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THE POTENTIAL FOR SMALL-SCALE, DECENTRALIZED ENERGY SOURCES AND THE FEDERAL ROLE IN THEIR DEVELOPMENT

by

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This paper has been prepared from a tape recording of the presentation made by Mr. Hayes and the discussion with the audience that followed. The tape transcript has been edited for publication.

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PREFACE

The idea that the solution to our energy problems is to be found in an expanded role for small-scale, decentralized energy sources, particularly solar energy, has gained considerable attention and increasing respectability in recent years. One of the most articulate spokesman for this point of view is Denis Hayes. Mr. Hayes, a Senior Researcher with Worldwatch Institute, a private, non-profit research organization in Washington, has long been a political activist on behalf of environmental causes. He was national coordinator of Earth Day in 1970, and he also helped found and headed Environmental Action, a public interest lobby. His recent book, Rays of Hope: The Transition to a Post-Petroleum World (W.W. Norton and Co., 1977) is a forceful presentation of the arguments for solar energy, and his activities in the solar energy movement have included chairmanship of the board of directors of Solar Action, the sponsoring organization of Sun Day, 1978.

At an evening seminar held at George Washington University on February 1, 1978, Mr. Hayes explained his perspective on the energy problem to an invited audience of about 85 professionals and students in the energy policy field, including staff members from Congressional committees and members' offices, officials from the Department of Energy and other Executive Branch agencies, representatives from non-government organizations based in Washington, and students, research staff, and faculty from GWU. This paper is an edited version of Mr. Hayes' presentation, as well as the hour-long question and answer session that followed.

In his presentation, Mr. Hayes discussed the prospects for fossil and nuclear energy, stressing the potential limitations on coal use due to the problem of CO_2 and the greenhouse effect, and highlighting the hazards of the plutonium economy. He described the role conservation can play in dealing with the energy problem, but declared that conservation alone is not enough. There is still a need, he indicated, to replace declining energy sources with some alternative. In his view, the most promising alternative is solar energy, and Mr. Hayes discussed the various ways in which it can be utilized.

The presentation concluded with a number of suggestions regarding federal actions and policy initiatives that Mr. Hayes feels are needed to encourage solar energy development. These ideas served as the focus for the question and answer session which followed the presentation. Questions dealt with many issues, including priorities in solar R&D, the role of the federal government vis a vis the private sector, the timing of solar energy implementation, and the strategy and tactics of the solar movement.

This seminar was part of a series sponsored under a grant from the U.S. Department of Energy to the Graduate Program in Science, Technology, and Public Policy. The purpose of the seminar series is to provide a neutral forum for energy policy professionals from the Washington area to gather, participate in a discussion on a topic of current interest, and talk informally with colleagues and counterparts from other agencies and organizations. Other energy policy seminars have dealt with such topics as "The Roles of Industry, Universities and Government in Energy R&D," and "Nuclear Waste Management: Policy and Politics."

Seminars on energy, as well as on other areas of science and technology policy, are among the wide range of activities in which the Graduate Program in Science, Technology, and Public Policy is engaged. Jointly sponsored by GWU's School of Public and International Affairs and the Program of Policy Studies in Science and Technology, the Graduate Program is one of the leading centers in the world for teaching and research in its field. Its student body during the past several years has averaged more than 50 active full and part-time graduate students. Most students are enrolled in a flexible course of study leading to an M.A. degree in Science, Technology, and Public Policy. Others pursue Ph.D. degrees in academic disciplines, particularly political science, while focusing their studies on some aspect of science and technology policy.

Graduate Program faculty and staff conduct research projects under sponsorship of a variety of federal agencies and private foundations. Current research interests include, in addition to energy policy, domestic and international technology transfer, policy-making in the U.S. space program, technology assessment, administrative behavior in scientific and technological agencies, and technical aspects of regulatory decision-making.

Information about the Energy Policy Seminar Series and about other activities of the Graduate Program may be obtained from the Program's offices, Library 714-West, 2130 H Street, N.W., George Washington University, Washington, D.C. 20052. (Telephone: 202-676-7292.)

Albert H. Teich

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SEMINAR PRESENTATION

I have a two-year old daughter, and like the fathers of all two-year old daughters, I take extraordinary pride in her every accomplishment. I was exceedingly pleased when she mastered the alphabet before she turned two, and was waiting eagerly for the first time she would master that big conceptual breakthrough of actually linking those letters together and forming a word. When we were driving down the street, not many weeks ago, the breakthrough came. We pulled up to a traffic light, and she looked at a sign outside and read, "E-x-x-o-n." Clearly she had put the concept together and related it to where we got gasoline. The fact that that is the first conceptual link in the mind of my daughter, this great breakthrough in her education, says something, I think, about the degree to which petroleum has penetrated our way of life.

