserving window systems; orientations that reduce energy needs	67, 73–80
Solar heating/cooling	10%	If 40% of today's heating and cooling were solar; economics depends on cost of glass, storage, and alternative fuels	62, 75, 81, 82
Total 1973 US demand: 30×10^{15} Btu. Hypothetical demand with maximum savings: 18×10^{15} Btu (62).			
Industry			
Process heat	5–12%	Once through the facility is sufficient, with insulation, leak plugging; more sophisticated treatment requires redesign, pipes, cascading high-temperature processes with lower temperature demands	68, 83–86
Total energy: cogeneration of electricity and heat at factory	3–5%	Energy independence to factories; siting communities near industry is a possibility	45, 47, 62
Returnable bottles, use of recycled materials	1–3%	Many institutional problems as "no deposit, no return" becomes ingrained	54, 87–90
Total 1973 US demand: 26×10^{15} Btu. Hypothetical demand with maximum savings: 14.5×10^{15} Btu (62).			
Transportation			
100% shift to 40% lighter cars	5%	Appreciable savings in energy cost of building car, refining oil; less congestion, less wear and tear, less pollution, with less traffic	37–39, 45, 91, 92
More careful driving cycle	1%		
Improved technical efficiency of autos	5%		
Switch one half of urban passenger miles to bus	2%		
Improved load factors in rail, bus, plane, mass transit	2%	Savings in freight and other passenger modes come mainly from fuller utilization of existing routes and higher load factors	6, 37–39, 91–94
Freight mode mix improved technical efficiency	2%		
Total US 1973 demand: 19×10^{15} Btu. Hypothetical demand with maximum savings: 10×10^{15} Btu. Note that transportation is nearly 100% dependent on liquid fuels.			

Table 7 continued

Area of Strategy	Potential Savings[b]	Notes	References
Other			
More durable, repairable, and recyclable goods	?	Substitutes quality work for endless throwing away	13, 33, 50, 95, 96
Urban design	?	Live near work, district heating, etc	
Changes in consumer preferences	?	"Output Juggling"—vacation near home, ride a bike, work in the garden	

[a] Source: (14, 15, 62) and references cited.
[b] Given in percentage savings of total use (early 1970s). Savings figured as optimum achievable at 1980 energy prices. Individual savings do not add. See also (6–16, 62).

energy consumption by approximately 33%, as is illustrated in Figure 9 (6–13, 45, 62). Since these savings require months to decades to be achieved, they appear as slower growth in energy use. This scenario is often referred to as the "technical fix" (see 13). Listed in order of the amount of energy saved, the three most important energy conservation applications are (*a*) better heating and cooling of buildings, (*b*) use of the second law as a guide in industrial heat treatment, and (*c*) reduction of the weight of automobiles. The order of implementation time is probably the reverse.

Most of the potential for energy saving in homes and buildings comes from leak plugging and input juggling, as owners or builders invest in technology and design options (listed in Table 7) that lower the requirements for energy. Energy savings

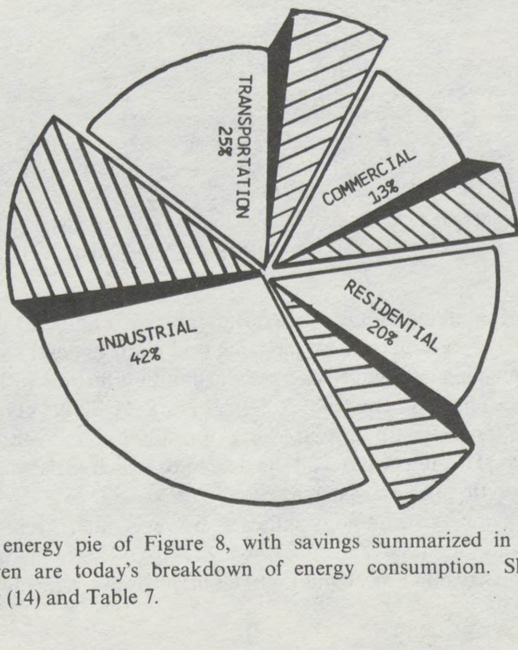


Figure 9 The energy pie of Figure 8, with savings summarized in the four sectors. Percentages given are today's breakdown of energy consumption. Shaded areas give savings. Source: (14) and Table 7.

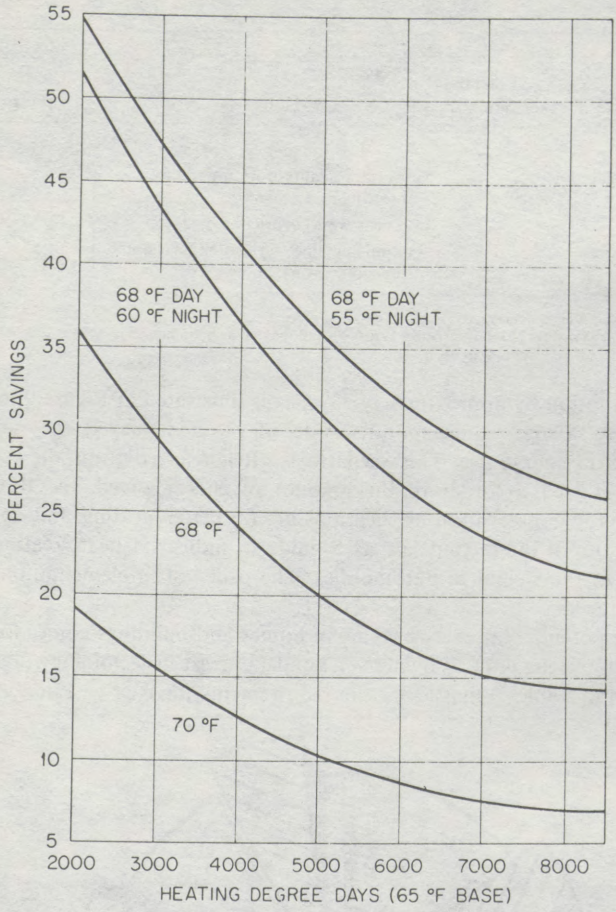


Figure 10 Management: predicted energy savings for several thermostat settings. (72°F is the reference setting, and night setback is from 10 PM to 6 AM.) Source: (97).

from management of systems also can be considerable, as Figure 10 demonstrates for thermostats [(97); for results of leak plugging and management, see (98)]. With new homes, input juggling can reduce energy consumption further with little or no change in the home environment (74, 75, 99), (Figure 11). The savings become larger as higher fuel prices justify increased use of insulation and other techniques that reduce heat loss. This illustrates well the degree to which input juggling might take place in construction of new systems.

Experiments with thrifty technology indicate, however, that even greater residential energy savings can be effected when the total home environment is considered. The Pennsylvania Power and Light Company's experimental low-energy

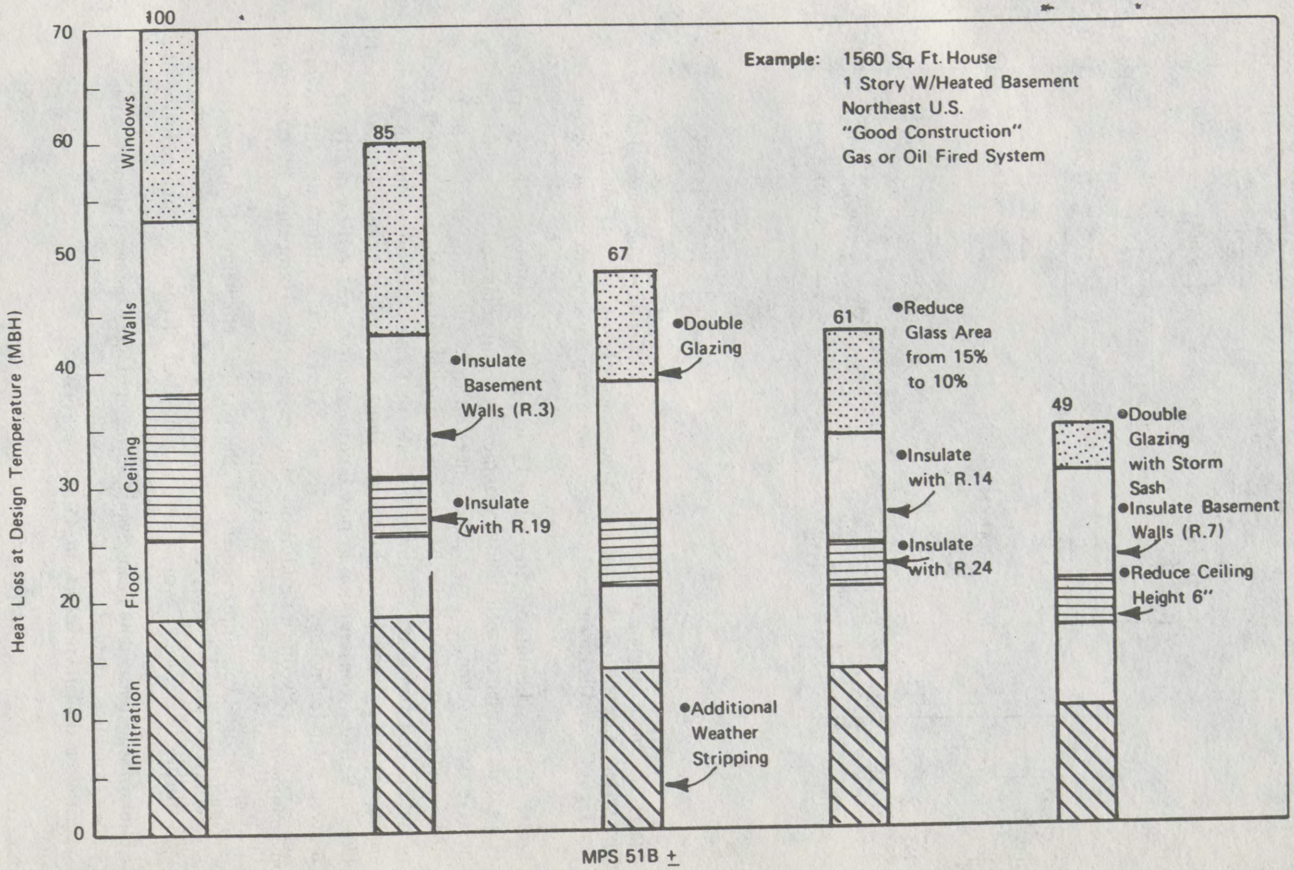


Figure 11 Leak plugging and input juggling: effect of more elaborate modifications of design and construction of a house on energy use for heating. Note the progressive savings. Source: (67).

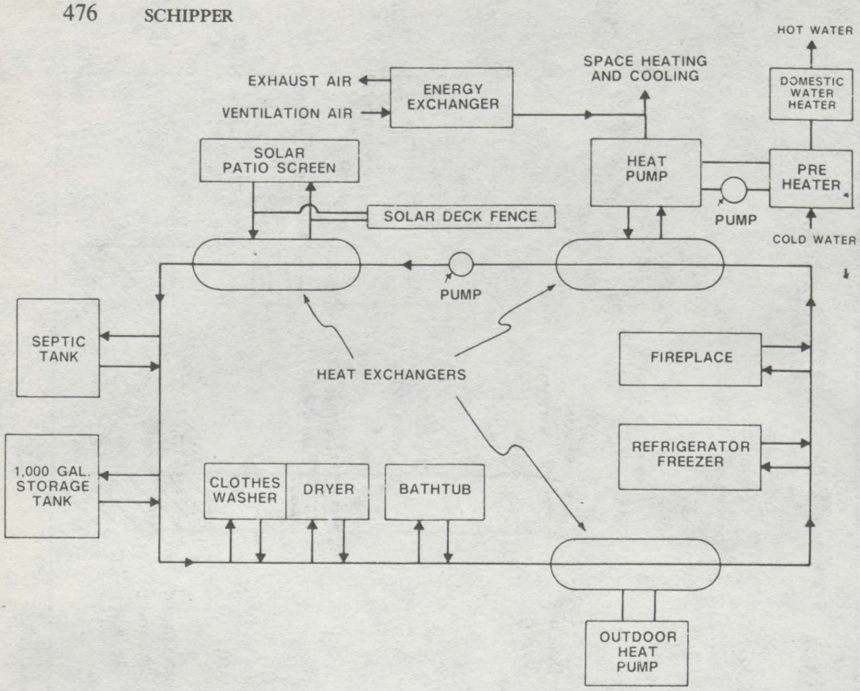


Figure 12 Input juggling and thrifty technology: schematic of the house of the future. This system is installed in the experimental low-energy house built by Pennsylvania Power and Light Co. in Allentown, Pa. Heat exchangers recapture as much heat as possible.

house, shown schematically in Figure 12, would reduce energy use by as much as two thirds compared with ordinary homes, by using solar collectors, heat pumps, heat recovery schemes, and conveniences such as automatic devices that close curtains at sunset to minimize heat losses through windows at night.[8] Other studies of actual and proposed buildings indicate that energy requirements in existing structures can be reduced by 20% in the short run and more over longer periods (76–78, 98), and consumption in new buildings can be reduced by nearly 50%, or more if solar technology is used[9] (78, 81, 82). Figure 13 illustrates the savings achieved in a new office building in Manchester, New Hampshire, by combining most of the conservation strategies discussed here.

In transportation, improvements in the physical efficiency of engines, such as greater use of diesel motors or development of advanced propulsion systems in cars (thrifty technology), would save a good deal of energy,[10] but reducing the

[8] Information released by Pennsylvania Power and Light Company, Allentown, Pa.

[9] See footnote 8.

[10] See discussion and references in (45). Also see (93).

Table 8 Identified savings potential of eight industrial plants[a]

Plant Type	Total Annual Energy Bill ($)[b]	Identified Savings ($)[b]	Percentage
Basic chemicals	5.5	2.39	43.4
Textiles	0.9	0.29	32.0
Agricultural chemicals	1.7	0.28	16.7
Oil refinery	10.3	1.12	10.8
Chemical intermediates	13.2	1.87	14.2
Food processing	1.1	0.33	30.1
Pulp and paper	5.3	1.70	31.5
Rubber and tires	2.9	0.47	16.4
Average	5.1	1.05	20.6

[a] Source: E. I. du Pont 1973 Energy Management Client List (83).
[b] In millions of dollars.

weight of cars (output juggling) would save even more (45, 94) (Figure 14). However, the degree to which people might reduce travel (output juggling) is difficult to estimate. Mode mixing depends on the availability and cost of alternative forms of passenger and freight transport, although increased load factors in public transit, including air transport, would save energy (38, 100). Improved freight handling procedures (management), including permission for interstate trucks to be fully loaded on return trips, would greatly increase energy efficiency in the movement of goods (6, 91).

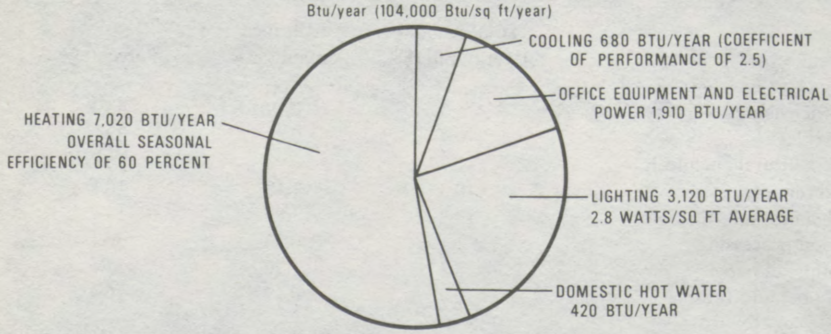
Many of the savings in transportation are not dependent on technological or economic breakthroughs but instead await changes in socioeconomic patterns, habits, and laws. Trends can work in the wrong direction also; both a continuation of population dispersal into suburbia and exurbia[11] (101) and the development of complicated or extremely fast vehicles, such as SSTs, high-speed rail vehicles, or short-takeoff and short-landing aircraft, would increase the energy requirements per passenger-mile and the per capita miles of travel. These trends are an example of how output juggling increases energy use.

