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GL03473

NUCLEAR AND OTHER ENERGY

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Fossil fuels now supply over 95 percent of the U.S. commercial energy, and, even with a maximum effort to develop alternatives, the bulk of our cumulative requirements between now and the end of the century will have to be met from oil, gas, and coal resources. Nuclear, geothermal, and most other alternative forms of energy are restricted to a few specific uses, such as the generation of electricity. Consequently, fossil fuels cannot be replaced in many uses even after we have developed practical technologies to produce energy from other sources.

Major changes in energy supply patterns have historically taken place at a very slow pace. The process of establishing technical and economic advantages of new sources and replacing previous consuming equipment has extended the period of changeover in the energy system to as long as 50 years. There has been a serious effort to promote the use of nuclear fission for 25 years, and in 1971 it still accounted for less than one percent of the total U.S. energy supply.

In this decade (and beyond) the problems relating to the supply and use of fossil fuels will dominate energy policy considerations. Before the year 2000, nuclear and other alternative sources will begin to make significant contributions to total energy, but it will be many years before they can help appreciably in alleviating the basic problems of energy systems dependent on fossil fuels.

Prospects for Alternatives

Positive contributions of nuclear and other non-conventional sources include (1) the lessening of our dependence on imported fuels, (2) conserving depletable oil and gas resources, and (3) easing adverse environmental impacts, especially in air pollution. But to gain national support, each of the alternatives will also have to demonstrate a significant capacity to provide an economic source of energy supply over a relatively long period of time. Its contribution to future supplies must be large enough to justify expenditures for R&D and other costs of introducing the technology. Finally, we must be able to keep environmental costs, peculiar to the source, within reasonable bounds.

If safety and environmental issues are satisfactorily resolved, nuclear energy has the best prospect of meeting all these performance criteria. It is the only alternative source capable of making a significant contribution in the near term. Furthermore, as part of an on-going process of technological de-

velopment leading to breeder reactors and eventually to fusion, nuclear energy has a potential for long-range replacement of fossil fuels.

Geothermal energy has proven practical at a few ideal sites, and there are widely varying estimates of the potential contributions of geothermal energy elsewhere. Prospective areas have not been extensively explored, first, because the promising locations lie outside of the sedimentary regions more thoroughly drilled for other purposes, and, secondly, because many potential sites are on public lands and had not been open for geothermal lease and development.

The Geothermal Steam Act of 1970 authorizes the Secretary of the Interior to grant geothermal leases on public lands, and some states including California, Oregon, and Colorado have moved to facilitate geothermal development. Exploration and technical development encouraged by these new provisions may provide a much better basis for estimating geothermal potentials in the next few years.

There also are some environmental problems with geothermal exploitation but these are probably manageable without too much addition to costs. Special provisions are necessary to prevent contaminants present in the natural steam or hot water from escaping into the air or water systems. A natural geothermal area to be of use depends on the simultaneous occurrence of heat, a suitable geologic trap, and a source of water supply. The natural occurrence of high quality steam adequate for power generation is rare, and geothermal sources more commonly generate hot water. Processes have been developed, however, to use hot water by flashing it to steam suitable for a low pressure steam turbine or by transferring heat from hot water to some other fluid which in turn could be used to drive a vapor turbine.

Suggestions have also been made for utilizing dry geothermal gradients and pumping water into the formations to recover the heat. It would be possible to use small nuclear explosives to augment natural geothermal systems or to develop new systems artificially by large underground detonations. It is difficult to evaluate the potential of such an approach or to foresee its technical and political limitations, but studies indicate that an impressive amount of geothermal energy might be developed with nuclear techniques.

Solar energy, although huge in potential, is limited in application because of its low intensity and its interruptibility. Successful application requires further development on methods of collecting, concentrating, and storing direct energy from the sun. Research on solar systems, especially those involving solar cells, has been strongly space-oriented but they may have other applications.

An idea proposed by Peter E. Glaser involves collection of solar electric power in space and its conversion to microwave energy at a satellite station for transmission to earth. Although the problems of conversion, transmission, assembly, and maintenance for such a scheme are formidable, and not feasible with current technology, it could ultimately lead to a reliable system essentially free of detrimental environmental effects.

A less exotic solar-electric system designed by Aden and Marjorie Meinel concentrates on the efficient collection of solar energy on the earth's surface. The key to success lies in the materials for the collectors, specifically the highly selective coatings that facilitate absorption of solar radiation and limit reemission losses. The collected heat would be used to drive a conventional steam turbine for the generation of electricity. At this stage, the system would be subject to the same problems of efficiency and environmental thermal discharges associated with other power systems.