We have built a civilization that is in very large measure dependent upon petroleum. The extent to which petroleum guides the various activities in which we engage is often forgotten when we talk about energy analysis. In such discussions we often just talk about the dollar costs, and occasionally the environmental or health externalities, of delivering BTUs of a given quality to perform a certain kind of task. Yet, the real impact of energy choices is far greater. We can see this by looking at energy in an historical context. The switch from wood and wind into coal ushered in the industrial revolution. The later conversion from coal to oil had a dramatic impact upon transportation systems -- making jet flight available and shrinking the globe, making automobiles possible and completely restructuring cities.

We are now facing the certain end of that petroleum era. There is nobody down there making more oil, at least not at a rate that's going to do us any good. You can play different games with petroleum numbers -- you can come up with different assumptions about what remains out there yet to be discovered that can be obtained with certain technologies at certain prices, and come up with a fairly broad range of estimates. Similarly, there is a broad range of views as to what is going to happen to global demand over the course of the next couple of decades. Hence, you find a range of estimates as to when global petroleum is likely to peak out. We assume in thinking of the peaking phenomenon that we are going to follow the same type of bell-shaped curve for the global resource that we followed for the American resource. The dates during which the peak is expected to occur range from seven or eight years in the future, to somewhere on the order of fourteen or fifteen years. Conventional wisdom would probably hold about eleven years. I've talked with the corporate planners for the major oil companies and they seem to believe that eleven years is a pretty good figure to work with in terms of planning. That means that anybody in the audience who bought a new 1978 Volvo -- and if you bought it because you believed their advertising -- is still going to be driving that car when global petroleum peaks. Domestic petroleum, in the lower 48 at least, peaked out in 1970. Even with the new oil from the Continental shelf and from Alaska, we will almost certainly never again reach the level of domestic production that we had in 1970. We are therefore going to be undergoing a transition of some kind that may well equal in its side effects, as well as its direct effects, those previous energy transitions that we were talking about. This future transition will have a profoundly important shaping influence upon the structure of the society that our children will inhabit.

If you look carefully at different energy sources, you can see some of the characteristics that may come to permeate that future society. Some energy sources are necessarily centralized, because of the engineering efficiencies possible with increased scale. Other energy sources are necessarily decentralized because of the diffuse nature of the resource that is being tapped. Some energy sources are inherently dangerous, and will be safely employed possibly only in a rather authoritarian society. Other energy resources have little potential for unsafe use, and as a consequence might lead to a different set of perceptions about the things that bring power to our lives. We could trace through a variety of other kinds of characteristics as well. These factors are largely ignored in policy debates over energy. We do not much think about those factors -- what we think about is the dollar cost of delivering BTUs to perform a certain kind of task.

The Worldwatch Institute is supposed to sit back a little bit from the battles that will be waged over the Carter budget -- from the battles that go on on a monthly, even daily basis, in this city, over politics and policies -- and try to look at things in a somewhat broader frame of reference, looking at their global long-term impacts. Doing that, let me sketch out a rough model that may yield some insights into the energy sources that are really available to the world in the long term.

Let us assume, optimistically, that global population will double one more time and then level off. I think almost every demographer would consider that to be an optimistic assumption. The current categories by age grades in the world and the likely birth rates that will be associated with them will mean more than a doubling, almost certainly, unless very effective programs are initiated to slow the rate of population growth.

Or else, more tragically, that growth rate will be dropped by increases in the death rate. Let us assume, optimistically, that we can have an educational program of sufficient scope and intensity that the birth rate is cut back and world population doubles only one more time. Let us assume further that energy use around the world comes up to a per capita level of about one-third of what we currently use in the United States. Presumably, the energy resource, like every other resource, will be somewhat inequitably distributed -- some people will use more than that amount, some will use less. On the average, however, people will use about one-third of what the average American uses today. Using that as our model for energy use -- admittedly a crude and unrealistic one -- let us see what it means for different energy sources that might be available to us in the long-term.

First of all, of course, petroleum is not going to play much of a role in that kind of a model. It will be exhausted, in terms of its importance as a major fuel for the economies of the world, before population reaches that level.