In energy-intensive industries, engineers and computers have been employed to effect immediate savings of 10–20% through leak plugging (6, 12, 68, 83–86). Table 8 shows some of the results of the energy conservation programs of E. I. du Pont Company (83). The costs of these programs and the actual equipment adjustments required were far less than the savings in fuel expenditures. Similar programs have been developed by I.B.M., Honeywell Corporation, and Johnson Controls.

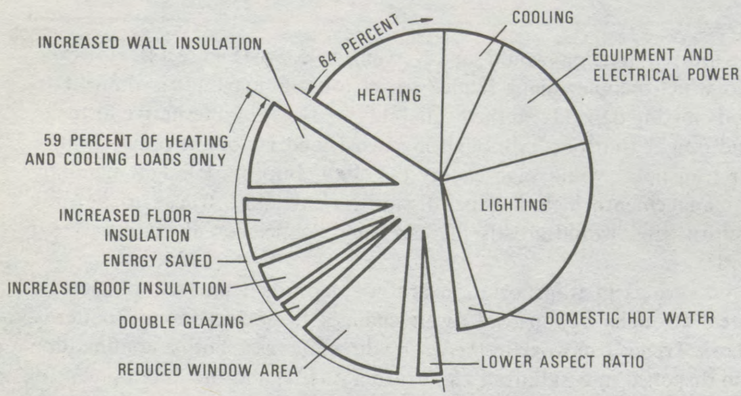
In the longer run, greater energy savings in industry are realizable as input juggling and thrifty technology help reduce process energy requirements of materials

[11] See (101). The BART electric train system in the San Francisco Bay Area underscores one dilemma in the interaction of urban planning, geography, and energy use: if a rapid rail system stimulates commuters to live farther from work than they otherwise would, some or all of the energy conservation benefits of this system would be lost.

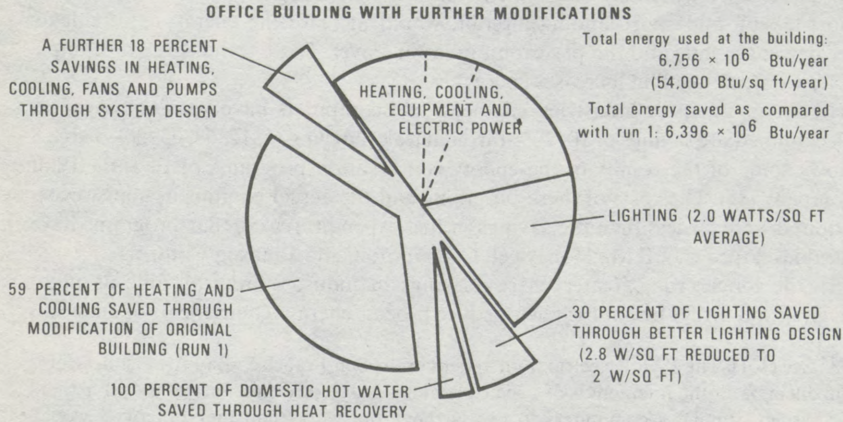
ENERGY CONSUMED IN A TYPICAL OFFICE BUILDING[a]
Total energy used at the building: 13,150 × 10^6
Btu/year (104,000 Btu/sq ft/year)



OFFICE BUILDING WITH DESIGN MODIFICATIONS[b]
Total energy used at the building: 8506.4 × 10^6
Btu/year–(68,000 Btu/sq ft/year)



OFFICE BUILDING WITH FURTHER MODIFICATIONS



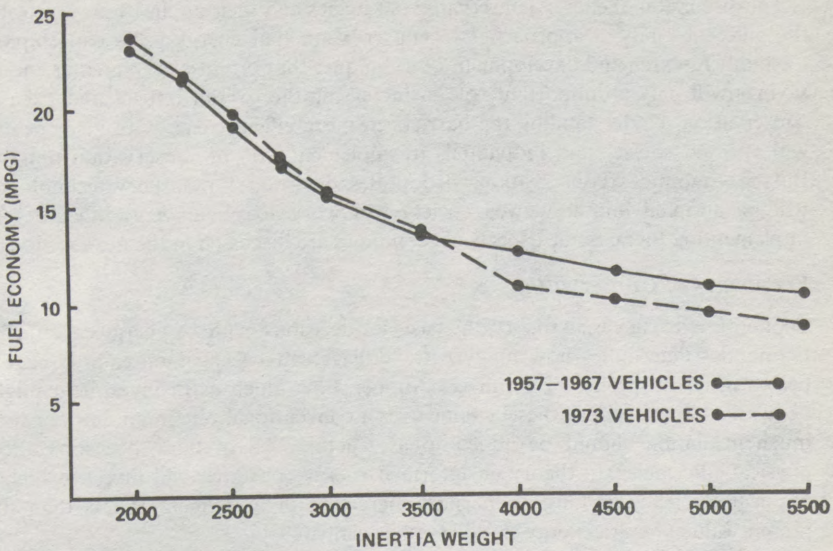


Figure 14 Design efficiencies: fuel economy vs inertial weight. The design efficiency of lighter cars is obvious. Source: (94).

closer to thermodynamic minima (45, 86; see also article by C. A. Berg in this volume) or as tasks are modified, especially to allow utilization of waste heat (45, 62). The economically optimum level of energy use will be sensitive to the price of fuel (86), but most process energy requirements declined during the past 25 years even as fuel prices fell (29).

Figure 15 shows this decline in energy consumed for an important energy-intensive product, cement (102). Input juggling has allowed each of the two processes to become more efficient, and at the same time the manufacturers have shifted to the more efficient dry process for future production. Similar short- and long-term trends have been observed in nearly every energy-intensive industry in the United States (103) and also in Sweden, where process energy requirements are generally lower (33).

← *Figure 13* All strategies: effect of progressive design modifications of an office building. Actual predictions of building being built for Government Services Administration, in Manchester, NH. Source: (77). Figures show equivalent energy units of 10^6 Btu/year.

(a) In New England; 126,000 sq. ft.; design based on "typical" New England design criteria; weather data from Manchester, NH; wall U value = 0.3 Btu/°F-hr-ft; floor U value = 0.25; roof U value = 0.2; single glazing, 50% window/wall area ratio; shading coefficient = 0.5 (year round); 6 stories tall; 2:1 aspect ratio (length: width); long axis, north-south.

(b) Wall, floor, roof U values = 0.06; double glazing, 10% window/wall area ratio; shading coefficient = 0.5 (year round).

The discussion of energy conservation strategies and their applications illustrates the different kinds of approaches to conservation that energy users can employ. Certainly research and development of techniques that promise even greater energy savings will play an important role in increasing the overall impact and pace of conservation. Understanding the barriers to more efficient energy use (see below) will also aid society and individuals in implementation of conservation options. But the economics of conservation will doubtless determine how fast new technologies will be adopted and how well society will work to circumvent difficulties in implementing them. Some aspects of economics are discussed in the next section.

Economics of Conservation

Economic efficiency is, in theory, the basis for decisions made by energy consumers. Economics determines how many extra dollars can be spent on improving the heat-transfer properties of an air conditioner, how much extra investment might be justified in choosing a diesel engine over a conventional one in an auto, or how much insulation should be added to a structure. All of these decisions affect physical efficiencies. In theory an informed energy consumer will invest in higher physical efficiency as long as the next increment of investment is less than the present value of extra energy saved [see especially (49)].

Most of the conservation options cited in Table 7 have been analyzed with respect to first cost, interest and taxes, and so forth. Fortunately the strategies that raise the physical efficiencies of energy systems raise the economic efficiencies as well. Some energy conservation strategies, such as insulation in refrigerators and

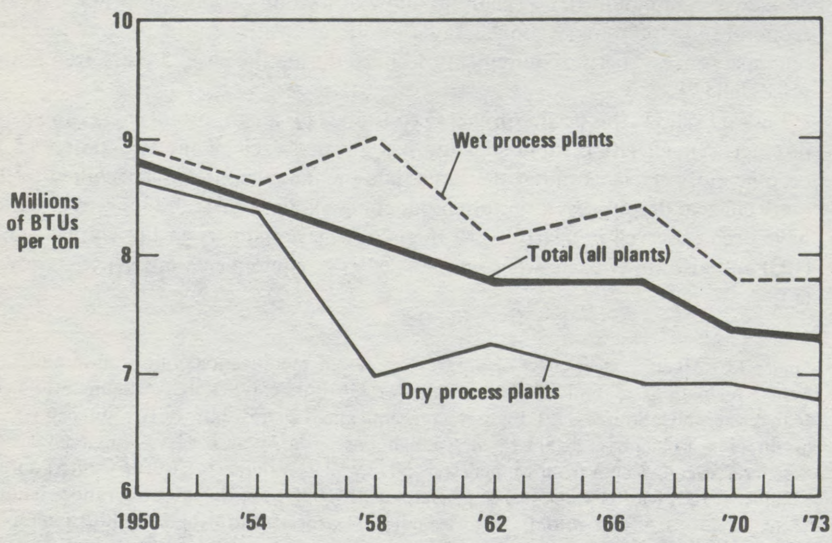


Figure 15 Historic trend in the cement industry's improvement in design efficiency. Source: (102).

water heaters, pay back the initial incremental investments in months (69–71), while others, such as industrial techniques, building insulation, and more efficient heating/cooling systems, require longer periods. Some options save money from the beginning, such as smaller cars and innovative designs of structures, while others, such as mass transit systems, are difficult to evaluate because much of the payoff accrues to society in general.

A few examples are worth noting here. Moyers (43) showed how much money a consumer could economically invest in a more efficient room air conditioner, based on the first-law efficiencies of models shown in Figure 5. His results (Figure 16) depend on number of hours of use per year, price of electricity, cost of money, and inside temperature desired. The calculations of Berg (68) (Table 9) compare yearly operating costs of different air conditioners and show clearly the savings achieved by higher efficiency. As Ross & Williams noted (62), it is usually less expensive for the user to invest in higher efficiency than for the local electricity utility to invest in extra peak capacity.

Other calculations show that proper insulation in buildings saves 20–50% of total energy and 10–30% of the expense required for heating or cooling (63) and that heat pumps save at least 30% of total energy and 20–30% of the total costs of using electric resistance heat (45, 62, 64, 104, 105). The alternative of providing extra energy by building more oil refineries, pipelines, and power plants would be far more expensive both in initial investment and in life-cycle costs (62).

Table 9 Efficiency and the cost of air conditioning[a]

Rated Cooling Capacity (Btu/hr)	Rated Current Demand (A)	Retail Price ($)	First-Law Efficiency (Btu/W-hr)[b]	Ten-Year Total (dollars/1000 Btu)
4000	8.8	100	3.96	84
	7.5	110	4.65	77.70
	7.5	125	4.65	81.45
	5.0	135	6.96	67.25
5000	9.5	120	4.58	74.90
	7.5	150	5.80	68.20
	7.5	150	5.80	70.20
	5.0	165	8.70	59.80
6000	9.1	160	5.34	67.30
	9.1	170	5.24	68.90
	7.5	170	6.96	61.80
	7.5	180	6.96	63.50
8000	12	200	5.80	67.30
	12	220	5.80	67.80

[a] Cost of air conditioning is inversely proportional to first-law efficiency. In each class of air conditioner, the model with the highest first-law efficiency has the lowest yearly cost. Examples worked out by Berg (68).

[b] Also called energy efficiency ratio (EER).

It is also important to consider the economic and energy impact of input juggling applied to all energy-using systems in a single structure. For example, Dubin et al evaluated a large number of energy conservation options that apply to electric homes in Florida (74). These are listed in Table 10, along with expected savings from each technology in kilowatt-hours per year consumed in the home (74). The incremental capital costs of each option can be compared with the present value of the electricity saved over the lifetime of the option. For a 30-year payoff time on these houses (15-year payoff time on appliances) the homeowner could invest at least 75¢ (38¢ on appliances) on conservation measures per kilowatt-hour saved yearly, assuming a present cost of 2.5¢/kW-hr and inflation in electricity cost at or greater than the general rate of interest. In these houses the cost of adding an overhang is not justified by energy savings alone. Solar heating is also difficult to justify on economic grounds because heating requirements in Florida are low, but a combined water heating/space conditioning system might be economically feasible.

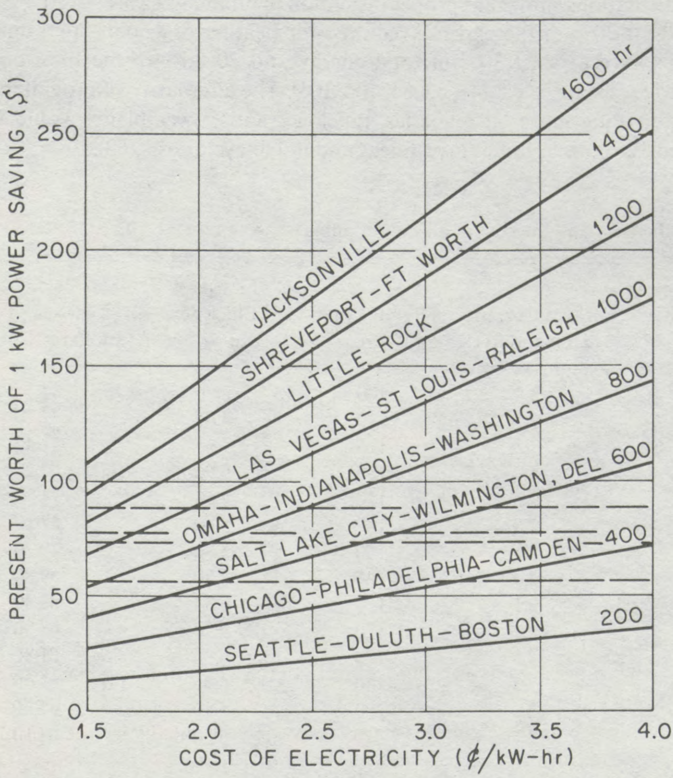


Figure 16 Present worth of 1-kW power savings as a function of annual hours and energy cost, for selected locations, 18% interest, 10-year amortization. If environmental costs were included, or if electricity was more costly during peak usage periods, consumers would be justified in paying much higher prices for more efficient air conditioners.

Table 10 Cost and energy savings of key design elements in all-electric homes[a]

Item	Extra Cost ($)	Annual Savings (kW-hr)	Investment Saved per kW-hr/yr
Styrofoam roof insulation	930		
5-ft overhang	1026		
Styrofoam wall insulation	375	2000	(65¢,
Casement windows and french doors	800		insulation only)
Door closers	80		
Single 3-ton water-to-air heat pump (design B)	1000	5420	20¢
Hot-water heater	300	3140	10¢
Refrigerator	100	650	15¢
Range	400	300	Self-cleaning, no charge
Dishwasher			
Air heater	25	110	12¢
Short wash		210	
Clothes washer	70	340	20¢
Dryer and clothes line	50	300	16¢
Freezer	50	300	16¢
Trash bins	(Save 130)	50	—
Fluorescent lighting	(Save 430)	840	—
Total	4646	13,700	

[a] Source: (74). Figures based on an all-electric home in Florida.

The kinds of analyses reviewed here for buildings have been performed on many other aspects of energy use (6, 68, 86). Such evaluations of the economic and energy savings potentials of conservation strategies allow planners to project future energy needs based on the economically optimal needs for energy. This is explored in the next section.

Conservation and the Energy Future

It has been emphasized in this review that the tasks for which energy is consumed can be carried out in different ways that require widely varying amounts of energy. Figure 17 illustrates a general relationship between economic efficiency (cost) and design efficiency. Some combination of energy with other inputs will provide the most economic use of all resources. This is shown symbolically by the optimal zero point at the minimum of the cost-energy curve in Figure 17. Environmental costs tend to push the optimum toward physically more efficient energy use, a fact rarely considered seriously in evaluations of the economics of solar energy or other supply or conservation options (22, 23, 106, 107; chapter by Budnitz and Holdren in this volume; also section on conservation and pollution, below).