With current technology, solar energy is most readily adaptable to residential use. At least in some climates solar space heat should now be promoted as a supplementary energy source. This may be a rational policy in many other areas if its potential benefits in terms of environmental advantages could be factored into the economic equation. Greater attention in building design to take advantage of solar heat in winter and to shield against the effects of the summer sun should also be actively promoted whether or not the home owner is depending on the sun as a prime energy source.

Schemes have been advanced for auxiliary solar devices for use in industrial applications. The capital costs involved in designing and constructing solar concentrators for separate application raise serious questions on the economics of these schemes. However, the problems of interruptibility and unfavorable economics of solar energy alone may be overcome by ingenious combinations of solar and other power sources. For example, solar powered topping units have been suggested for geothermal electric generating stations. If solar concentrators could be used as superheaters, hot water or low quality steam from many geothermal sites in Pacific Coastal and Rocky Mountain states might be developed to meet the power needs of specific areas.

Specialized operations based on geothermal, solar, wind, tidal, and other renewable sources may be feasible only where conditions are exceptionally favorable. Projects to develop sources that meet environmental criteria should be regarded as opportunities, but they will often be by-passed unless there is some way of offsetting the preferences for the established commercial energy supplies. If these specialized or minor sources are to have any measurable impact on total supply, there must be an active promotional policy of encouragement perhaps with Governmental participation or through tax preferences or subsidies. Such projects will often require unique equipment, such as the specialized turbines for geothermal or for tidal projects. The unique characteristics of the undertakings make them vulnerable to competition in the mass market. Their development and viability, therefore, are dependent upon an overt recognition of superiority in terms of environmental impacts.

As our most accessible and richest fossil resources are depleted and we are forced to exploit lower-yielding materials, such as oil shales, the amounts of waste generated will accelerate. This will increase the comparative value of the continuous or renewable forms of energy. Sources such as solar, wind, tidal, and hydro-power can be harnessed, largely without returning materials in the form of waste to the environment. On the other hand, each has its own environmental impacts, if only that of occupying space, altering patterns of land use, or affecting the natural status of water bodies.

General Considerations

Typically, productive activity involves depletion of resources and their transformation into a combination of goods for human use and of waste returned to the environment. The energy systems based on depletable resources are subparts of this main stream of economic activity involving depletion and waste. While we do not have the option of abandoning energy systems based on depletable resources, we can lessen the gross impact on the land in terms of materials extracted and the degradation of the environment in terms of pollution and waste.

It will usually be appropriate, on both economic and ecological grounds, to obtain the necessary flow of goods with a minimum flow of material into waste. The economics of materials handling should normally cause us to be as parsimonious as possible with natural resources and satisfy our needs with the least possible deranging of the environment. Unfortunately, our economic and ecological interests often have not run parallel, especially where technology has been developed which permits massive disturbance of the environment with no economic penalty to the offender. With greater emphasis on preserving the environment, these crude techniques could be replaced by more careful methods of extracting necessary goods while conserving resources and leaving the land intact.

It is vital to note, however, that the latter approach is much more demanding in terms of scientific and technical knowledge and competency. Its success is contingent upon a more vigorous effort to develop the techniques, not only to maintain a decent quality of life but to improve the quality of the environment. At the same time, we should recognize that our technological advances in the past have permitted improvements in this direction. The basic shifts from mechanical to chemical industries, the related revolution in materials, and the reduced dependence on conventional natural resources have helped to make rapid economic growth at least endurable. Without such changes there would undoubtedly have been more massive exploitation of resources before the growth process ended. By whatever method and manner choices are made between further growth and protection of the environment, it will be easier to carry out if more intricate and sophisticated technologies are available to facilitate the transition to new socio-economic arrangements.

The historical pattern of changing from one major fuel source to the next involved an element of resource conservation made possible by the continuing development of new technology. Reverting now to fuels once superseded, or shifting to source materials that are less rich or less productive, will only increase the strain on resources and the adverse effects on the environment. The shifts from wood to coal and from coal to the hydrocarbon fuels, although based primarily on economic efficiency, were also technologically more efficient in terms of resources exploited, labor expended, and land areas disturbed. These increases in technical efficiency have been reflected in the

amount of resource extracted to provide a unit of useful energy. The following data on energy obtainable from one short ton of source material show the progressive change from wood to uranium in sources of fuel.