Coal is a substantial resource globally, and particularly in certain parts of the globe. Coal development is the cornerstone of the Carter energy program. When the President announces his goal of trying to avoid giving the Saudi Arabians mineral rights to Fort Knox, what he is really talking about doing is substituting American coal for their oil. Globally, coal resources are enormous. However, if you look at availability by country, you find that 55 percent of the known coal in the world lies within the Soviet Union; about 18 percent lies within the United States; and about 8 percent lies within China. That means that three countries have about four-fifths of the world's coal. Coal, unlike oil, is difficult to transport and it is unlikely to become the international commodity that oil has become. There are a lot of problems with mining coal, whether on the surface or underground. We find increasingly in the coal versus nuclear debate that the nuclear people are coming up with some fairly persuasive evidence that coal is a rather dangerous energy resource, especially for those people who are involved in mining it and in converting it into what we think of as clean fuels. The conversion processes themselves are often not very clean, in terms of the carcinogens that they produce. In addition, with regard to coal combustion, there are a number of problems that current technologies are not doing a very good job of cleaning up. If, in fact, the Carter plan were to be successfully implemented even with the best available pollution control technology on the facilities, we would still have in this country a significant gross deterioration in air quality.

A lot of the problems with coal can be ameliorated with various technological fixes. Better pollution control equipment can be developed; there are ways of mining underground without causing as much of a hazard to health; and, for many different types of coal, you can strip it, and within some limits reclaim the land so it at least has some productivity (but generally not its original productivity).

But with coal there is one absolutely intractable problem: you cannot get the energy out without burning it, and you cannot burn it without producing carbon dioxide. Talk of the greenhouse effect has become sufficiently commonplace that I don't think I have to belabor the point. Atmospheric CO_2 has increased about 13 percent, we believe, since the beginning of the industrial revolution. If the postulated level of global demand -- the doubling of the population with one-third as much energy per person as we currently use in America -- were to be met entirely with coal, atmospheric CO_2 would increase at the rate of about four percent a year. That is a pretty impressive number. You rather rapidly find CO_2 under that sort of a model to simply overshadow all of the other atmospheric consequences of coal combustion -- the emission of particulates and other gases.

A recent report by the National Academy of Science has suggested that we could run into some very severe long-term problems with coal combustion, as the total percentage of CO_2 in the earth's atmosphere begins to rise. This is for all practical purposes, within time frames that we are interested in, an irreversible phenomenon. That is to say, once CO_2 goes into the atmosphere, most of it is going to stay up there. You can pull some of it out with vegetation; you can pull some of it out in the ocean where it sinks down into the lower, colder levels and stays; but most of it does not come out of the atmosphere very rapidly. What is more, most of the CO_2 that is used by vegetation goes right back into the atmosphere as the vegetation falls and decays or is cut down and burned. Before you get to the levels that the National Academy of Sciences was worried about, you get to other levels that may well prove to be pretty frightening. An article in the current issue of Nature magazine suggests that if global CO_2 levels simply double once, which with our model would probably happen in about 20 years, it would almost certainly result in the melting of the Western Antarctic ice floe. The impact of that melting on the world's oceans would be a rise in mean depth of about five meters. The implications of that possibility are pretty staggering. Of course, this is not something that would be considered as gospel by everybody, but the person who wrote the article is certainly one of the foremost authorities on meteorological conditions in the Antarctic. It is an opinion that has to be respected, and it is one which is concerned with an irreversible phenomenon. It is frightening; there is no way around it. You cannot burn the coal without producing the CO_2.

Another energy source that has been talked about as a long-term global prospect is nuclear power. Once again, as with coal, there are a variety of problems that are associated with its use -- reactor safety problems, nuclear waste disposal problems, and other problems that have to do with any kind of highly centralized system that is probably going to have to be situated in energy parks and hence will have consequences for local meteorology. Potentially, the cooling systems could result, for example, in some areas in continuous cloud cover (as a study by Princeton suggested would result from a proposed energy park in New Jersey).

Many of these nuclear problems, once again, can be somewhat ameliorated by technologies. There are things that you can do -- they are costly, but you can do them -- to make plants safer against terrorists, against earthquakes, against all sorts of forces. You can ameliorate the various conditions somewhat. One problem, however, I think is absolutely intractable when you try to apply nuclear power to that global model that we were discussing. If you were to meet that level of global energy demand with nuclear power, it would first require the operation of 15,000 reactors as big as the biggest reactors now available in the world. If you are going to reach that by the time the population grows to the predicted level, you are going to have to start building a reactor every week or two rather soon. By the end of the period, given replacement times, you probably are going to have to be building four or five reactors a day to maintain that level. These are big 1100 megawatt reactors, and those reactors and the breeders that are going to be necessary to fuel them are going to be producing enough plutonium every year to manufacture four million Hiroshima-sized bombs. That plutonium, of course, is not intended to be used for bombs, but it is a commodity whose use will not necessarily follow the intentions of current energy planners.