That the energy use in most systems in 1970 or 1975 was economically inefficient is indicated by the position in Figure 18 of *actual* for those years. Here *projected* gives an estimate of the energy use that would occur if energy consumption grew at historical growth rates in spite of price increases. If energy costs continue to rise, however, then the economically optimal amount of specific energy consumption for tasks will fall, as is indicated by O_{90} in Figure 18.

The discussion of "barriers" (below) presents reasons why energy use today is not optimal and why certain governmental actions may be necessary if energy use is to approach the optimal point in the future. Energy conservation policy can be considered as that group of laws, standards, incentives, taxes, or other governmental, institutional, or private actions that aid this approach to the optimal energy utilization.

A curve like those in Figure 18 can be drawn for most energy-using activities or systems, as is done for space comfort in buildings in Figure 19. The data presented in Tables 8 or 9 would fit on a curve of this shape. The costs of providing comfort fall with conservation, first through retrofitting of insulation, then through more sophisticated designs and increased efficiency of new structures, as long as marginal benefits exceed costs. Some options, like solar heating and cooling, may not be the most economic in every case, as is symbolized by the upturn of the cost curve as energy use falls further. As fuel costs rise, however, solar heating and

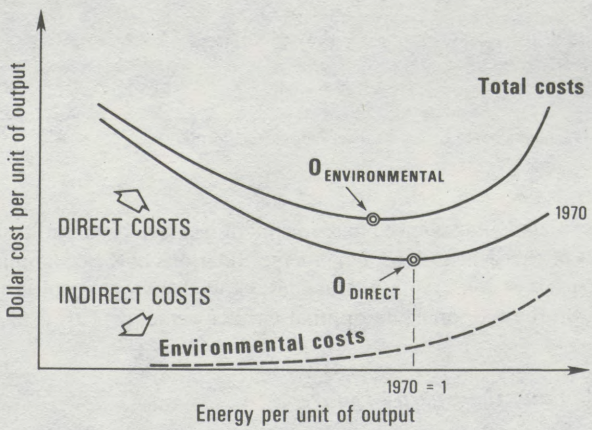


Figure 17 Optimizing energy use. There are many combinations of energy use and other economic inputs that provide a given output. This figure shows the total cost of that output for different amounts of energy use. As energy prices rise, the optimum moves toward lower energy use. The shift of optimum from O_D to O_E is exaggerated to show the effect of the environmental cost of energy on optimal use. Even if energy use were economically efficient (based on direct costs), inclusion of environmental costs, which tend to rise nonlinearly with increased energy use, would shift the optimal point of energy use toward slightly lower energy use. The arrows on the axes point to higher energy and dollar costs.

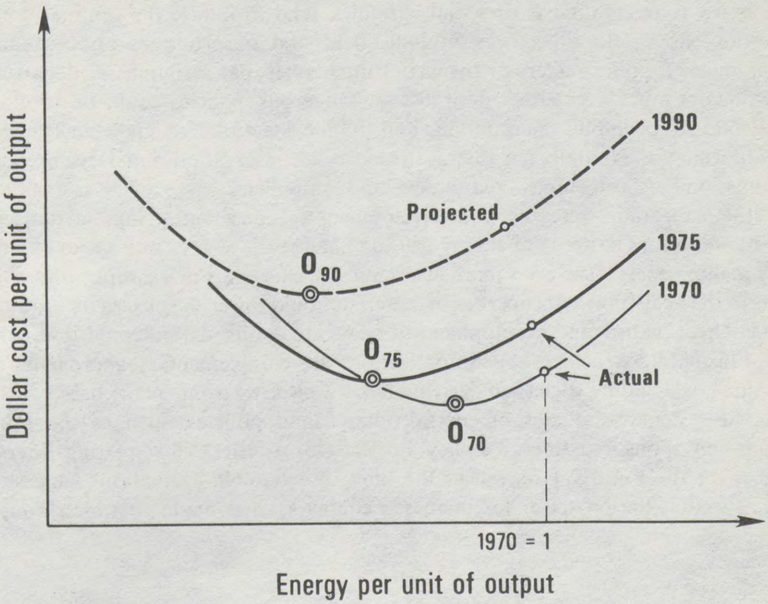


Figure 18 Optimizing energy use. Energy use was economically inefficient in 1970 and 1975, as symbolized by the differences between *actual* and O. If historical growth in use persists despite higher energy prices, use will be even more economically inefficient than use in 1975.

cooling will become economically efficient in more and more instances, in comparison with fueled systems[12] (see also 43, 49, 63).

Amassing a large number of curves such as in Figure 19 is a formidable task if one is to include all of the options available to the major energy-consuming systems in this country. However, such curves would then allow projection of energy needs both on the basis of desired goods and services and on the basis of the most economic, specific energy needs of these goods and services. The cost of conserving an additional Btu for each task, relative to today's consumption, could be compared with the cost of producing each additional Btu beyond some reference price and supply that is assured. Adding up these curves would indicate ranges and costs of total supply and demand. The area where these demand and supply curves cross would indicate the most economic amount of energy consumption in a future year, for a given mix of tasks. Other balances of supply and demand would probably cost more than the optimum. This is indicated in Figure 20. Non-market factors,

[12] See (82) for a comparison of costs of fueled and solar systems in various locations. It is generally anticipated that solar heating/cooling systems will fall in cost through economies of scale in manufacture as well as through technological advances.

such as environmental costs or social variables, tend to diffuse the optimal point somewhat, as would differences in judgement and uncertainties about future technologies. If policymakers or their constituents felt that a significant departure from this optimum were either desirable or dangerous, policies could be adopted that would aid or inhibit the economic and technical factors that shape energy use. In California, for example, the Energy Resources Conservation and Development Commission has been empowered to develop such policies.

At the same time, research and development of conservation applications to present and future patterns of energy use can change the shapes of Figures 19 and 20 by making energy use even more economically efficient. For example, improvements in the heat-transfer properties of materials could lower the electricity requirements of heat pumps, and development of new kinds of insulation could lower the cost of insulating structures. Such applications are complementary approaches to the same goal—aiding society in deriving more well-being from energy use.

Recent systematic studies of energy options and policies, such as the Ford Foundation–sponsored Energy Policy Project (13) or ERDA's "Creating Energy Choices for the Future" (16), reflect the kind of economic evaluations suggested here, as well as the prospects for increased energy savings made possible through

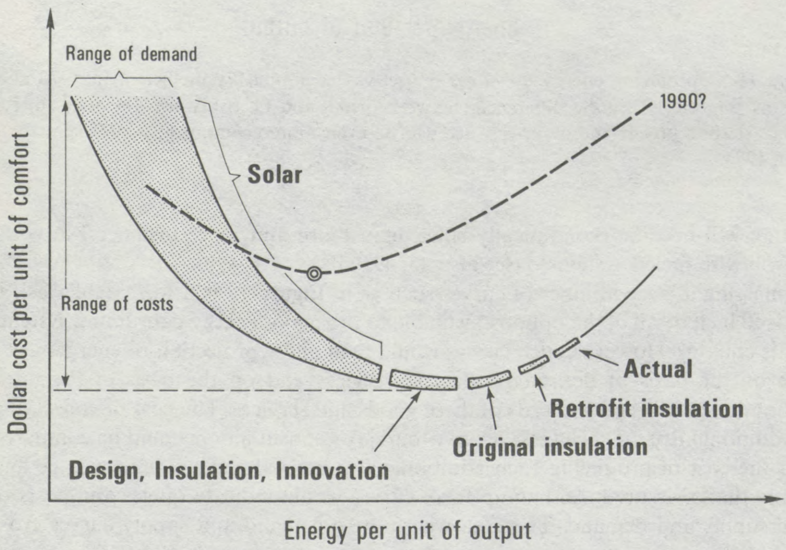


Figure 19 Optimizing energy use: buildings. Actual conservation strategies, such as those listed in Tables 9 and 10, can be displayed in curves similar to this one. Solar heating/cooling is not economic in many buildings at 1975 energy prices, but it would become more economic in the future (1990) as energy prices rise. The ranges for cost and energy savings of solar heating/cooling reflect uncertainties as well as the use of nonsolar backup systems. Comfort can be defined by using temperature, humidity, and other physical-physiological parameters.

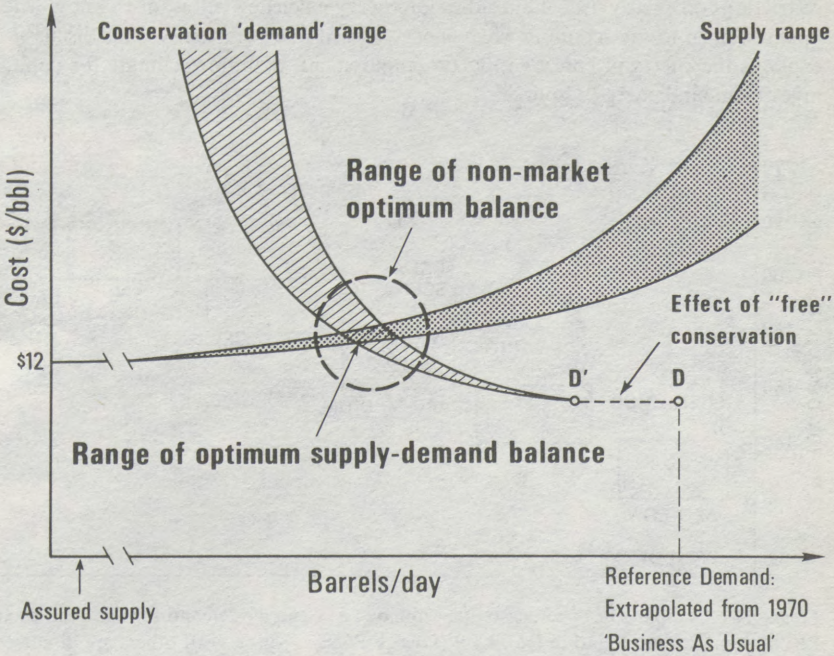


Figure 20 Generalized comparison of future costs of increasing supply and increasing efficiency. Compared with historical extrapolations, demand would be lower through conservation that takes place with immediate cost savings—"free" conservation. Beyond that point other economic factors substitute for energy (as explained in the text) until the cost of saving an additional barrel of oil, or barrel of capacity per day, exceeds the marginal cost of generating one. Because of qualitative and quantitative uncertainties, the optimal supply-demand balance is best represented by the darker shaded area, with the circle indicating the effect of non-market factors on this optimum.

R & D into energy use and conservation. Energy projections from these studies, which explicitly recognize the effects of more efficient energy use, are summarized in Figures 21 and 22. Although some observers feel that energy demand cannot be modified significantly by technical and economic changes (108, 109), it is clear that an enormous potential exists for raising the efficiency of energy use. It is important, however, to consider the long-term implications of realizing this potential.

LONG-TERM IMPLICATIONS OF EFFICIENT ENERGY USE

Total expenses for energy in the United States average around 10% of the GNP (13, 14), and this figure is expected to grow. Therefore, a substantial conservation program means that billions of dollars will be redirected from energy expenditures to non-energy expenditures. Policymakers considering efficiency standards, taxes, restrictions on energy use, or subsidies for energy efficiency will want to know what might happen to the economy when energy is used more efficiently. This discussion explores the effects of conservation on employment, pollution, climate for capital investment, and energy resources.

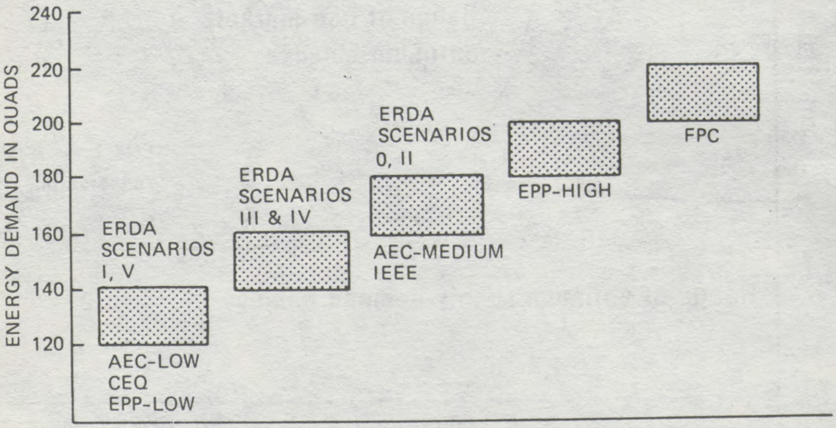


Figure 21 Comparison of forecasts for estimated US energy demand for the year 2000. ERDA scenarios are found in (16), EPP (Energy Policy Project) (13); others are discussed in (1, 4).

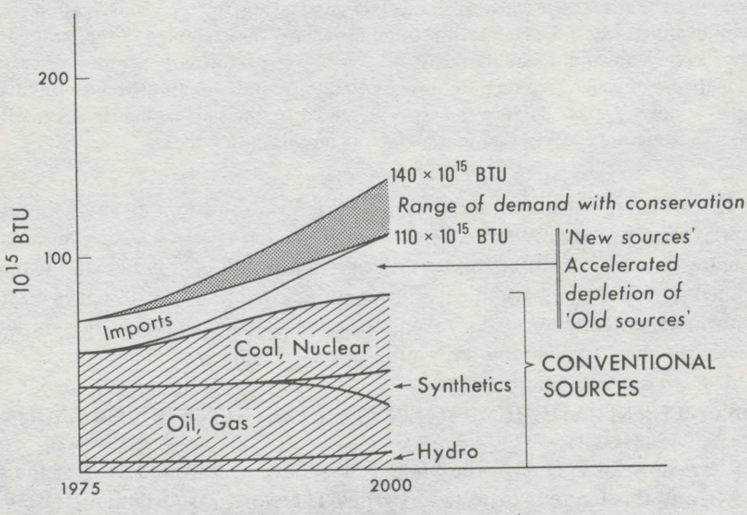


Figure 22 One possible approach to the "low" scenarios of Figure 21. Source: (14).

Employment

The use of energy is essential to nearly all employment in this country, but energy requirements of different goods and services vary greatly. Input-output techniques reveal the average amounts of energy and labor required to satisfy the demand for a product or service (50–52). These values include indirect energy and labor required by industries whose output was used by the producing industries, and the energy and labor required by suppliers of those industries, and so on.

Figure 23 displays the energy and labor requirements per dollar of demand for some goods and services, and Table 11 gives the intensities of some important personal consumption activities. Energy forms (and raw materials) have low labor intensity and high energy intensity. Manufacturing is intermediate, whereas services are labor-intensive but not energy-intensive. Closer inspection of the energy industries shows them to be very capital-intensive but far less labor-intensive than the economy as a whole [see Tables 3 and 4 in (14)].

Table 11 Energy and labor intensities of the top 20 (dollarwise) personal consumption activities in 1971[a]

Personal Consumption Expenditure—Sector Description	Energy Intensity (Btu/$)	Labor Intensity (Jobs/$1000)
Electricity	502,473	0.04363
Gasoline and oil	480,672	0.07296
Cleaning preparations	78,120	0.07332
Kitchen and household appliances	58,724	0.09551
New and used cars	55,603	0.07754
Other durable house furniture	45,493	0.08948
Food purchases	41,100	0.08528
Furniture	36,664	0.09176
Women and children's clothing	33,065	0.10008
Meals and beverages	32,398	0.08756
Men and boys' clothing	31,442	0.09845
Religious and welfare activity	27,791	0.08636
Privately controlled hospitals	26,121	0.17189
Automobile repair and maintenance	23,544	0.04839
Financial interests except insurance co.	21,520	0.07845
Tobacco products	19,818	0.05845
Telephone and telegraph	19,043	0.05493
Tenant occupancy, non-farm dwelling	18,324	0.03258
Physicians	10,271	0.03258
Owner occupancy, non-farm dwelling	8,250	0.01676
Average, including energy purchases	70,000	0.08000
Average, non-energy purchases only	52,000[b]	—

[a] Source: (100).
[b] 1967 figure. The corresponding 1967 figure for average including energy was 80,000 Btu/$. Source: R. Herendeen, private communications.