Source Material	Energy Content (Btu × 10^6/short ton)	Coal Equivalent (Short ton coal = 1.0)
Fuel Wood*	10	0.4
Coal	25	1.0
Petroleum	38	1.5
Natural gas	46	1.8
Uranium ore†		
LWR technology‡	900	36
Breeder technology	80,000	3,200

* Assuming ½ cord = 1 short ton.
† Ore containing 0.2% or 4 lbs U_3O_8 per short ton.
‡ Light water reactors, data reflect losses in conversion and enrichment of nuclear fuels.

Energy from nuclear fission involves revolutionary technological change, but in terms of economic efficiency it appears as part of the continuing evolutionary change from one fuel source to the next with advantages that are authentic but not spectacular.

In selecting our energy options, the technologies permitting us to use energy more efficiently and those making it possible to obtain equivalent energy from less resource material provide obvious advantages. Nuclear fission, even with the technology currently in commercial use, provides the opportunity to extract vast amounts of energy from the natural source material. The potentialities in changing from the current light water reactors to the breeder would minimize the strain on energy resources even more spectacularly than a shift from fossil fuels to the present nuclear technology.

Clearly uranium offers far-reaching advantages measured in terms of the physical flow of materials extracted, processed, and consumed. But while the same energy is concentrated in smaller amounts of natural resource, the material is more difficult to handle and the waste products must be disposed of with great care. It follows that the first priority in a civilian nuclear power program is to protect the health and safety of the public from the hazards of radiation and from the potential risks of nuclear operations. The future of nuclear power hinges upon how well we evaluate the hazards, meet the stringent technical demands, and accept the discipline associated with the regulation and control of highly toxic and dangerous materials.

Implementing Environmental Policy

Historically, the course of energy development has proceeded without explicit long-term national policy direction. Decision-making in the energy industries was largely market oriented, incorporating the first-order effects of economic activity and largely ignoring the effects not factored into the market equation. By law and custom, exploiting the bounties of nature has been a social prerogative, and protecting the environment leads inevitably to conflicts with traditional economic and social norms.

A social reorientation involves not only technological but institutional change, and we should not be complacent about the problems confronting us in the energy and environmental fields. The great danger is that we will underestimate the problems, and overestimate the effort and the cost which society is willing to bear to achieve results. What we lack most of all is "room for maneuver" in dealing with energy and environmental problems. There has been a diminishing flexibility in the system as the development of some energy resources falls behind the growth of demand for the derivative fuels. Our continued dependence on these fuels, the inadequacies of technologies to control pollution or meet desired standards, and the institutional and organizational obstacles to effective action narrow the field and limit our options.

The enunciation of policies to improve the environment without regard to these limitations becomes little more than a simple expression of goals. The supply problems and the technical deficiencies are probably amenable to solution given sufficient time, but the emerging social and institutional problems may be very difficult to resolve. The administrative machinery and the analytical tools are not readily available to implement the new environmental laws on a timely basis. At least for an interim period there will be conflicts between economic and environmental objectives.

Socio-economic programs have an institutional advantage in that we operate from a ready-made concept of a healthy economy measured in objective terms such as the level of unemployment, the increase in the Gross National Product, and changes in the cost of living. By comparison, environmental goals are subjective and disputable. We are not used to dealing with non-economic social goals, and our ecological frame-of-reference is too incomplete to define goals that are understandable and acceptable to a majority of the population.

The most likely course toward an acceptable public program and effective environmental protection lies in the development of standards, means of measurement, and strategies of control devised by Federal environmental agencies and the regional and state pollution abatement organizations. This may be a slow and laborious process as the agencies are organized and the programs are devised and implemented. There are advantages, however, in creating new organizations to develop acceptable criteria and find the most secure methods of institutionalizing environmental protection. The alternative of distributing the administration of environmental law within the confines of existing organizations, where often there is neither talent nor enthusiasm for the job, may be a temporary expedient but a long-range impediment. Environmental protection is a new social departure, and we ought to approach it with the most innovative and revolutionary techniques available in our social and political system.

A new awareness that improving the environment is both desired and politically tenable led to an understandable impatience for quick action. This led to new environmental laws of which the National Environmental Policy Act of 1969 (NEPA) has had the most dramatic impact. NEPA was de-

signed as a statement of policy, but it also outlined certain procedures for all agencies of the Federal Government to follow. By recent court interpretations these directives have taken on great force and required agencies to make careful reappraisals of important programs. The courts have held that specific NEPA procedures are enforceable through suits of interested citizens. Citizen litigation in several cases has been instrumental in forcing Government and industry to consider, or be more sensitive to environmental needs. It has sped the legal process in the environmental area by opening up issues to court interpretation. In the process, it has seriously delayed the construction of vital facilities, especially electric power plants, and may contribute to energy shortages and other economic disruptions in the near term.