In any chemical factory, there are losses that simply cannot be accounted for. With different factories, the losses range around a half a percent, a third of a percent, two-thirds of a percent. Plutonium reprocessing plants are basically chemical factories and there are going to be losses. If you look at the operation of the American reprocessing system, you find that we have sufficiently large measures of uncertainty in it right now that somebody could already have stockpiled a fairly formidable arsenal. Enough bomb-grade material is missing to manufacture about 750 atom bombs. That seems to me to be a rather alarming margin of error. Any country that is carefully operating its own reprocessing facilities and is willing to operate within existing margins of error can assemble its own arsenal without anyone ever being the wiser. There may well be a couple of arsenals around the world right now that no one can really talk about for certain.

The problems with nuclear energy go beyond weapons proliferation among countries, fearful though that is as a global prospect. You also have to talk about aspects of the system other than simply the reprocessing facility, for example, transportation. Look at the world transportation system today: you find in every transportation system, for every commodity, what is referred to as leakage -- which is a polite term for theft. You can look at oil, at gold, at almost anything. Many of the world's airports and many of the world's ports have been infiltrated by organized crime. Other aspects of transportation systems have similar vulnerabilities to criminal elements and could have increased vulnerabilities to terrorist groups that took it upon themselves to try to penetrate them at some point in the cycle.

The leakage rate in general for the transportation system for most commodities hovers somewhere around 1 percent -- 1 percent of 4 million Hiroshima-sized bombs every year gets you rapidly into a pretty frightening circumstance. Assume, however, that plutonium -- or if you use a thorium breeder, uranium 233 -- is treated as a very special material and we are willing to go to some rather elaborate lengths to make the process secure. If you move into a rather authoritarian regime, you can reduce the leakage rate very substantially, I believe. You might reduce it to a tenth of a percent or maybe a hundredth of a percent. A hundredth of a percent of 4 million Hiroshima-sized bombs a year--400 bombs every year-is still not very reassuring, if one is worried about global stability in the long run. That is a problem to which I do not see any technological fix.

Far more promising, in my view, than either coal or nuclear power, is the broad range of energy resources that are powered by relatively short cycles of the sun. The fossil fuels, of course, are also powered by the sun, but on a cycle that lasts a few hundred million years. We are talking here about using the sunlight either directly as it strikes the earth, or indirectly as it generates winds, or as it evaporates water and carries it up to the mountains where we can tap it as hydropower when it flows back down, or in biological sources which capture it through photosynthesis and store it in chemical bonds that can be tapped and used as an energy source. The biological systems have as an advantage over the fossil fuel systems the fact that once the biological systems are in equilibrium -- that is to say, once you are burning as much each year as you are growing -- then there is no net contribution of CO_2 to the atmosphere. You are producing CO_2, but the plants are taking it out of the atmosphere just as fast as you are putting it in. Some of these benign renewable resources can have substantial environmental effects associated with them. But these effects should be far less significant than those associated with current conventional fuels.

Before we discuss them, however, it is clear that what is needed in this country is a massive investment in energy conservation. You can look at different studies that make different assumptions about what kinds of investments are plausible, and about different levels of anticipated future energy prices that we can experience as a society and come up with different levels of investment. But I think, at an absolute base minimum figure, we should probably be investing something on the order of $250 billion, a quarter of a trillion dollars, in increased energy efficiency before we realistically should be making any investments in expanding energy use. As the oil supply continues to go down, we have to replace it with something; as facilities wear out we have to replace them with other facilities. But before we experience energy growth, economically it makes a lot more sense to put that money that would go into energy growth into stretching a bit farther the energy that we already use. For example, if you buy a new refrigerator, you have an option: you can buy a $400 refrigerator, or you can buy a $440 refrigerator. The $440 refrigerator uses about 60% as much electricity as the $400 refrigerator, which means that if you have your previous generating capacity, 40% of that electricity is now available to do something else -- to, if you will, fuel growth someplace else in the economy. The extra $40 in terms of providing that much electricity simply cannot be matched by any production technology we know of to produce electricity. If you buy the $400 refrigerator, then somebody else is going to have to pay a great deal of money -- more than $40 -- to produce the electricity that would be otherwise available. Efficient refrigerators make great sense, but few people are buying them. Philco-Ford manufactured a very efficient refrigerator which cost a little more than $40 more, I think it was about $45, and saved a lot of electricity, and that model went out of production. Somehow or other we have to make those purchasing decisions differently. We have to get people to think not just in terms of initial cost. If we cannot get them to consider life cycle costs, at least it would be good to have their time frames extend over a couple of years, because many of the energy-saving devices have payback periods of a year and a half or two years. At the extreme, of course, you can come up with examples where you have payback periods on the order of five to six months. I would hazard the guess that probably no more than five percent of the people in this room who have hot water heaters that are not solar hot water heaters have jackets of insulation around them. If you put a jacket of insulation around your electrical hot water heater, you have a payback period probably on the order of four to six months, depending upon how much hot water you use. Maybe some of you are venture capitalists and you have a lot of places where you can get a 200% return in a year, but few of us do. I do not have any place else that I can get the kind of return on my money that I can get with conservation. That's where we should be going as a society as well as we as individuals. But getting there from here is one awfully tough task.