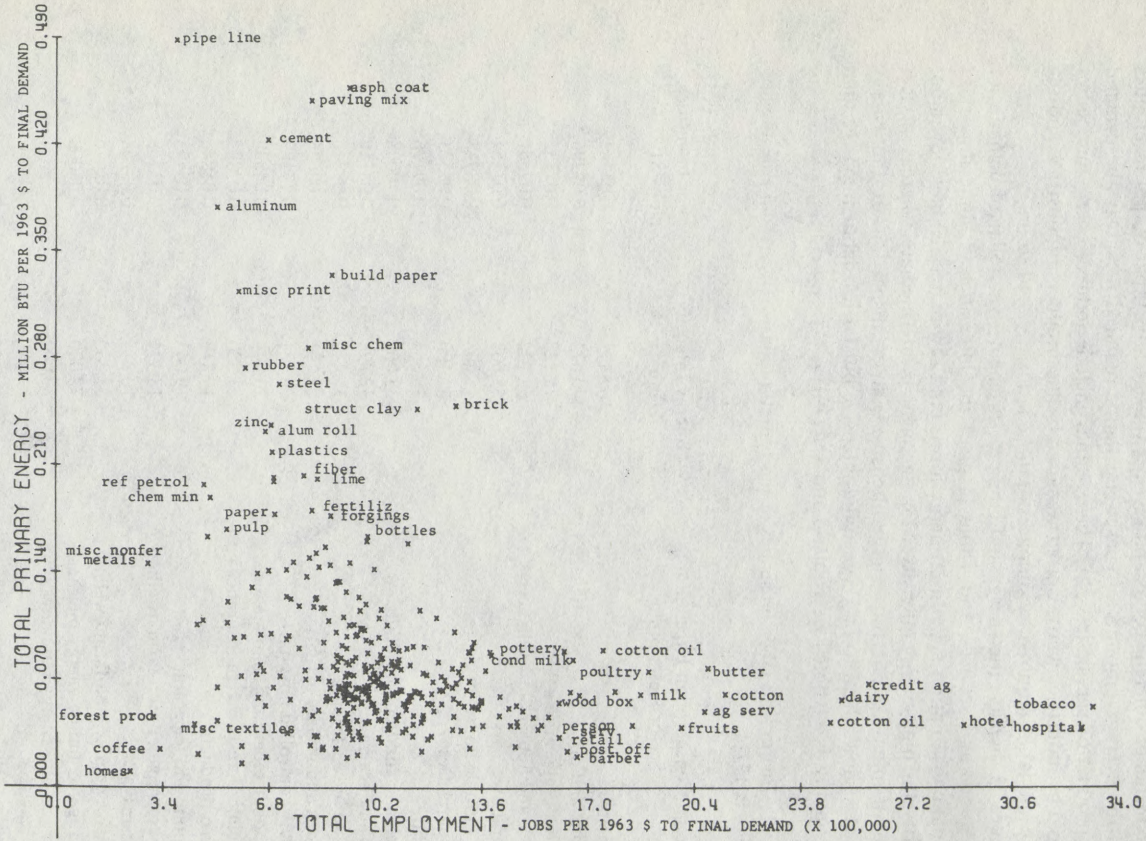


Figure 23 Total direct and indirect energy and labor intensities for 362 economic sectors in 1963. Source: (51). 1971 figures are similar.

The strategies of energy conservation considered here substitute capital, materials, labor, know-how, or management for energy. Compare, for example, two air conditioners of equal capacity, operating in similar homes under similar loads in the same climatic region, one requiring half the power of the other. If a consumer buys the more efficient unit, some of the money otherwise spent on energy is used for extra materials and labor, and this expenditure results in a more carefully constructed, more efficient air conditioner. Since manufacturing is generally more labor-intensive than electric utilities, the redirection of spending—from paying for electricity to investment in a more efficient unit—raises the total demand for labor per unit of air conditioners and still provides for the consumer's desire for comfort [see Table 11, or details in (50)]. When the consumer spends the money he saved by energy conservation, his new purchases will require increased labor, in contrast to buying electricity (50–52). The result is more goods or services and more employment, with less energy consumed. The notion that welfare or employment can only grow in step with energy use completely ignores the effects of strategies that increase efficiency.

In industries that conserve energy, employment will generally increase, since nearly every energy conservation strategy calls for energy specialists to monitor and adjust energy usage in the plant or building. Similarly, the implementation of long-range conservation plans (input juggling, thrifty technology) calls for equipment, consultants, architects and designers, and other specialists not otherwise required. The costs of changing to a more efficient use of energy are, of course, borne out of savings from energy bills, and the net dollar savings is either passed on to consumers, reinvested, or taken out in profits. In these and most other conservation applications, energy expenditures are replaced by non-energy expenditures, which generally increase employment.

One of the arguments for output juggling has been the observation that goods and services that are less energy-intensive tend to be labor-intensive (Table 11). If consumers preferred less energy-intensive items, whether in response to higher energy prices or from a desire to save energy for the public good [as suggested in (95) concerning gifts], the energy/GNP ratio could decrease even with no changes in the technologies of energy utilization in production of goods or in the ratio of services to goods. Some changes in consumer preferences, such as greater use of buses, could improve design efficiency by increasing load factors (100); changes in travel and tourism would affect transportation energy use; and changes in aesthetic and architectural preferences would alter energy demands in housing and buildings (110).

Hannon (50) concluded that output juggling cannot save a large percentage of US energy use. On the other hand, a study of Sweden (33) suggests that substitution of social services for large cars or other energy-intensive personal consumption does reduce energy consumption somewhat for a given level of GNP. But it may not be necessary to engage in output juggling to save energy, since the other techniques discussed here promise such large savings with little or no change either in life-style or in the mix of goods and services in final demand.

It is important to remember that many of the changing patterns of employment and intermediate demands effected by a policy of energy conservation would appear in any case as a result of natural market forces, although perhaps over a longer period of time. Certainly any changes in the structure of the economy, whether gradual or forced by an embargo, could create temporary unemployment and some social dislocation. The short-term effects of changing energy-use patterns will continue to raise issues, and one must insist that those affected not be asked to bear a burden that is too heavy. Society can and must cushion these effects during the transition to a period of more efficient energy utilization.

Conservation and Pollution

When energy-conserving practices are adopted, the net result is an increase of useful output per unit of energy input. This has important environmental consequences because energy use and harvesting are among the most polluting activities in our economy. If a homeowner in the Tennessee Valley Authority service area replaces electric resistance heating with a heat pump (saving approximately 50% of the electricity commonly used to heat homes there), less coal need be mined [about

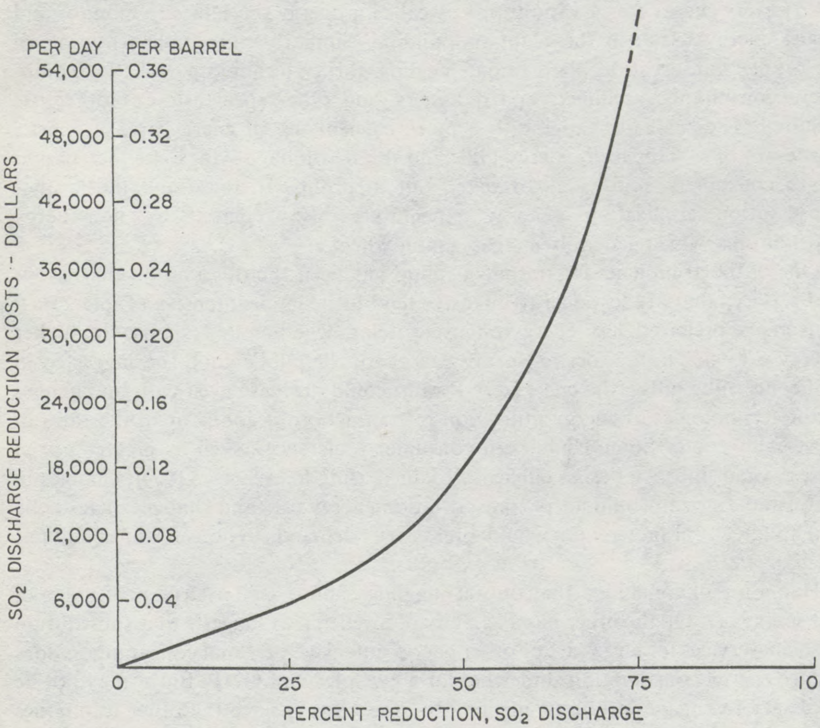


Figure 24 Costs of reducing discharge of SO_2 from a typical US petroleum refinery. Source: (21).

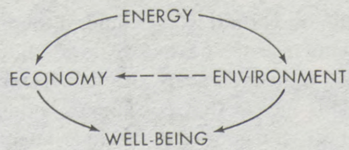


Figure 25 Symbolic representation of the double interaction of energy and well-being. The beneficial use of energy in the economy is partially offset by the adverse impact that energy use has on the environment, affecting well-being directly as well as through the economy itself. Drawing due to J. Holdren, private communication.

3–4 tons less per house per year (105)], fewer power plants need be built, less cooling water is used, and less air, land, and water pollution occurs for each night of comfort in the winter or day of cooling in the summer. Similar considerations apply to industries that conserve energy. Since the demands for materials required by energy-saving technologies are usually only slightly higher than correspondingly less efficient options, the reduction in all forms of pollution will be appreciable.

The effect of conservation on pollution is important, for as the number of various polluters grows and as the amount of pollutants grows in kind and total amount, more abatement technology will be required to hold constant the concentration of pollutants in the environment (107). But costs of pollution control tend to increase faster than the increments of control (Figure 24). The total bill for abatement of pollution could thus rise in the future faster than the GNP itself (106, 111). Pollution also means costs to health, welfare, and property (112–114). More efficient energy use reduces all of these costs and the pollution as well.

It is often said that "large amounts of energy will be needed to clean up the environment" (115). Actually the energy requirements for environmental control, while not insignificant, are not large. It has been estimated that energy requirements for pollution control raise total energy consumption by only 2–4% (116, 117). Reduced automobile size, increased use of mass transit, or longer-lived cars all reduce pollution per passenger-mile, as well as provide energy savings. In addition the percentage of fuel penalty imposed by pollution control on automobile emissions is generally smaller for lighter cars than for heavier ones (94, 116). Moreover, recycling, which reduces solid wastes, also saves energy (87–89, 117), and some solid waste can even be used as fuel.

Use of energy has two effects on well-being—it is positive through its application to satisfying human needs and negative through its adverse effects on the environment (see Figure 25). Increased economic and human well-being obtained per unit of energy, through conservation, reduces the environmental costs per unit of well-being, and this adds to our welfare.

Energy Conservation and Investment Requirements

New energy production facilities demand large, and ever increasing, amounts of capital per Btu produced or per unit of capacity. The energy sources most often cited as vital to our energy future—nuclear energy, shale oil, coal gasification, enhanced recovery of oil and natural gas—would, if the historical trend continued, require capital investments over the next 25 years totaling trillions of dollars (118–120), making the energy industry's share of all investment grow faster than the economy as a whole. This means that consumers, industry, and the government would have to forego both consumption and investment, through higher interest rates, higher prices, or higher taxes, in order to finance the expansion of the energy industry.

Higher energy productivity, on the other hand, slows the growth of investment in energy systems to a more manageable rate, easing pressure on interest rates and allowing more personal consumption of other investments, because conservation is cheaper. If the criterion of greatest marginal benefit is applied to investments, it can be shown that proper conservation techniques (see Table 7) save more energy than new energy sources can produce, per dollar invested (62). Some of the money that would have been invested in greater energy production should be invested instead in greater energy productivity—that is, in conservation practices. This point, that

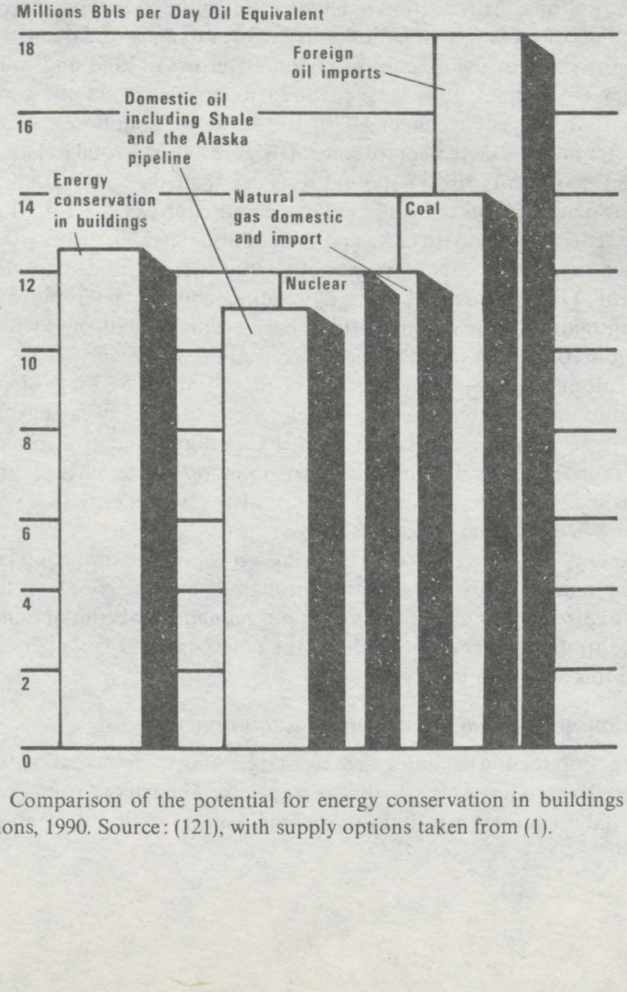


Figure 26 Comparison of the potential for energy conservation in buildings with some supply options, 1990. Source: (121), with supply options taken from (1).

conservation is a cheaper substitute for greater production (at least up to the point shown in Figure 20), is not sufficiently appreciated.

The cost of an investment in Btu, or capacity added, is especially important in the case of buildings, which tend to outlast most energy production facilities. The American Institute of Architects (121, 122) estimates that investments in extra efficiency in new and old buildings could economically replace the supply equivalent of 12 million barrels of oil per day by 1990 (Figure 26). Again, a Btu saved costs less than a Btu harvested.

Similar estimates have been made regarding industry. A recent study by Dow Chemical Company (47) estimated that if both electricity and heat were co-generated on site by large industrial power users, with power and steam being shared with existing public utilities, the required investment of $13 billion would replace an investment in utilities alone of $29 billion and would save the equivalent of 725,000 bbl/day of oil or equivalent. In the Technical Fix scenarios of the Ford Foundation's energy study, a reduction of energy demand by 33% in the year 2000, compared with historical growth, would mean a capital savings of $300 billion (13).

Growth in energy demand would have to be met by construction of energy systems not yet in existence. One can therefore estimate the energy-harvesting facilities that would not be needed if future energy-use technologies become more efficient. Electric resistance heating and large, inefficiently designed office buildings would have been major ingredients in the growth in electricity use. Poorly insulated homes, leaky industrial processes, and fuel-hungry autos make up much of the future demand for fuels based on historical growth [see (5) for a naive description of future demand]. An insulation program alone that would result in a savings of one third of the energy used to heat homes and buildings (more in new structures, and less in existing ones) would replace the equivalent energy output of oil refineries totaling 2 million bbl/day or 75 1000-MW nuclear power plants operating at 60% capacity factor.[13] Replacing resistance heating with heat pumps would reduce system capacity needs still further (64, 104, 105).

Therefore, what conservation means to investors is that relatively more energy-related investment should take place at the end point of energy use, displacing even more dollars on the energy production side. Since the ingredients in more efficient structures and industrial processes are usually highly dependent on careful engineering, quality work, and tender loving care, one expects that the employment requirements of conservation investments will be slightly higher than those for the additional investment in energy production. This point has already been made in the discussion of employment.