If the forcing of environmental issues continues to be highly dependent upon citizen intervention, there is a question of the ability to sustain interest and to support action in the long term. To prevent retrogression there must be some reliable method of sustaining interest, and environmental responsibility must become an institutional part of the Governmental and industrial organizations. NEPA directives were general in nature, but court interpretations have required the specific agencies involved to take the lead in formulating new techniques in implementing those parts of the law dealing with agency decision-making. The responsibilities of energy agencies affected by environmental issues were extended not on the basis of their special designation as environmental experts but in relation to their strategic positions in licensing or authorizing activities in a specific area of expertise.

Under the landmark *Calvert Cliffs* decision (July 1971), the Atomic Energy Commission (AEC) becomes responsible not only for radiological aspects but for evaluations of the total environmental impact of nuclear power plants, including their auxiliary non-nuclear facilities. The AEC is required to perform an independent balancing of total environmental costs in comparison with benefits of any licensing action. Environment appraisals are required for all major Federal actions, and this has had a far-reaching impact on decision-making in the energy area.

Other agencies dispensing Federal licenses, permits, or leases have been similarly affected by NEPA procedures. The Federal Power Commission's licensing by hydro-electric projects and the Department of the Interior's leasing of geothermal sites and offshore oil properties now require environmental impact statements, and by court interpretation, comprehensive cost-benefit analyses of the proposed project.

Court interpretations of new environmental law, arising out of citizen litigation, have tended to center decision-making on a wide range of matters in the specific Federal licensing agencies. The AEC through its role in licensing nuclear plants becomes the final authority on a wide range of non-nuclear matters ranging from thermal effects of plants to the environmental impact of transmission lines. While the AEC may be readily equipped to deal with this wide range of issues, there are other jurisdictions (state and local) and other Federal agencies that have regulatory authority in these same areas.

This raises problems not only of duplication but of the potential pre-emption of effective control over power programs.

Policy Appraisal

It would be well to take a careful look at the Federal regulatory processes in terms of what the specific laws prescribe, what the regulatory agencies can be expected to deliver, and what the citizen gains in terms of health and safety, service, and environmental quality.

Under the Atomic Energy Act, nuclear safety has been, and continues to be, the primary concern of the AEC. The public must be assured of protection from harmful radiation, and the risk of nuclear accidents must be reduced to a minimum. Neither radiation nor threat of nuclear accidents can be reduced to zero, but the best-assumed interest of the public in nuclear regulation is undoubtedly to make every reasonable effort to approach the ideal. The decision to accept any nuclear power must be based on the premise that risk of catastrophic portions will be extremely improbable.

Under NEPA an agency such as the AEC with a specific mission requiring unique expertise must now assume a general responsibility in the environmental area. Obviously, the mission agencies can be and are being prepared to implement the broad provisions of the new laws. They must be equipped, as quickly as possible, to discharge these new responsibilities in a meaningful way, but, at least in some cases, the public may be better served by reserving their special expertise for vital specified tasks.

We should ask ourselves, "What sort of organizations would we devise to regulate the environmental impact of energy operations if the opportunity existed to create such a force? What tools would we expect them to use to arrive at their conclusions? And what authority would we want them to have to implement and enforce their decisions?"

The logic that a Federal agency issuing licenses, permits, or leases should take account of all potential ramifications of its actions seems unassailable. But in a complex industrial society heavily dependent upon specialists and specialized groups this may be a questionable procedure. If we force existing specialized regulatory authorities to become enmeshed in control efforts of widening responsibility and increasing complexity, the result may simply be reduced efficiency and dilution of their primary mission.

The criteria under NEPA appear to be, at once, too broad and too narrow. They are too broad in that they severely tax the capacity of regulatory authorities to deal with the catalog of issues and the variety of alternatives in any meaningful way. They are too narrow in application by making the specific project under license (or the related object of a Federal action) the center of analysis.

In following the Court's interpretation of NEPA, the AEC is required to make an overall environmental review and benefit-cost analysis on each nuclear plant subject to license. Aside from doubts relating to the analytical technique itself, and the pretensions of putting a price on "environmental

amenities," the application of the analysis to specific (individual) plants may be very inappropriate.

Environmental consequences are best observed in a broad setting such as an entire river basin. Especially in power plant siting, regional considerations are paramount—both from the viewpoint of power production and the burden of pollution on the quality of air and water.