The reason that those conservation investments now make sense is that energy is no longer cheap, and we have a great deal of substitutability within the various factors of production in our economy. You can substitute, within some limits, energy for materials, energy for capital, energy for a bit of creativity in the way that we arrange things, energy for labor. As energy becomes more expensive, it makes increasing sense in terms of economic optimization to begin substituting some of those other things for energy. But to get people to do that, you have to make energy prices really reflect what they should in the marketplace. That means that you've got to start moving toward replacement costs, if you are in fact going to move into a new era in a realistic fashion. You can do that by deregulating fuels -- but that is going to be just about politically impossible to do in America. You can do it by taxing fuels up to the levels to which they would rise through deregulation, and then figuring out a way to return that money back to the people who paid it so that they have about as much purchasing power as they had before -- or more probably, a little bit less, if you allow for inflation. However, the menu of possible things that they can buy is going to be differently priced, and as a consequence they are going to be buying less energy with that same amount of purchasing power than they would otherwise. They are going to be substituting things differently. That's what the President tried to achieve; it doesn't look like it's a salable position. Another way to do it is by rationing -- that looks about as politically impractical. Another way is by regulation -- that has some fairly substantial costs in terms of building an elaborate bureaucracy, in terms of the inefficiencies that are going to be involved, and the random judgment which is involved -- one person's extravagence is another person's necessity and vice versa. You encounter some rather big problems, but that at least looks like it could be done.

You can come up with a law that says Detroit cannot sell a car that does not deliver a certain gasoline mileage, or that you cannot build a house unless it has a certain level of insulation. That seems to be the course that we are taking. It becomes difficult to move that process out of just the transportation and residential sectors and into the commercial and industrial sectors. If you talk about the different levels of energy use associated with literally tens of thousands of different pieces of machinery, about which there is not much competence to be found in the federal bureaucracy, it does not seem to me to be very practical.

I am afraid that what a couple of years ago I thought were my brilliant ideas for dealing with this problem are things I am no longer as confident can be passed politically. One of the nice things though, about living in a period of change, is that the things that are impossible today may be quite possible three months hence. Once the Arabs institute a new boycott, once we have the first major nuclear plant accident, once we have a coal strike that really begins to make itself felt, not just in the Midwest but across the country -- you can come up with your own examples of what the next Sputnik, the next Pearl Harbor, will be -- America will spring once again to attention with regard to saving energy.

Conservation is not enough, however. We have to replace our declining energy sources with something. We are almost certainly going to be having some energy growth beyond our current level, because we cannot make conservation investments as fast as they should be made to economically optimize them. The question now is whether we will move increasingly into coal and nuclear power as our transitions -- since I've been trying to make the case that they do not hold much promise in the long-run -- or whether we will move into a combination of solar in the long-run, and intensive conservation measures immediately.

It does not seem to me to make a great deal of sense to move into technologies that are necessarily highly centralized, if the transition that we are talking about is toward a series of sources that are necessarily highly decentralized. The investments both in the facilities themselves and the infrastructures that surround them (the transmission and distribution systems, the transportation systems) are so enormous that we cannot afford to make mistakes -- particularly if our society is as tight on capital as it appears to be at the moment. What I think we should be doing is biting the bullet on conservation today and coming up with a set of policies that will become politically practical sometime soon for energy growth to turn to the renewable options. Solar heating today in the United States -- space-heating and water-heating -- makes a good deal of economic sense, provided you are doing your economic analysis at the margin. That is to say, you cannot talk about the cost to a person of going solar, or using a gallon of heating oil, but the costs to the society of going solar versus the costs to the society of producing one new gallon of heating oil. Similarly, with electricity: the only places in America, if you are using an average cost comparison against solar marginal cost, that solar water-heating does not really make sense today are Washington, Oregon, and Idaho. These states have the Bonneville power administration, with a lot of huge dams that were built 30 or 40 years ago, providing exceptionally cheap hydro-power; I think it is on the order of nine-tenths of a cent now, and nothing can compete with that. But if you are competing at the margin, if you think the Bonneville power administration does not have any more hydroelectric capacity to develop, then you must talk about comparing solar heating with the Trojan nuclear plant, or better yet against a new nuclear plant that will be ordered today for delivery in 1984 or 1985 (if, in fact nuclear power speeds up its delivery time). Compared to that, even in the Pacific Northwest where the climate conditions are not enormously favorable, solar power once again makes sense.