Conservation and Marginal Energy Sources

Conservation has another effect on the future of energy production, by slowing the rise in physical and dollar costs associated with marginal, less accessible, more

[13] J. Holdren, personal communication. These numbers are easy to calculate. Heat pumps are becoming increasingly common in areas where electric resistance heating is appreciable, like the TVA service territory (105).

energy-costly sources of energy. "Scarcity" of an energy resource really means "high entropy" (high degree of dispersal) of the energy fuel; increased amounts of high-quality, low-entropy energy fuels are needed to recover each Btu of marginal fuels.

The degree to which the real marginal cost of energy production from conventional sources is rising today is evident from Figure 27 (21). The rise in cost of drilling is nearly exponential with depth. Increased requirements for earth moving, drilling, and water and waste disposal forewarn of rising environmental spoilage per unit of net energy actually gained from all energy harvesting. Lignite, with only half the Btu content of bituminous coal, requires substantially larger environmental disruption per Btu recovered and produces more ash and sulfur per Btu of heat obtained in a boiler (58). A nuclear power program can consume a large fraction of its own output during excessively rapid expansion (59, 60), and tertiary oil recovery, shale oil, and coal gasification produce far less net energy than the actual Btu content of the fuel resource in situ (21). Vyas & Bodle (123) have estimated the net energy output from various synthetic fuel processes (Table 12).

Expensive or marginal energy resources, no matter how large they may be in Btu content, pose tremendous environmental problems if they are to be exploited on a

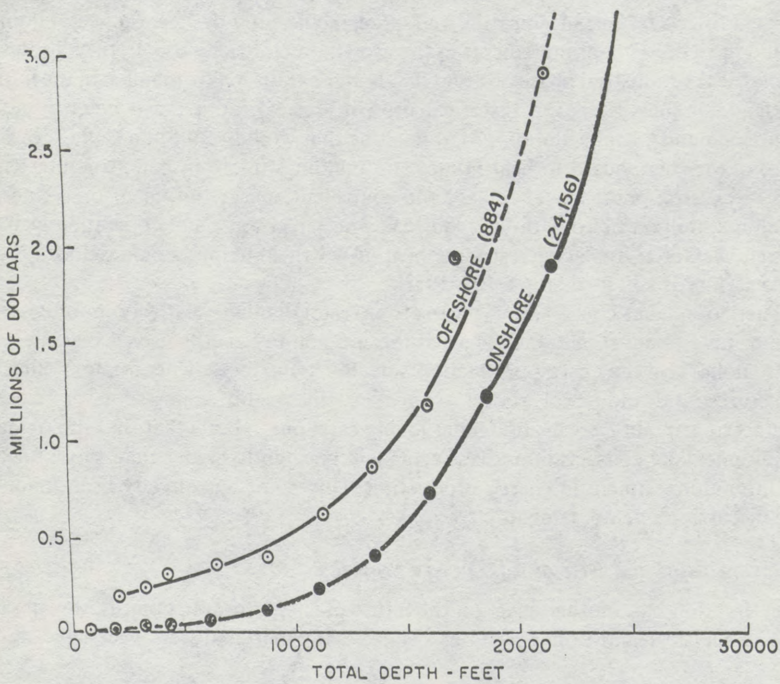


Figure 27 Cost of drilling and equipping oil and gas wells (including dry holes) in the United States, 1971. Source: (21).

Table 12 Net energy output from various synthetic fuel processes[a]

Process	Lurgi-Gas	Hygas	CSF-Coal Process	Coal-Methanol	Shale-Syncrude
Percentage of Btu's recovered in desired form	56.2	59.7	55.0	39.6	66.5
Other by-products by Btu content	15.3	8.2	12.2	1.5	7.4
Total	71	68	67	41	74

[a] Source: (123). The estimates do not include energy expenditures for capital equipment or harvesting (earth moving, crushing, water supply), nor are transportation energy requirements given. Figures are percentages of Btu-inputs.

large scale compared with 1975 energy demands in the United States (106).[14] Environmental questions are also important for the technology of nuclear power where the risks from mismanagement are great (124). Conservation, in promoting slower growth in energy harvesting, allows society to buy time for the testing and environmental engineering that are required to insure safe and clean recovery of net energy and other social benefits from these resources. "Income" sources such as solar or geothermal energy, which are large in supply but limited in utilization rate, are better suited to an energy budget reduced by conservation. Solar energy, in particular, offers environmental advantages because it makes use of already existing solar heat (125). A society's choices of which energy sources it will exploit depend greatly on what total rate of energy utilization will be required. Conservation makes that rate more manageable.

Social considerations related to future energy sources are also important. Certainly the cost to society of energy shortages is large. But there will be many social costs of the new energy sources, which are far more complex technologically and environmentally than energy conservation strategies. We must consider fully the social costs of building the Alaska pipeline, of offshore oil development with its hazard of oil spills, of creating and maintaining large-scale strip mining, shale oil, or coal gasification centers in the West. Distressing is the lack of understanding about the social implications of a large-scale commitment to nuclear power, including the social cost of the eternal vigilance that proponents and critics of nuclear power agree is required in order to manage the nuclear waste products, which long outlast the power plants themselves (124, 126, 127). These kinds of social issues must influence decision-making about energy use, especially since they favor more efficient energy use than would be dictated solely by microeconomic considerations.[15]

[14] See the discussions in (21) or (114). It is important to consider the various costs associated with different levels of "clean" in production from "new" sources. As Figure 24 suggests, these costs will also rise with the level of use of "new" sources.

[15] Page (23) discusses some of the difficulties of applying economics to environmental problems that stretch out over decades or centuries.

NONTECHNICAL BARRIERS TO EFFICIENT ENERGY UTILIZATION

Studies of insulation (63) and air conditioners (43) suggested that even before energy prices began to rise in the early 1970s energy use for space comfort was far from optimal. This section reviews some of the reasons why energy use in these and other applications today may not be economically efficient. These reasons suggest that important barriers to more efficient energy use in the future still exist.

Economists invoke the mechanism of the marketplace as the measure of efficient use of resources. Price determines the optimal use of resources, balancing the rate of supply of energy with the rate of demand. When the price of a commodity rises, the user may elect to use less of that commodity, substitute, or do without the

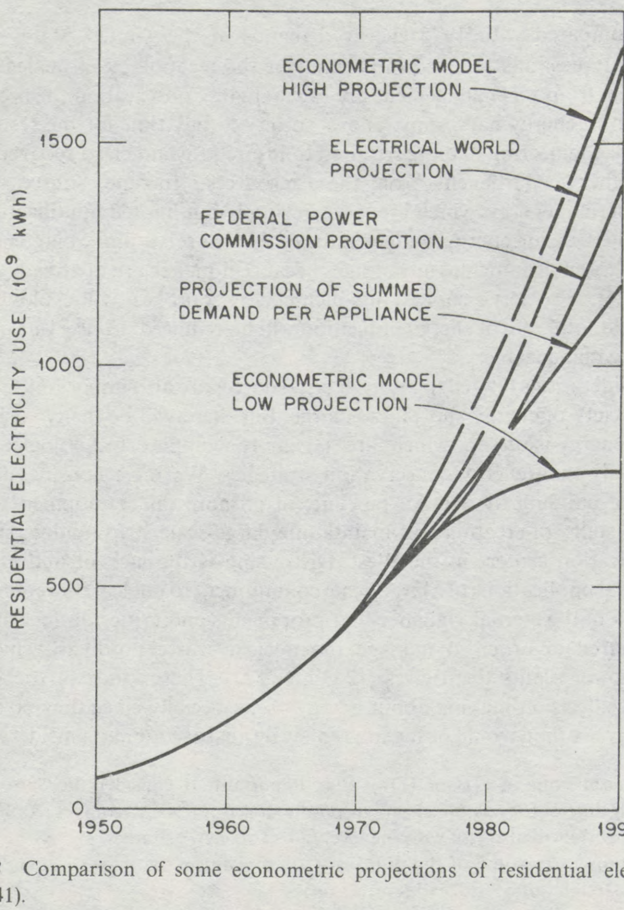


Figure 28 Comparison of some econometric projections of residential electricity use. Source: (41).

benefits of that commodity. If use is sensitive to price, the relationship between use and price is termed *elastic*. If, on the other hand, changes in prices do not induce changes in use, or induce relatively small changes in use compared with the change in price, the relationship is termed *inelastic* [for studies in elasticity of energy use, see (128–130)].

Elasticity is really a characteristic of human behavior, and economic models that predict this behavior are important. Some predictions are illustrated in Figure 28. But responses to higher prices are slow to come about: obsolete systems must be replaced, new technologies must be developed, or the fact must be "discovered" that energy is being wasted. That short-run elasticities to energy prices may be low should not discourage society from expecting that long-run changes in the patterns of energy use will in fact come about as a result of higher prices.

Unfortunately, few studies of elasticity evaluate the efficiency of energy use or model the technical options available to the consumer of energy. Physical analysis of changing economic conditions as well as the technologies involved reveals surprisingly effective options for energy conservation that are not predicted by conventional econometric studies. The *summed demand* in Figure 28, or the Brookhaven Model [results of which are shown in (16)], explicitly takes technologies into account. The projections of Makhijani and Lichtenberg (72), illustrated in Figure 29, show the often dramatic difference between efficient scenarios and pure exponential growth.

Energy Prices

As was suggested above, the price of various fuels plays a decisive role in determinating which of the energy-use options is the most economically efficient. For many years, however, the real prices of energy fuels and electricity fell (13, 41), stimulating growth in energy demand while inhibiting concern for efficiency. Since 1970, however, energy prices have begun to rise dramatically, so it can be expected that the rate of growth of energy use, as well as energy-use patterns, will begin to change in response to changing energy prices. The response can lead to increased efficiency of energy use through application of the first five conservation strategies listed in Table 6 or through output juggling, as energy users turn to products, services, or materials less affected by rising energy costs. Additionally some output juggling may be expected in the form of reduced automobile travel, lower thermostat settings in winter, reduction in hot water use and its temperature, and so on.

There are, however, also distortions and imperfections in energy prices themselves. While the fuel and capital costs of electric utilities are rising, electric power is still sold on a declining block basis in most parts of the country: the more one uses, the less one pays per kilowatt-hour (131–133). As long as large amounts of electric power were cheap, the aluminum smelters ignored efficiency. Similarly, the attractive prospects for large savings in fuel from on-site cogeneration of process steam and electricity are severely inhibited by the present rate structure for electricity (47). Extra charges for peak-period usage, when production is most expensive, do not yet exist in the United States, although the maintenance of a peak reserve is expensive in terms of capital, and the peaking equipment is usually less efficient

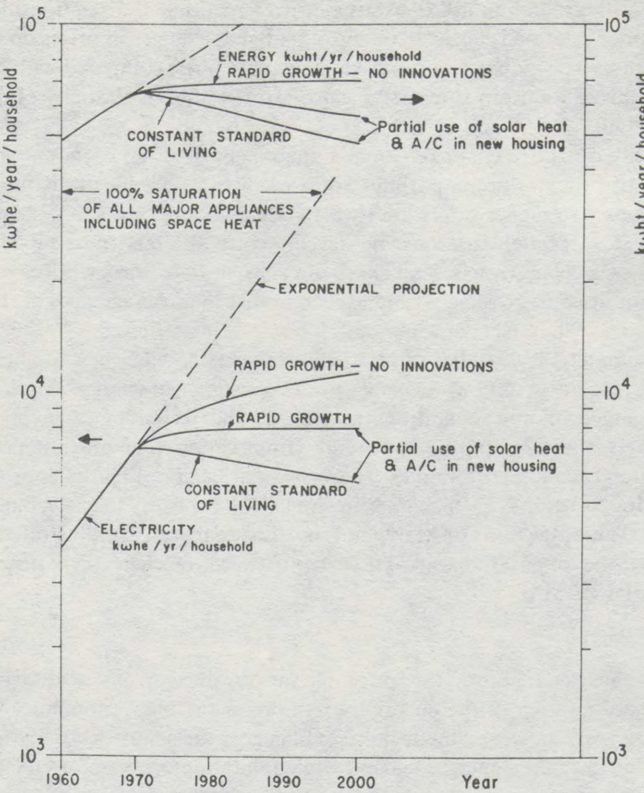


Figure 29 Some projections of residential electricity and energy demand. Higher efficiency and innovations make continued exponential growth (predicted by some models) superfluous. Source: (72).

than the baseload equipment (62). It now appears that there will be revisions in electricity pricing schedules in the near future (see the chapter by Sander in this volume).

Other price distortions are equally harmful. Price controls keep energy prices below market prices and sometimes below actual marginal costs. The depletion allowance on fuels allows some of the "risk" cost of exploration to be paid by taxpayers instead of the fuel users, by allowing producers a substantial tax benefit; other pricing practices for petroleum do the same (134). Elsewhere governmental policy subsidizes housing, highways, or air travel, regulates natural gas in interstate commerce but not in the state produced, and so on. The result is, of course, a price system wildly distorted from real costs. Economists have long warned that this leads to misallocation of scarce resources.

Further distortions in the price system are caused by the exclusion of environmental costs from market prices. Political battles take place in the US Congress over such environmental issues as a sulfur tax on coal, a reclamation tax on strip mining, smog devices on cars, and the cost of using low-sulfur oil or lead-free gasoline.[16] The environmental risks of nuclear power have not been quantified sufficiently to indicate whether nuclear power is underpriced, but the cost of safety is of concern to the nuclear industry, to regulators, and to opponents of nuclear power (124, 126, 127).

As public discussions of the risks and benefits of the various options indicate, environmental, safety, and social costs have come to dominate much of the concern (and research) regarding these technologies. Since these problems are largely excluded from the market system of prices, that system may be increasingly inappropriate to deal with energy problems. Internalizing the external costs of energy use will be a difficult political process because politicians and consumers alike will be faced with charging themselves for that which they apparently now get without costs: pollution.

It is difficult to imagine that appreciable conservation efforts will take place if energy prices continue to be controlled or rolled back, since few users will bother with the investment or the thought that is necessary to effect conservation. Voluntarism works well only for "the other guy." At the same time higher prices of energy, whether caused by real scarcity, monopoly power, fuel taxes, or environmental costs, are by no means an automatic cure by themselves for energy waste, because of the barriers to conservation discussed here.

Barriers to Efficient Energy Use

As costs of energy and systems change, different systems will be more economic (cheaper) than others. In a free market, each consumer will in theory adjust her energy use to the economic optimum, responding to price changes. Unfortunately economic systems, enterprises, entrepreneurs, and private consumers cannot readily respond to changes in energy prices. To be able to do so, energy users must have complete and accurate information about the energy and life-cycle costs of systems and about the cost of energy embodied in various products. This information has been difficult to find. Recently labeling of appliances and automobiles has begun to raise both the consciousness and the level of available information about energy (135). The government has also aided homeowners and building owners by publishing several books of suggestions and conservation procedures as well as displaying the results from efforts in its own buildings (67, 136); many utilities and fuel companies have done the same. Some industries using large amounts of energy, such as those in travel, plastics, and aluminum, take pains to measure and plan their energy use, but homeowners, small businessmen, and renters of office space

[16] Reader should consult the transcripts of hearings held by Congress. The Committees on Commerce or Interior and Insular Affairs are the most active in the Senate, whereas the Committees on Science and Astronautics, Ways and Means, Interior and Insular Affairs, and the Subcommittee on Energy and Power of the House hold most of the energy hearings where policy is debated. In addition to these committees, the Senate Committee on Public Works has debated most of the important environmental policy issues.

can rarely afford this practice individually, and few understand the theory and practice of life-cycle costing, upon which economic efficiency depends heavily.