Long-range environmental goals are the only really meaningful ones, and a plan for improvement or protection will have little meaning unless it can consider plant additions as part of an on-going process of industrial change. It involves complex issues of land use, public acceptance, and the capacity of natural environments to tolerate additional loads.

National power plant siting bills now before Congress are generally designed to deal with these complex issues in the context of long-range power planning. It may be possible for such legislation to supersede the environmental reviews on a plant-by-plant basis now required under NEPA.

This need not interfere with or alter the AEC review for plant safety and radiological effects which in any case are related more to plant design and engineering quality and are regulated accordingly. Likewise, the development of new technology through test facilities or demonstration plants should be considered as distinct undertakings unrelated to the complex of commercial facilities to serve a market area. The existing industrial order should be challenged by new technology, and an innovative society will need to continuously test and try techniques that serve its purposes better, on either economic or ecological grounds.

Consideration should be given to the most appropriate regional grouping for energy planning, in general, and power plant siting, in particular. There are a few river basin commissions already operating that would seem well equipped to assume a central role in the environmental planning process. With the expansion of nuclear power, it may be an opportune time to break with past institutional arrangements. We need to experiment with new ideas in terms of organizing the production and distribution of electric power to deal effectively with environmental impacts.

There is a danger of falling into undesirable, or at least sub-optimum, channels through a series of small decisions when decisive changes are more appropriate. Furthermore the environmental impacts and the risks of nuclear power cannot be evaluated with every increment of new capacity. We need to look at these problems at some stage in the future when nuclear capacity is operating on a large scale.

As Dr. Alvin Weinberg and others have suggested, we need to visualize how the world would look with nuclear power as the dominant energy source. We can then begin to comprehend what must be changed to arrive at an appropriate configuration of energy use and pollution control. The problems of siting plants in the current institutional and organizational setting may prove to be inconsistent with long-term expansion of nuclear power. Alternatives such as the development of "energy parks" described by Dr. Weinberg should be considered in the process of institutionalizing our environmental practice.

Real progress to improve the environment could be advanced if there were more provision for experimentation and testing to find new departures from undesired trends. Environmental requirements when superimposed on existing modes of operation may be burdensome and confining, but when introduced in conjunction with new technologies and new organizational arrangements environmental objectives may be more effectively accomplished and more readily accepted.

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MINERALS AND METALS

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At the 1970 International Joint Conference on *Environment and Society in Transition*,[1] the Working Group on Cultivating Resources concluded that the best approach to the problem of environmental quality appears to be the establishment, on a global basis, of a steady-state ecology approximating a closed cycle for all resources consumed, that is, for all products, waste products and pollutants. In view of this aim, it should be noted that most metal industries have long recycled large amounts of scrap. For example, the steel industry uses about 55 million tons of scrap in making 100 million tons of raw steel. The proportion of scrap recycled in the production of aluminum, copper and a number of other metals is commonly somewhat smaller, though very substantial.

But there are formidable problems in the reuse of scrap metal. One is adequate control of its chemical composition. Although scrap that has been properly classified can be a valuable source of alloying elements, the presence of some unidentified elements can lead to serious trouble. For example, in steelmaking the presence of tin or copper in certain range of composition causes brittleness and bad surface conditions. Nickel and tin may not only contaminate a heat but may leave a residue in the furnace which causes problems in later heats. Lead is harmful to furnace refractories.

Much of the scrap metal is generated during production in such forms as the crop ends of blooms, trimmings from flat-rolled product, or product which has been damaged in finishing or handling. Segregation of such material by composition is usually relatively simple and is under the direct control of the producing plant. In the steel industry almost two thirds of the scrap used is generated, in this way.

The rest of the scrap is purchased either from a consumer or from a scrap dealer. If the former, the composition is often known, as in the case of trimmings from an auto body or aircraft plant, whereas scrap purchased from a dealer is often of unknown origin and composition. Spot samples can be taken for chemical analysis, and there are many rough checks, such as spark or magnetic tests, but these are not too satisfactory in many cases and become quite expensive if made in large numbers, as is desirable when dealing with millions of tons of such metal. The magnitude of the problem is well illustrated by the fact that in the iron and steel industry there exist over seventy different specifications covering various grades of scrap to be used in different operations.

Another problem is that most metallurgical processes are limited in the amount of scrap they can utilize. For example, in making steel the open-hearth furnace, which used to be favored in this country, can use from 35 to 60% scrap. The basic oxygen process, which is rapidly displacing the open-