So far, when people have talked about renewable energy resources they have mainly contented themselves with talking about residential applications for hot water and space heating -- the sorts of things that are obvious. If you go to a passive system for the bulk of your energy supply, you can, with a very small adjustment, a trifling adjustment in many circumstances, get back an enormous payback. Doug Kelbaugh in Princeton, New Jersey, whom I visited a couple of weeks ago, has a house with a "Trombe" wall. It was expensive, comparatively speaking, as an initial investment; it cost him $9000, which means he had to pay up front when he built his house about $1800 more than he would have had to pay without it, and his additional mortgage bills every month come out to something on the order of about $60. Last year, during the coldest winter in a very long time in New Jersey, Doug Kelbaugh's energy bill for heating his house was $75 for the winter. That $75 plus the $60 per month for the increased mortgage is a much lower total bill than any other system will produce. In Arkansas, houses were built, at no additional cost whatsoever, that were well-insulated, had most of their windows on the south, had overhangs that protected the window from the summer sun, etc. They found that they could reduce their space conditioning energy demands by about 75% at no additional costs. You can go to a housing style that is architecturally so extreme that some people might not want it: Harold Hay's sky-therm house in Atascadero, California, cost him a bit under $5000 to build and meets 100% of his space conditioning requirements. If you go to those kinds of systems for the bulk of your energy, there is nothing that can compete with them at the margin, and hence that's what much of the discussion of renewable energy resources is focused on. But there are a variety of other resources we should be looking at, that vast chain of things that we were talking about at the beginning.

Wind power today is attractive. If you buy existing windmills from existing distributors, your total cost per installed kilowatt of capacity will, depending upon where you bought your windmill and who built it, range somewhere between maybe $450 and $900 per installed peak kilowatt. That is a pretty attractive energy source, especially when you consider that those wind distributors have not really moved into mass production yet, and that they are using windmill designs that have not profited very much from advances in aeronautical engineering over the course of the last 30-40 years.

Look at small scale hydro-power. This country has 49,000 dams that are 25 feet or higher, 800 of which produce electricity -- the other 48,000 do not. These dams are the smaller ones, and were built to serve agriculture, recreation purposes, or flood control; they have a potential installed capacity of about 54,000 megawatts. Different dams would cost different amounts of money to install some hydrocapacity in, depending on whether you are going to have to dig a channel around it, and have to do some construction as well as install the turbine. But such installation will probably range between about $400 to a maximum of perhaps $1,000 per installed kilowatt. That is power that is available whenever you want it.

Biological energy sources hold similar promise. I can go out today and buy ethanol for something like -- depending on where in the country I get it -- 60 to 90 cents per gallon. That is fairly competitive with the average price of gasoline and it is very competitive with the price of gasoline on the margin.

Photovotaic cells, on the other hand, are expensive. But they show promise of great cost reductions. They were developed for the space program, where cost was not a constraint. Parenthetically, I should note that