Most important, energy use is rarely a goal in itself but occurs in conjunction with other processes toward personal or economic ends. The price of energy is

Table 13 The energy content of selected goods and services in 1971: partial list[a]

Product	Energy Content (Btu/$)	Gasoline Equivalent (gal)	Energy Value Content (¢/$)
Plastics	218,097	1.74	13.2
Man-made fibers	202,641	1.62	7.4
Paper mills	177,567	1.42	7.9
Air transport	152,363	1.22	12.0
Metal cans	136,961	1.10	7.3
Water, sanitary services	116,644	0.93	11.6
Metal doors	109,875	0.88	6.7
Cooking oils	94,195	0.75	7.1
Fabricated metal products	91,977	0.74	5.8
Metal household furniture	91,314	0.73	5.9
Knit fabric mills	88,991	0.72	6.5
Toilet preparations	85,671	0.70	5.1
Blinds, shades	81,472	0.65	6.3
Floor coverings	79,323	0.63	5.8
House furnishings	75,853	0.61	5.3
Poultry, eggs	75,156	0.60	7.3
Electric housewares	74,042	0.59	5.6
Canned fruit, vegetables	72,240	0.58	5.2
Motor vehicles and parts	70,003	0.56	5.9
Photographic equipment	64,718	0.52	3.8
Mattresses	63,446	0.51	4.5
New residential construction	60,218	0.48	4.5
Boat building	60,076	0.48	4.9
Food preparation	58,690	0.47	4.8
Soft drinks	55,142	0.44	4.5
Upholstered household furniture	51,331	0.41	4.1
Cutlery	50,021	0.40	4.0
Apparel, purchased materials	45,905	0.37	4.0
Alcoholic beverages	43,084	0.34	3.0
Hotels	40,326	0.32	5.4
Hospitals	38,364	0.30	5.4
Retail trade	32,710	0.26	4.4
Insurance carriers	31,423	0.25	4.4
Miscellaneous professional services	26,548	0.21	4.3
Banking	19,202	0.15	2.5
Doctors, dentists	15,477	0.12	1.9

[a] Source: (136a). These values are for producer's prices and do not take into account markup to retail price, about 66%.

Table 14 The cost of electricity as a percentage of production costs: US manufacturing industries 1939–1967[a]

Industry	Cost of Purchased Power (% of Product Value) 1939	1967
Primary metal industries	1.8	1.8
Fabricated metal products		0.6
Chemicals and allied products	2.0	1.7
Paper and allied products	3.9	1.9
Food and kindred products	1.1	0.4
Transportation equipment	0.7	0.4
Petroleum and coal products	1.2	0.8
Stone, clay, and glass products	3.2	1.5
Textile mill products	2.3	0.9
Electrical machinery	1.1	0.5
Machinery, except electrical	0.9	0.5
Rubber products	1.6	1.0
Lumber and wood products	1.8	0.9
Printing and publishing	0.8	0.4
Apparel and related products	0.4	0.3
Instruments and related products	—	0.4
Furniture and fixtures	1.0	0.5
Leather and leather products	0.6	0.4
Tobacco manufactures	0.2	0.2
Miscellaneous manufactures[b]	0.9	0.4
All manufacturing	1.41	0.79

[a] Source: Edison Electric Institute, 1973.
[b] Includes ordnance and accessories.

usually a small fraction of the cost of consumer goods (Table 13) or the cost of production (Table 14). The relatively low cost of energy compared with other expenses may mean that even where conservation is economic, the potential cost savings may be ignored.

The problems of sharply rising energy costs are particularly acute for energy-intensive industries addicted to unusually cheap or subsidized energy supplies (137). For airlines, the cost of fuel is now about 20% of the cost of doing business.[17] In these and other energy-intensive activities[18] the responses to higher energy prices—input juggling and thrifty technology—will be limited only by the time it takes to raise money and replace presently inefficient equipment. For example, the aluminum industry has a new process for producing aluminum from ore, which

[17] The major airlines sent telegrams to President Ford after his announced intention (January 1975) to "free" oil prices. The airlines asked for a percentage quota of their 1972 fuel use—at controlled prices—instead of the higher prices that the President's action would have allowed.

[18] The average dollar of expenditure for personal consumption requires about 80,000 Btu.

reduces energy requirements by one third (138). With the disappearance of low-cost electricity (the main ingredient in aluminum production besides the ore), smelters will turn more quickly to the new process even with its higher initial cost, because its life-cycle costs are lower.

The fact that energy consumption is so dependent on existing capital equipment is a general barrier common to all conservation strategies. If relative prices of certain foods change, consumers can alter their demands on a day-to-day basis, independent of past expenditures or present possessions. On the other hand, energy use is largely pre-determined by the existing stock of devices and structures, so that a time lag can be expected between the rise in the price of energy and the response to conserve it. For a homeowner, the physical condition and design of the house and heating system, and the weather, determine how much heating fuel is needed to maintain a given indoor temperature. The homeowner can belt-tighten and plug leaks through improved maintenance, retrofitting of insulation devices, and use of warm clothes and lower temperatures, but the savings are usually smaller than those available if the house and furnace had been optimized (input juggled) in the first place. The same applies to large buildings. It is a fact that the energy savings possible from building energy-efficient structures in the future are as much as the total energy consumption of today's automobiles (15, 62) (Table 7). But while automobiles and industrial equipment tend to be replaced within ten years, buildings remain in use for decades or centuries. Thus if wastage of energy is built into structures, only feeble responses can be expected to the rising price of energy.

Even with complete information, it may not be possible for energy users to juggle inputs or plug leaks. Homeowners may not be able to choose homes (new or used) on the basis of energy fitness alone: families who move often are not in one home long enough for conservation to pay off to themselves; renters cannot easily add insulation to property they do not own, nor can they force landlords to insulate buildings if they, not the landlords, pay the utility bills. The same dis-

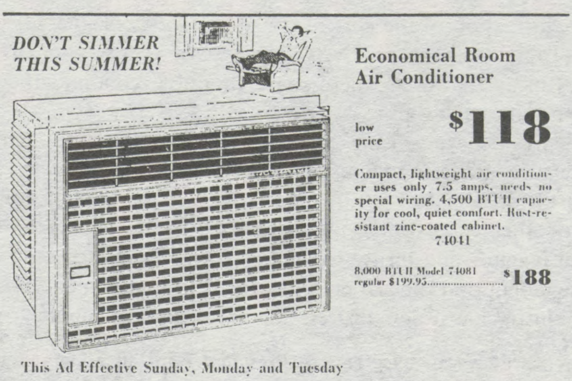


Figure 30 Advertisement depicting air conditioner with high operating cost and low first cost. A bargain?

advantage hits small businessmen in large structures, where the utility bills are hidden in the rent. Industries affected by rising energy costs can pass those costs on to the consumer, especially if competition is limited or if the energy costs are small compared with the total value added, as is often the case.

Incentive barriers also exist for the production of energy-efficient equipment. Manufacturers have no incentive to produce energy-efficient autos or appliances if advertising, social pressure, consumer habits, or marketing procedures (such as rebates) give apparent advantages to less-efficient equipment. This holds especially if the buyer sees only the first cost, not the operation cost or life-cycle cost (see Figure 30). For refrigerators the energy costs are much larger than the purchase price (69, 71), but models packed with every feature (except insulation) tend to be advertised and sold on the basis of first cost alone. It was reported (139) that as of early 1975 buyers were largely still ignoring efficiency in selecting appliances, probably for the reasons cited here. Performance standards, which set minimum design efficiencies for energy-using equipment and structures, seem necessary to assure that systems surviving several owners or several generations are built efficiently in the first place. The advantage of performance standards is that the systems in question operate efficiently, while the marketplace allocates the cost and savings of higher efficiency.

The problem of misplaced incentives hinders conservation in new buildings as well. Banks now have little incentive to lend extra money to make structures energy-tight, although utilities could refuse to provide services to inefficient structures. Developers will not risk the extra cost of insulation and other energy-conservation measures if competitors can omit the same, charge less, and obscure the differences with advertising (140, 141). Requiring efficiency standards on appliances and statements of heat loss through walls or limiting energy consumed per square foot in large buildings would assure that all developers and builders, as well as the banks that finance them, work under the same cost-effective constraint of energy effectiveness. The higher first costs, passed on to buyers and renters, would be more than repaid during the life of the structure or appliances.

The impact of higher prices for fuels on low-income groups cannot be ignored, and rebates have been suggested to aid these groups. But people earning more than about $10,000 per family require more energy indirectly for the goods and services they purchase than they do directly as heat, electricity, and gasoline. This means that the impact of energy costs is only mildly regressive with income (142) (see Figure 31). Some economists suggest that it is better to aid directly those who cannot afford expensive energy rather than make energy artificially cheap to all, which encourages everyone to waste energy.

President Ford has suggested an energy tax coupled with rebates that rise with income; this idea was lost in the debate over the antirecession program (143). Another alternative is a system of flat rebates, which distribute a nearly constant amount of money to all families, under the assumption that well-to-do groups have more opportunities to improve efficiency, allocate resources more carefully, or simply do without certain luxuries such as airplane travel, second homes, recreational vehicles, or swimming pool heaters. This assumption appears to be borne out by

Herendeen's work (Figure 31). Input-output data also suggest that price increases for energy will affect basic food and clothing and housing construction far less than luxury items such as large cars and travel.

Whether the economic barriers to efficient use discussed here can be overcome by legislative, institutional, or personal actions is of course an open question. Although economic models of energy use rarely consider these non-price variables in attempting to predict energy use, higher energy prices should stimulate energy users towards more optimal energy utilization. At the same time the effects of higher prices can be monitored and anticipated, as the input-output work cited here suggests. But society may want to conserve energy for non-market problems such as pollution, the effects of reliance on imported fuels, or the impact on the poor of expensive energy used inefficiently. Additionally, the nation may wish to implement conservation strategies at a faster pace than would occur in response to market forces alone. In these cases additional incentives for efficient use may be called for; some of these are discussed briefly in the next section.

Additional Incentives to Conserve

In addition to higher prices, incentives in the form of low-interest loans, tax benefits, rebates, or penalties, and other "carrots and sticks" should be considered carefully. The most common "stick" for encouraging more efficient energy use is higher prices, but bans on certain forms of consumption, rationing of fuels,

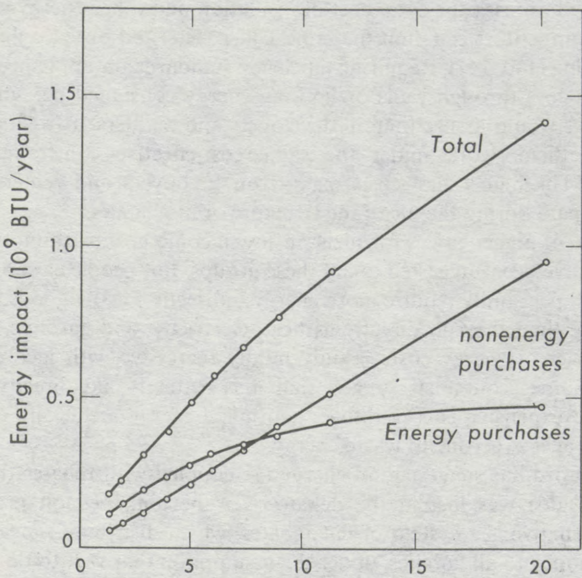


Figure 31 Direct and indirect use of energy as a function of household income. Direct means gasoline, heating, electricity; indirect is energy used to provide goods and services. Source: (142).

voluntary quotas, and so forth are often discussed (143). At the same time "carrots" are receiving increasing attention; some are shown in Figure 32. Additional incentives to invest in energy conservation can come from the tax system.

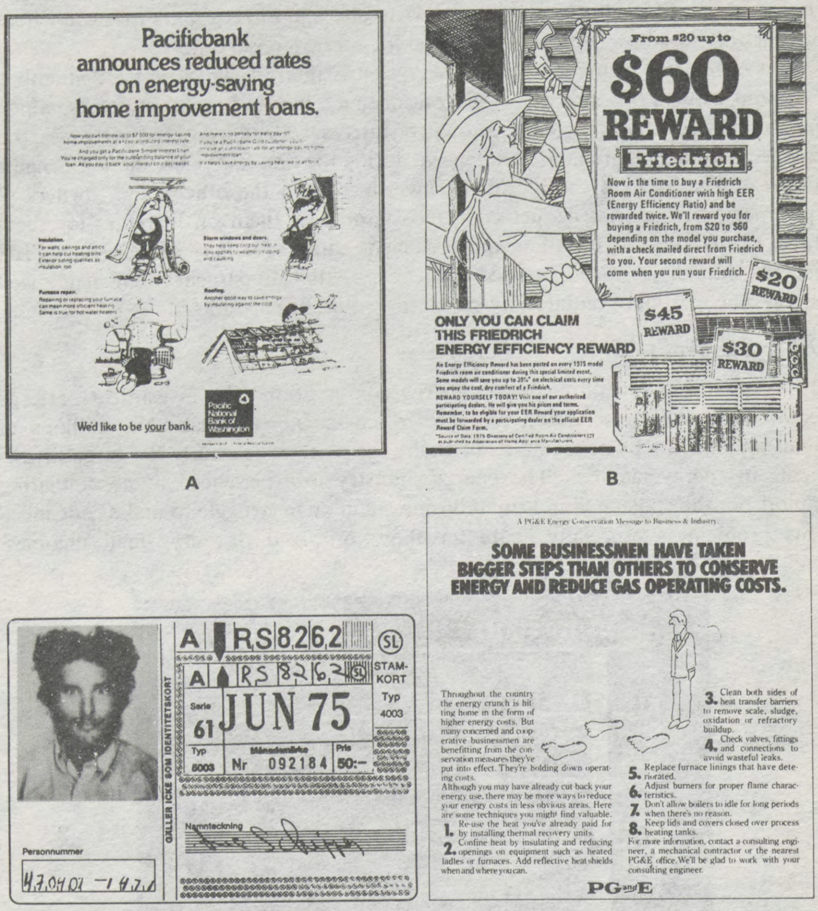


Figure 32 Incentives ("carrots") for energy conservation. **A**: low-interest loans for household improvements. **B**: rebates for more efficient air conditioners. **C**: a mass transit card from the greater Stockholm "Stockholms Lokaltrafik" mass transit district. (For $17.50/mo. the author was permitted to ride all buses, trains, subways, and many boats in an area the size of the San Francisco Bay Area.) **D**: direct appeal for higher efficiency—with offer of direct aid from the local utility.

Governments can allow tax benefits for investments in energy-efficient equipment, provided that the investments are clearly aimed at efficiency. These incentives would include tax forgiveness in the increased valuation of property upgraded through conservation, tax credits or accelerated write-offs, and direct grants to those whose incomes do not allow setting aside capital for energy conservation.

Part of the cost of investing in conservation is interest, which is tax-deductible. For homeowners this interest is paid out of saved fuel and electricity costs, which are not tax-deductible. If conservation investments were added onto mortgages, the payments for which are interest-intensive during the first few years, the tax benefits would accrue early in the life of the investment. On the other hand, owners of apartments or factories deduct energy costs or pass them on in rents; for them direct tax credits for installing more efficient equipment may be necessary. Tax benefits should rise with increased efficiency, so that investment in efficiency well beyond the minimum required by standards would be encouraged.

Other Barriers to Efficient Energy Use

Other economic difficulties inhibit energy conservation. The investment patterns required for the conservation measures discussed above mean that millions of small investments by consumers must take the place of relatively few large investments in energy facilities. The energy industry is experienced at accumulating capital, but the consumer and small businessman often struggle to make ends meet. This problem is especially acute for those on fixed or very small incomes.

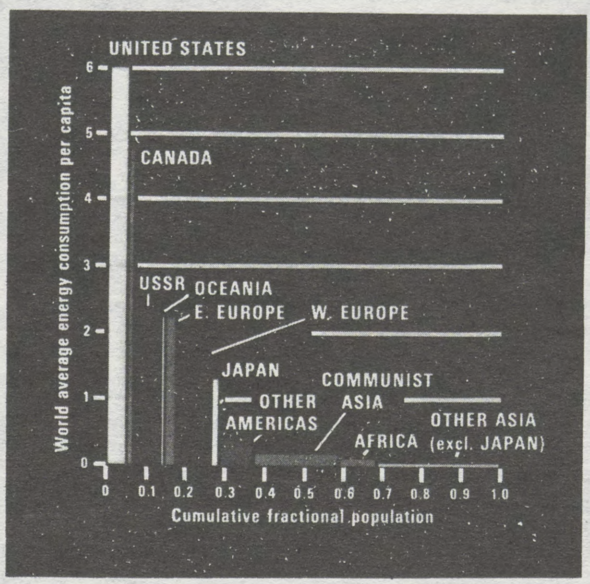


Figure 33 Per capita energy consumption as a ratio to the world average population, as a fraction of the world total. Source: *International Petroleum Yearbook*, 1972 ed.

Governments should engage in conservation campaigns in which low-interest loans or grants are made available for clearly defined conservation investments. Sweden has already embarked on such a campaign to help finance the insulation of buildings (144).

A further barrier to conservation, perhaps one of the most difficult, is that consumers do not directly perceive some of the "hidden benefits" of conservation outlined here. Instead, these benefits accrue to society as a whole, through the millions of individuals who find more employment, cleaner air, lower energy prices, less congestion, better mass transit, and diminished threats to national security. Perhaps these common benefits need to be reinforced by taxes or subsidies, so that individuals can also perceive direct economic benefits to themselves from energy savings. Other benefits from more efficient energy utilization include lower world energy prices, and this can only be of help to the two thirds of the world that has not yet begun to realize the great social benefits that careful energy utilization brings (Figure 33). Last but not least, fossil fuels that are saved now will be available to future generations for use as chemical feedstocks.

The most often discussed reasons for conserving energy are the "necessity" to reduce oil imports and the desire to minimize threats to national security presented by interruption of fuel supplies (143).[19] Whatever the merits or problems of these two reasons, the derived benefits are difficult to quantify economically and do not accrue directly to individuals. Policymakers include energy conservation as part of the overall national plan to reduce oil imports, yet this plan may not explicitly recognize that even without the problem of imports present energy use is far from economic.

Because economics favors more efficient energy use, it would seem that conservation has few opponents. On the other hand, the energy industry is threatened with slower growth than at any other time since the Depression (145). As noted above, some industry spokesmen or organizations have continually endorsed the need to continue historical growth in energy use (24, 25).[20] This is particularly true for some electric utilities. Under the name "People at America's Investor-Owned Electric Companies," one group has stated that growth in electric power consumption at historical rates is beneficial and inevitable, as Figure 34 illustrates. The claims of advertisements such as this have been challenged elsewhere (147–149), and it has been noted that they have seldom carried any suggestions about energy conservation. However, other utilities have now begun earnestly to tell subscribers how to conserve electricity and gas, as Figure 32**D** shows.

It has been suggested that if utilities were to engage in the selling of comfort systems, rather than only of energy, they would find a greater incentive to participate in energy conservation programs. In this idea, the utility would own and maintain the entire energy system in a structure and lease it to the firm or individual. One utility (150) now installs insulation in residential property and allows owners to pay off the investment on the same bill as for natural gas. Another arranges for

[19] See footnote 16.

[20] For a view supporting the aggressive promotion of load growth in electricity use, see (146).

outside financing and installation (W. Zitlau, San Diego Gas and Electric Company, 1974, private communication). The degree to which the energy industry participates in energy conservation R & D and implementation will appreciably influence the future demand for energy.

The very notion that energy is being used inefficiently, that Americans must husband resources and eke out the next unit of welfare from higher efficiency rather than higher gross inputs, suggests a confrontation between aspects of the traditional American way of life and the true finiteness of the world vis-à-vis the rates of use of resources. As is often noted, energy prices fell for many years while the side effects of cheap energy use—pollution, urban sprawl, decay of the mass transportation system, the endless substitution of energy for other production factors—became a part of that way of life. Now American society, and indeed the world, is faced with the prospects of intervening in these trends in order to use energy more efficiently, not because society has run out of energy, but because society is having difficulty even running at today's rate of use. The distribution of energy usage in the world (Figure 33) shows clearly that most of the world has not begun to realize the social

Figure 34 Advertisement from a group representing many utilities. The advertisement, which appeared in *Newsweek* in late 1974, expresses the opinion that electricity needs will grow.

benefits of energy, while part of the world struggles with the side effects and economic dangers of the wasteful use of energy (151).

To some, the challenge for changes in energy utilization might be interpreted as some kind of threat to the American economic system. To me, however, the need for energy conservation must be interpreted as a fortunate signal. Indeed while man's physical activities and uses of resources are rate-limited,[21] both technical and social changes in structure and operation of systems are possible which will allow us to win more social benefit from increasingly scarce resources. The hope for "cheap nuclear fission," "cheap nuclear fusion," or "cheap solar energy," none of which is in fact cheap, constantly distracts individuals and institutions from making economic adjustments now to more efficient energy use and obscures the possibility that nature has, in reality, imposed a kind of speed limit on our activity.

SUMMARY

The role of energy in an economy can only be understood through consideration of both an economic description of energy inputs and outputs and a physical analysis of the activities in the economy that use energy. Such analysis leads to several definitions of energy efficiency, waste, and conservation, definitions that are sometimes, but not always, close to those of traditional economics. Conserving natural resources for future generations, or for those who cannot afford them today, and preserving environmental quality are important reasons for conserving energy. But economic analysis of the physical options for energy conservation shows that saving 30–40% of the expected future total energy demand in the United States would be far less expensive than supplying the increased amounts of fuels and electricity dictated by naive extrapolation of historical trends.

Conservation strategies also tend to increase employment and decrease pollution, while saving energy and money. By easing demands on dollar and energy capital required to build and run energy-producing facilities, conservation slows the real rise in the cost of energy. However, conservation faces a full range of important nontechnical problems, which are rooted in the history of energy utilization at low energy prices, as well as barriers connected with defects in the pricing of energy, the control of the end use of energy, and the time necessary for society to adjust to sharply rising energy costs.

A variety of social, political, economic, and technical changes are often suggested as remedies for today's energy problems (96, 142, 143, 151–156).[22] These include decontrol of fuel prices, energy taxes, rationing or allocation, subsidies or low-interest loans for efficient use, bans on certain end uses or social activities, and educational programs designed to change people's attitudes. Energy policy designed to encourage efficient use of energy will probably have to incorporate many of these measures, using both traditional and novel market and non-market tools. Even before considering the question of what sources of energy to develop tomorrow, one must

[21] See (151).

[22] See also footnote 16.

confront energy conservation today: inefficient energy use means inefficient and costly malfunctions in the US economy. Perhaps recognition of the influential role of energy waste in exacerbating our economic and environmental problems will aid progress toward more efficient energy utilization.

ACKNOWLEDGMENT

I wish to thank J. M. Hollander and M. K. Simmons, of the Lawrence Berkeley Laboratory, Energy and Environment Division, for their help in preparing this manuscript. This research was supported in part by the Lawrence Berkeley Laboratory, under contract with the US Energy Research and Development Administration. Opinions are solely those of the author.

Literature Cited

1. US Congress, Joint Committee on Atomic Energy. 1973. *Understanding the Nation's Energy Dilemma.* Washington DC: Joint Comm. At. Energy
2. Battelle Northwest Laboratories. 1969. *Review and Comparison of Selected Energy Forecasts.* Washington DC: Office Sci. Technol.
3. Erickson, L. 1974. A review of forecasts for U.S. energy consumption. In *Energy and Human Welfare,* ed. B. Commoner et al. New York: Macmillan
4. Portola Institute. 1974. *Energy Primer.* Menlo Park, Calif: Portola Inst.
5. Chase Manhattan Bank. 1972. *Energy Outlook in the United States to 1985.* New York: Chase Manhattan Bank
6. Office of Emergency Preparedness. 1972. *Potential for Energy Conservation.* Washington DC: GPO
7. Shell Oil Company. 1973. *Energy Conservation Potentials.* Houston: Shell Oil
8. Kovach, E., ed. 1974. *Technology of Efficient Energy Utilization.* Scientific Affairs Division, NATO, Brussels, Belgium
9. Large, D. 1973. *Hidden Waste.* Washington DC: Conservation Foundation
10. US House of Representatives, Subcommittee on Science and Astronautics. May 1974. *Conservation and Efficient Use of Energy.* Pts. 1–4. Washington DC: GPO
11. US Senate, Committee on Interior and Insular Affairs. Aug. 1973. *Energy Conservation and S 2176.* Washington DC: GPO
12. US Senate, Committee on Commerce. May, June 1974. *Energy Waste and Energy Efficiency in Industrial and Commercial Activities.* Also US Senate, Committee on Commerce. Oct. 1974. *Industry Efforts in Energy Conservation.* Washington DC: GPO
13. Ford Foundation, Energy Policy Project. 1974. *A Time to Choose: America's Energy Future.* Cambridge, Mass: Ballinger
14. Schipper, L. 1975. *Energy Conservation: Its Nature, Hidden Benefits, Hidden Barriers.* Rep. No. LBL 3295. Lawrence Berkeley Lab., Berkeley, Calif. Also 1976. *Energy Communications.* In press
15. Schipper, L. 1975. *Efficient Energy Use.* Rep. No. ERG-75-08. Energy and Resour. Group, Univ. Calif., Berkeley
16. US Energy Research and Development Administration. June 1975. *A National Plan for Energy Research, Development, and Demonstration.* Publ. No. ERDA 48, Vols. 1, 2. Washington DC: ERDA
17. Keenan, J. H. 1941. *Thermodynamics.* New York: Wiley
18. Keenan, J. H. et al. 1974. The fuel shortage and thermodynamics. In *Energy: Demand, Conservation, and Institutional Problems—Proc. MIT Energy Conf., Feb. 1973.* Cambridge, Mass: MIT Press
19. Priest, J. 1973. *Problems of Our Physical Environment: Energy, Transportation, Pollution.* Reading, Mass: Addison-Wesley
20. Cottrell, F. 1955. *Energy and Society.* New York: McGraw-Hill
21. Cook, E. 1975. *Study of Energy Futures.* Chapel Hill, NC: Environ. Design Res. Assoc. Also Cook, E. 1971. The flow of energy in an industrial society. *Sci. Am.* 224:134
22. Barclay, J., Seckler, D. 1972. *Economic Growth and Environmental Decay.* New York: Harcourt-Brace-Jovanovich
23. Page, N. T. 1976. *Economics of a*

Throwaway Society. Resources for the Future, Inc. In preparation
24. National Petroleum Council. 1972. *U.S. Energy Outlook, A Summary Report*. Washington DC: Nat. Pet. Counc.
25. Cook, D., Vassell, G. 1974. Energy conservation within the framework of vital societal objectives. *Public Util. Fortnightly* 65(10): 1
26. Darmstadter, J. et al. 1971. *Energy and the World Economy*. Baltimore, Md: Johns Hopkins Univ. Press
27. Rubin, B. et al. 1972. *Energy: Sources, Uses, Issues*. Rep. No. UCRL 51221, Lawrence Livermore Lab., Livermore, Calif. Springfield, Va: Nat. Tech. Inf. Serv.
28. See Ref. 13, comments by D. Burnham
29. Meyers, J. Feb. 1975. *Energy Conservation and Economic Growth: Are They Incompatible?* In The Conference Board *Record*, p. 27. Reprinted in ERDA Authorization Hearings, Pt. 1, Feb. 18, 1975, Subcomm. on Science and Astronautics, US House of Reps. Washington DC: GPO
30. National Economic Development Office. 1974. *Energy Conservation in the United Kingdom*. London: HMSO
31. Elbek, B. 1975. *Energi—Energi—Energi Krise*. Copenhagen: Munksgaard
32. Stanford Research Institute. 1975. *Comparison of Energy Consumption Between West Germany and the United States*. Prepared for Fed. Energy Admin. Menlo Park, Ca: Stanford Res. Inst.
33. Schipper, L., Lichtenberg, A. 1975. *Efficient Energy Use: The Swedish Example*. Rep. No. ERG-75-09. Energy and Resour. Group, Univ. Calif., Berkeley
34. Makhijani, A., Lichtenberg, A. 1971. *An Assessment of Energy and Materials Use in U.S.A.* Mem. No. M-310, Energy Res. Lab., Univ. Calif., Berkeley. Also 1972. *Environment* 14(5): 10
35. Energi Prognos Committeen. 1974. *Energi 1985–2000*. Rep. No. SOU-64, Industridept., Stockholm, Sweden: Almanna Förlaget. 2 vols.
36. Swedish Federation of Industries. 1974. *Energy Conservation in Swedish Industry*. Stockholm: Industriförbundets Förlag
37. Mooz, W. E. June 1973. *Transportation and Energy*. Santa Monica, Ca: Rand Corp.
38. Hirst, E. 1973. *Energy Intensiveness of Passenger and Freight Transportation Modes*. Rep. No. ORNL-NSF-EP 44. Oak Ridge, Tenn: Oak Ridge Nat. Lab.
39. Federal Energy Administration. 1974. *Project Independence and Energy Conservation: Transportation Sector*, Vol. 2. Washington DC: GPO
40. Foster Associates. 1975. *Energy Prices 1960–73*. Energy Policy Project, Ford Foundation. Cambridge, Mass: Ballinger
41. Tansil, J. M. 1973. *Residential Consumption of Electricity*. Rep. No. ORNL-NSF-EP-51. Oak Ridge, Tenn: Oak Ridge Nat. Lab.
42. American Gas Association. Oct. 1974. *A Pilot Project in Homeowner Energy Conservation*. Washington DC: Fed. Energy Admin.
43. Moyers, J. 1973. *Room Air Conditioners as Energy Consumers*. Rep. No. ORNL-NSF-EP-59. Oak Ridge, Tenn: Oak Ridge Nat. Lab.
44. Allen, J. Oct. 1974. The craft of electric motors. *Environment* 16(8): 36
45. American Physical Society. 1975. *Efficient Use of Energy: A Physics Perspective*. 1974 Summer Study. New York: Am. Inst. Physics
46. Lawrence Livermore Laboratory. 1973. *U.S. Energy Flow Charts*. US Atomic Energy Commission. Rep. No. UCRL 51487. Springfield, Va: Nat. Tech. Inf. Serv.
47. Dow Chemical Company et al. June 1975. *Energy Industrial Center Study*. For Nat. Sci. Found., Grant No. OEP 74-20242. Washington DC: NSF
48. Hise, E. C. 1975. *Seasonal Fuel Utilization Efficiency of Residential Heating Systems*. Rep. No. ORNL-NSF-EP-82. Oak Ridge, Tenn: Oak Ridge Nat. Lab.
49. Petersen, S. R. 1974. *Retrofitting Existing Housing for Energy Conservation: An Economic Analysis*. Nat. Bur. Standards. Washington DC: GPO
50. Hannon, B. July 1975. Energy conservation and the consumer. *Science* 189: 95
51. Hannon, B. Feb. 1974. Options for energy conservation. *Technol. Rev.* 76(4): 24
52. Bullard, C. W., Herendeen, R. A. Jan. 1975. *Energy Costs of Goods and Services*. Center for Adv. Computation, Univ. Ill., Urbana
53. Chapman, P. March 1975. The energy cost of materials. *Energy Policy* 3(2): 47
54. Berry, R. S., Fels, M. Sept. 1973. Production and consumption of autos. *Bull. At. Sci.* 27: 11
55. International Federation of Institutes for Advanced Study. 1974. *Energy Analysis Workshop on Methodologies and Conventions*. Nobel House, Storegatan 14, Box 5344 s-10246, Stockholm, Sweden