America's photovoltaic-powered satellites come down to earth now and then, and they do not cause global panic when they come down, as did the recent nuclear satellite the Russians lost over Canada.) Photovoltaic cells cost about $600,000 a peak kilowatt in the early 1950's. The cost began falling rather rapidly; by the end of the 1950's they were about $200,000 a peak kilowatt. Interestingly, a Ford Foundation panel issued a report last year that has been very influential in the Carter administration in dealing with nuclear power issues and alternatives. It was a very distinguished panel and several of its members have since accepted high positions in the Carter Administration. Harold Brown, now the Secretary of Defense, and Joseph Nye, who is now directing non-proliferation issues at the State Department were both members. The panel put together a report which mentioned photovoltaic cells as one alternative to nuclear power, but paid them scant attention saying they cost about $200,000 a peak kilowatt. This shows more clearly than anything else the sloppiness with which the scientific elite of the United States -- and it would be hard to find a more elite panel than that one -- has dealt with solar issues. That figure was 20 years out of date, and it was not a misprint; I had hoped that they really meant $20,000, because they would thus then have been at least within striking range. At the time that the panel was assembled, photovoltaic cells cost about $15,000; by the time the panel issued its report the cost was down around $12,000, and has now fallen, for flat plate collectors, down to somewhere on the order of about $11,000. For an order that was given for a community college in Arkansas, which is going to be using tracking-concentrating photovoltaic array, the contract cost was about $3000 per peak kilowatt. For different parts of the United States you would multiply that figure by 4 or 5 to get base load cost. Within the Department of Energy, the expectations are that the costs are going to be -- following a sort of business as usual approach -- something on the order of about $500 by about 1986 and $100-$300 by 1990. Those figures are, of course, based on learning curve studies and other paper studies about which one can have a degree of skepticism. But the experience of a semi-conductor industry with similar cost-reductions elsewhere leads to a degree of optimism that those price reductions can in fact be met. I have been talking in terms of converting from peak wattage to base load wattage because that is what is generally done when one talks about photovoltaics. I would like to qualify that by saying that I do not think that is what you ought to do. Society does not use electricity evenly 24 hours a day. There are proposed rate reforms around the United States to try and get us to even out our demand, because right now we meet our peak electrical demands (which just about everywhere in the country now occur on hot summer afternoons) with relatively expensive generating facilities and look to what are currently less expensive base load facilities -- large coal and nuclear plants -- for the other power. But naturally unconstrained electrical demand tends to coincide with when people enjoy being awake and working, which is when the sun is up, which is when photovoltaic cells can produce their energy. As a consequence I think one can make a reasonable case that if society were trying to choose a future (calling into mind once again the kinds of external effects that we were talking about several minutes ago), I think we'd find that the storage demands with the photovoltaic system might well be no more than, and conceivably less than, the storage requirements with a base load nuclear system. You can say that with the nuclear system you are going to have something else to meet your peaks; well then, you can say with the photovoltaics you can rely on something else to meet your valleys.

Before concluding, I would like to talk for just a couple of minutes on what one can do within the federal system. This is more to spark comments and questions than it is to provide a very comprehensive discussion. One constraint on solar energy development is clearly going to be scarce capital. Capital tends to flow into things that are proven and that have a clear market, so that not much of it has gone so far into the solar options. I think the federal government might want to enact something like a synfuels bill for solar; that is to say, if we can guarantee the capital that people are going to put into synthetic fuels, maybe we can guarantee the capital that people put into solar plants, including some of these $100 million-plus facilities that are discussed when people talk about really driving down the cost of solar cells.

Another approach, if one were to be really daring about it, might be actually use some of the federal money as capital in some ot these projects. Either the projects could be partly publicly owned, or the money could be used as a venture capital pool to be repaid to the federal government directly by the entrepreneur who borrowed it. For capital to come from the private sector (and before capital should come from the public sector) you have to have some kind of guaranteed market. I think the federal role in guaranteeing the market should be substantial. I think it need be no more than saying that the government will buy solar technologies for all purposes for which they make economic sense -- that is to say, a federal declaration that we will, for a change, spend the taxpayers' dollars intelligently. If you do that with photovoltaic cells you find immediately that they have a fair range of uses that would make a good deal of sense, particularly within the foreign aid budget. If we consider as an example the Import-Export Bank, funds can be used for financing photovoltaic arrays instead of for financing nuclear power plants. The guaranteed federal market for photovoltaic cells both for remote applications within the federal government and for foreign aid would be very substantial. As volume increases, costs should plummet.

Another problem is that people want to have some guarantees before they move into a new area, some warrantees. You do not want to buy something, have it break down after two years, and find, for example, that the manufacturer has declared bankruptcy and moved to an area where there is a lot of sunshine. One way around that potential problem that I think makes a good deal of sense has been proposed in California. It would make the state the warrantor of last resort. If you have the federal government as the warrantor of last resort, everyone could buy solar equipment and be assured that under the worst possible conditions they would still not lose their shirts.

The federal government is now trying to figure out something to do for farmers. One way to improve their lot is to reduce their production costs; one way to do that and to put them on a series of production costs that will remain fixed into the future, instead of fluctuating with the vagaries of the oil sheikdoms, would be to encourage the rapid development on farms of renewable energy resources. The American agricultural sector can turn to solar energy so fast it would make your head spin. They have crop residues, many of which could be converted without ecological problems into biological fuels. There is a lot a space around the farm that could be used to capture solar energy, that could be used as sources of electricity through photovoltaic cells, or to meet requirements for grain drying with very low grade heat. There is a wind technology throughout the midwest, which used to provide the bulk of the water that was needed; we can return to that method fairly inexpensively now that the marginal costs of electrical capacity are no longer going down each year as they did when we originally replaced those windmills.