56. Pilati, D., Richards, R. Aug. 1975. *Total Energy Requirements for Nine Electricity Generating Systems.* Doc. No. CAC 165. Center for Adv. Computation, Univ. Ill., Urbana
57. Chapman, P. F., Leach, G., Slesser, M. Sept. 1974. The energy cost of fuels. *Energy Policy* 2(3):231
58. Rieber, M. 1974. *Low Sulfur Coal: A Revision of Resource and Supply Estimates.* Doc. No. CAC 87. Center for Adv. Computation, Univ. Ill., Urbana
59. Rieber, M. et al. Nov. 1974. *Nuclear Power to 1985.* Doc. No. CAC 137P. Center for Adv. Computation, Univ. Ill., Urbana
60. Price, J. Dec. 1974. *Dynamic Analysis of Nuclear Power.* Available from Friends of the Earth Ltd., London
60a. Chapman, P. Dec. 1974. The ins and outs of nuclear power. *New Sci.*, Vol. 64
60b. Leach, G. Dec. 1974. *Nuclear Energy Balances in a World with Ceilings.* London: Int. Inst. for Environ. and Dev.
61. Putnam, D. E. Aug. 1975. *Energy Benefits and Costs: Housing Insulation and the Use of Small Cars.* Doc. No. CAC 173. Center for Adv. Computation, Univ. Ill., Urbana
62. Ross, M., Williams, R. 1975. *Assessing the Potential for Fuel Conservation.* Rep. No. 75-02. Inst. for Public Pol. Altern., SUNY, Albany, NY
63. Moyers, J. C. 1972. *The Value of Thermal Insulation in Residential Construction: Economics, and the Conservation of Energy.* Rep. No. ORNL-NSF-EP-9. Oak Ridge, Tenn: Oak Ridge Nat. Lab.
64. Delene, J. Nov. 1974. *A Regional Comparison of Energy Resource Use and Cost to the Consumer of Alternate Residential Heating Systems.* Rep. No. ORNL-NSF-TM-4689. Oak Ridge, Tenn: Oak Ridge Nat. Lab.
65. Achenbach, P. 1973. *Effective Energy Utilization in Buildings.* Washington DC: Nat. Bur. Standards
66. *Technical Options for Environmental Conservation in Buildings.* 1973. NBS Tech. Note No. 789. Washington DC: Nat. Bur. Standards
67. Federal Energy Administration. Nov. 1974. *Energy Conservation: The Residential Sector,* Vol. 1. Proj. Independence. Washington DC: GPO
68. Berg, C. Feb. 1974. Technical basis for energy conservation. *Technol. Rev.* 76(4): 14. Also Berg, C. 1973. *Energy Conservation through Effective Utilization.* Washington DC: Fed. Power Comm.
69. Goldstein, D., Rosenfeld, A. 1975. *Projecting an Energy Efficient California.* Rep. No. LBL 3274. Lawrence Berkeley Lab., Berkeley, Calif.
70. Mutch, J. May 1974. *Residential Water Heating: Fuel Conservation, Economics, and Public Policy.* Santa Monica, Calif: Rand Corp.
71. Center for Policy Alternatives. 1974. *The Productivity of Servicing Consumers Durable Products.* Rep. No. CPA-74-14. Cambridge, Mass: MIT Center for Pol. Altern.
72. Makhijani, A., Lichtenberg, A. 1973. *An Assessment of Residential Energy Utilization in the U.S.A.* Eng. Mem. No. ERL-M370. Univ. Calif., Berkeley
73. Appel, J., MacKenzie, J. 1974. How much light do we really need? *Bull. At. Sci.* 30(10):18
74. Dubin-Mindell-Bloom Associates. Feb. 1975. *Report to U.S. Home Corp. on Resources Saving House.* Project No. DMBA-PC-43-73. 42 W 39th St., New York, NY
75. Hammond, J. et al. 1974. *A Strategy For Energy Conservation.* Winters, Calif: Living Systems Inc.
76. Dubin-Mindell-Bloom Associates. 1974. *Energy Conservation for Existing Buildings.* Rep. No. ECM 1, 2. Prepared for Fed. Energy Admin. Washington DC: FEA
77. Dubin, F. Aug. 1973. G.S.A.'s energy conservation test building—a report. *Actual Specif. Eng.*
78. Stein, R. Oct. 1972. It's a matter of design. *Environment* 14(8):17
79. Berman, S., Silverstein, S. 1975. *Energy Conservation and Window Systems.* New York: Am. Inst. Physics
80. Dubin, F. Feb. 1973. Total energy for mass housing. *Actual Specif. Eng.*
81. Morrow, W. Dec. 1973. Solar energy, its time is near. *Technol. Rev.* 76(2):30
82. Löf, G., Tybout, R. 1973. Cost of house heating with solar energy. *Sol. Energy* 14:253–78
83. E. I. du Pont de Nemours and Co. 1973. *Du Pont Energy Management Services.* Educ. and Appl. Technol. Div., Wilmington, Del. 19898
84. Federal Energy Administration. 1974. *Energy Conservation in the Manufacturing Sector, 1954–1990.* Proj. Independence. Washington DC: GPO
85. Gatts, R. 1974. *Industrial Energy Conservation.* Pap. No. 74-WA/Energ-8. New York: Am. Soc. Mech. Eng.
86. Gyftopolous, E. et al. 1974. *Potential Fuel Effectiveness in Industry.* Cambridge, Mass: Ballinger
87. Bravaard, J. et al. 1972. *Energy Costs*

Associated with the Production and Recycling of Metals. Rep. No. ORNL-NSF-EP-24. Oak Ridge, Tenn: Oak Ridge Nat. Lab.

88. Lowe, R. A. 1974. *Energy Conservation Through Improved Solid Waste Management.* Rep. No. SW-125. Washington DC: US EPA
89. Hannon, B. 1972. *System Energy and Recycling: A Study of the Beverage Industry.* Doc. No. CAC 23. Center for Adv. Computation, Univ. Ill., Urbana
90. Berry, R. S., Makino, H. 1974. Energy thrift in packaging. *Technol. Rev.* 76(4): 32
91. Rubin, D. et al. 1973. *Transportation Energy Conservation Options.* Rep. No. DP-SP-11 (draft). Washington DC: US Dep. Trans.
92. Rice, R. 1974. Towards more transportation with less energy. *Technol. Rev.* 76(4):44
93. Marks, C. Dec. 1973. *Which Way to Achieve Better Fuel Economy?* Presented at Seminar, Energy Consumption of Private Vehicles, Present and Possible, Calif. Inst. Technol., Pasadena. Available from General Motors Corp., Detroit, Mich.
94. US Environmental Protection Agency. Oct. 1973. *A Report on Automobile Fuel Economy.* Washington DC: US EPA
95. Schipper, L. 1974. *Holidays, Gifts, and the Energy Crisis.* Rep. No. UCID 3707, Lawrence Berkeley Lab., Univ. Calif., Berkeley. Washington DC: Nat. Tech. Inf. Serv.
96. Fels, M., Munson, M. 1975. Energy thrift in urban transportation: options for the future. In *Energy Conservation Papers,* ed. R. Williams. Cambridge, Mass: Ballinger
97. Pilati, D. 1975. *Energy Conservation Potential of Winter Thermostat Reduction and Night Setback.* Rep. No. ORNL-NSF-EP-80. Oak Ridge, Tenn: Oak Ridge Nat. Lab.
98. Federal Energy Administration. 1974. *Lighting and Thermal Operations:* Case Studies. Washington DC: GPO
99. Fox, J. et al. Dec. 1973. *Energy Conservation in Housing—First Year Progress Report.* Rep. No. 16 (revised). Princeton Center for Environ. Stud., Princeton, NJ
100. Hannon, B., Puleo, F. 1974. *Transferring from Urban Cars to Buses.* Center for Adv. Computation, Univ. Ill., Urbana. Reprinted 1975 in *Energy Conservation Papers,* ed. R. Williams. Cambridge, Mass: Ballinger
101. Real Estate Research Corp. 1974. *Cost of Urban Sprawl.* Prepared for Counc. Environ. Qual. Washington DC: GPO
102. MacLean, R., Portland Cement Association. May, June 1974. In *Energy Waste and Efficiency in Commercial and Industrial Activities.* Committee on Commerce, US Senate, Washington, DC
103. Meyers, J. et al. 1975. *Energy Consumption in Manufacturing.* Cambridge, Mass: Ballinger
104. Dunning, R. 1973. *Comparison of Total Heating Costs with Heat Pumps vs. Alternative Heating Systems.* Rep. No. PSP-4-2-73. Westinghouse Electric Corp., Pittsburgh, Pa.
105. Tennessee Valley Authority. 1975. *A Heat Pump Program for the TVA Area.* Chatanooga, Tenn: TVA
106. Singer, S. Nov. 1974. Future environmental needs and costs. *Eos*
107. Holdren, J., Ehrlich, P. 1974. Human population and the global environment. *Am. Sci.* 62(3):282
108. Linden, H. R. Dec. 1974. Testimony before US Dep. of State, Seminar on US Energy Policy. Available from Inst. Gas Technol., Chicago, Ill.
109. Mobil Oil Company. 1974. *Energy Manifesto.* In *New York Times.* Available from Mobil Oil Co., New York
110. Stein, R. 1973. In *Energy Conservation—Implications for Building Design and Operation,* ed. D. Abrahamson. Univ. Minn. Counc. on Environ. Qual., Minneapolis
111. Ehrlich, P., Holdren, J. 1972. Impact of population growth. In *Population, Resources, and the Environment,* ed. R. Ridker. Washington DC: GPO
112. Chapman, D. et al. 1973. *Power Generation, Health, and Fuel Supply.* Submitted to Nat. Power Survey, Fed. Power Comm., Washington DC
113. Smith, K., Weyant, J., Holdren, J. 1975. *Evaluation of Conventional Power Systems.* Rep. No. ERG-75-5. Energy and Resour. Group, Univ. Calif., Berkeley
114. Epstein, S., Hattis, D. 1975. Pollution and human health. In *Environment,* ed. W. Murdoch. Sinauer Assoc., Sunderland, Mass.
115. See Ref. 5, page 26
116. Ross, M. et al. 1975. Energy needs for pollution control. In *The Energy Conservation Papers.* Cambridge, Mass: Ballinger
117. Hirst, E. 1973. *Energy Implications of Several Environmental Quality Strategies.* Rep. No. ORNL-NSF-EP-53. Oak Ridge, Tenn: Oak Ridge Nat. Lab.

118. Anderson, C. et al. 1974. *An Assessment of U.S. Energy Options for Project Independence.* Rep. No. UCRL-51638, Lawrence Livermore Lab. Springfield, Va: Nat. Tech. Inf. Serv. See also *Project Independence* Reports. Washington DC: Fed. Energy Admin.
119. Hass, J., Mitchell, E., Stone, M. 1975. *Financing the Energy Industry.* Cambridge, Mass: Ballinger
120. Bullard, C., Pilati, D. Sept. 1975. *Direct and Indirect Requirements for Project Independence Scenarios.* Doc. No. CAC 178. Center for Adv. Computation, Univ. Ill., Urbana
121. American Institute of Architects. 1974. *Energy and the Built Environment: A Gap in Current Strategies*; 1974. *A Nation of Energy Efficient Buildings by 1990.* Washington DC: AIA
122. American Institute of Architects. 1974. *Energy Conservation in Building Design.* Washington DC: AIA
123. Vyas, K., Bodle, W. 1975. Coal and oil shale conversion looks better. *Oil Gas J.* 73(12): 45
124. Holdren, J. 1974. Hazards of the nuclear fuel cycle. *Bull At. Sci.* 30(8): 14
125. Schneider, S., Dennett, R. 1975. Climatic barriers to long-term energy growth. *Ambio* 4: 65
126. Weinberg, A. M. 1972. Social institutions and nuclear power. *Science* 177: 27
127. Foreman, H., ed. 1972. *Nuclear Power and the Public.* Garden City, NJ: Anchor
128. Anderson, K. P. Oct. 1973. *Residential Energy Use: An Econometric Analysis.* Santa Monica, Calif: Rand Corp.
129. Chapman, D. et al. 1972. *Predicting the Past and Future in Electricity Demand.* Agric. Econ. Pap. No. 72-9. Cornell Univ., Ithaca, NY
130. Mount, T. D. et al. 1973. *Electricity Demand in the U.S.: An Econometric Analysis.* Rep. No. ORNL-NSF-EP-49. Oak Ridge, Tenn: Oak Ridge Nat. Lab.
131. Cicchetti, C. 1974. Electricity price regulation. *Public Util. Fortnightly* 94(5): 13
132. Berlin, E., Cicchetti, C. J., Gillen, W. J. 1975. *Perspective on Power: A Study of the Regulation and Pricing of Electric Power.* Cambridge, Mass: Ballinger
133. Bierman, H., Hass, J. Jan. 1974. *Public Utility Investment and Regulatory Practices.* Cornell Energy Project, Pap. No. 74-1. Cornell Univ., Ithaca, NY
134. Lichtenberg, A., Norgaard, R. 1975. *Tax Treatment of Oil and Gas Income and Energy Policy. Nat. Resour. J.*, Vol. 14, No. 4
135. US Senate, Committee on Commerce. 1973. *Truth in Energy and Car Pooling.* Washington DC: GPO
136. Federal Power Commission. 1975. *Measures for Reducing Energy Consumption for Homeowners and Renters.* Washington DC: FPC
136a. Bullard, C. 1973. *Energy Conservation Through Taxation.* Doc. No. CAC 95. Center for Adv. Computation, Univ. Ill., Urbana
137. *The Wall Street Journal.* March 31, 1975. p. 3
138. Rubin, M. Dec. 1974. Plugging the energy sieve. *Bull. At. Sci.*, Vol. 30. See also Ref. 11, Vol. 2, p. 659
139. *The Wall Street Journal.* Jan. 28, 1975. Back page
140. Rauenhorst, R. 1973. See Ref. 110
141. Fraker, N., Shorske, E. Dec. 1973. *Energy Husbandry in Housing: An Analysis of the Developmental Process.* Rep. No. 5. Princeton Center for Environ. Stud., Princeton, NJ
142. Herendeen, R. Oct. 1974. Energy and affluence. *Mech. Eng.* Also Herendeen, R., Tanaka, J. 1975. *Energy Cost of Living.* Doc. No. CAC 171. Center for Adv. Computation Univ. Ill., Urbana
143. Ford, G. R. Jan. 1975. *The President's 1975 State of the Union Message, including Economy and Energy.* Washington DC: The White House
144. Department of Industry and Riksdagen, Stockholm, Sweden. Feb. 1975. *Energi-Hushållning m.m.*
145. *Towards Responsible Energy Policies.* 1973. Policy Statement of Nat. Coal Assoc., Am. Pet. Inst., Am. Gas Assoc., Atomic Indus. Forum, Edison Elec. Inst. Available from Edison Elec. Inst., New York
146. Rydbeck, V. Aug. 1975. Rx for utility financial vitality. *Public Util. Fortnightly,* Vol. 96, No. 4
147. Hirst, E. 1972. *Electric Utility Advertising and the Environment.* Rep. No. ORNL-NSF-EP-10. Oak Ridge, Tenn: Oak Ridge Nat. Lab.
148. Council on Economic Priorities. 1972. *The Price of Power.* Cambridge, Mass: MIT Press
149. Schipper, L. 1975. *The Efficient Energy Future and ERDA-48.* Testimony before Counc. Environ. Qual. on US ERDA, Los Angeles, Calif., Sept. 8–9, 1975. Washington DC: Counc. Environ. Qual.
150. Ralls, W. 1974. See Ref. 10, Vol. 2, p. 467

151. Lovins, A. 1975. *World Energy Strategies.* Cambridge, Mass: Ballinger
152. Seidel, M. et al. 1973. *Energy Conservation Strategies.* Rep. No. R5-73-021. Washington DC: US EPA
153. Acton, J. et al. 1974. *Electricity Conservation: The Los Angeles Experience.* Santa Monica, Calif: Rand Corp.
154. Wildhorn, S. et al. Oct. 1974. *How to Save Gasoline: Public Policy Alternatives for the Automobile.* Santa Monica, Calif: Rand Corp.
155. National Science Foundation. 1975. *Energy Conservation Research: Proc. NSF/RANN Conf., Feb. 18–20, 1974.* Washington DC: NSF
156. Darmstadter, J. July 1974. *Limiting the Demand for Energy: Possible? Probable?* Washington DC: Resources for the Future Inc.