Finally, an area where the federal government may not have a role but in which somebody has to play a role sometime fairly soon, is the problem of solar access in the metropolitan areas. Nobody is going to put a solar collector on their house if there is a reasonable chance that a fast-growing tree or a 12-story building is going to block out their sunlight. One thing that does make a solar collector absolutely valueless is having something between it and the sun. So you have to do something that is fair and equitable to the people who own the properties to the south, that nonetheless allows persons to the north to know before they make solar investments that those investments can have the anticipated lifetimes of solar access that are necessary to make them financially viable.

Obviously there are many other areas in which the federal government can play a role. I hope these comments will serve to stimulate thinking and provoke ideas among members of the audience.

DISCUSSION

Question:

Could you say a few words about what the implications of your remarks about decentralized energy sources -- solar in particular -- are with respect to the federal government's energy R&D program? I would also like to hear your comments on the priorities within the present R&D budget.

Answer(Mr. Hayes):

The Carter energy budget for solar this year -- if you add in the funds for biomass and combine R&D with demonstration projects -- would, I think, come to a total request of about $400.5 million. Last year, if you add the same set of figures together, the total was $410.7 million. Therefore, this year there has been an actual decline in solar energy funds, not even allowing for the effect of inflation. We can trace how that is broken down in terms of individual categories. It turns out that heating and cooling went down rather substantially, as DOE began to phase out the heating portion of the heating and cooling demonstration program; hence the overall decline in funds does not necessarily represent an overall decline in the relative status of solar in the federal budget. The increases in the total federal energy budget were very largely governed by the fact that the government is trying to build up an increased petroleum stock pile.

Having said all these qualifying things, however, I think it is an embarassingly small solar budget. I do not think that it is in accord with the kinds of signals on energy priorities that the President gave the nation during his campaign. Compare this solar budget with the vast amounts of money that have been invested, and are still being invested, in nuclear technology. The energy technology that one would think of as being of last resort in nuclear energy, in the wake of the Clinch River breeder reactor veto, would clearly be liquid metal fast breeder reactors. I think that the target amount for LMFBR's was about $400 million this year, roughly equal to everything that is given to all solar technologies combined, and there is roughly another couple hundred million going into alternative breeder technologies. That is a different set of budgetary priorities for energy R&D than I had expected from candidate Carter.

Within the solar budget, I suspect that we may be spending about the right amount of money on large centralized terrestrial solar options; I think that they will probably play some role in America's future. But that would be the right amount of money presuming that we were spending the right amount of money on all the other solar options. If we were indeed spending enough on other solar options, we would have a billion dollar program. If we hold the budget at $400 million, then I think we have a grossly disproportionate amount of money going into the solar electric options, and in particular into the large highly centralized solar electric options -- the power towers and the very large windmills. In terms of redirecting, my criteria are relatively simple. What we need to do is pay a little bit less attention to decisions governed by the very substantial engineering economies of scale that are attainable with expanded turbine sizes, and move instead into alternative economies. Probably the most exaggerated of the instances in which big would appear to have substantial advantages over small is windpower, because power increases geometrically not only with turbine size, but also with wind velocity. However, you may well find that by moving to a lot of small devices that can be turned out on assembly lines instead of larger ones which must be hand crafted on the site, you will be able to produce very expensive equipment which will not produce as much power as the larger equipment, but will produce power at a much higher percentage of the time. Smaller units can be used at a vastly greater number of sites, and hence the overall resource use could be very good for the country.

As an outsider looking in, it appears to me that the kind of thinking that goes into those sorts of decisions is the kind of thinking that makes, within some constraints, a good deal of sense with regard to nuclear power. There is within the Department of Energy a set of people who have been survivors: they were there during the Atomic Energy Commission, they were there in ERDA, and they are still there in DOE. They are the ones who are helping to set research priorities, and they are doing it, I suppose, in the solar division in a way that makes some intuitive sense. They are trying to find blocks of energy that can be substituted for nuclear power. But I think that solar technology demands something more than simple substitution of sunlight for uranium. We have to start thinking of things in a different perceptual framework. I hope that either those people will begin showing some increased flexibility in the way that they are viewing this issue, or else that perhaps some new people will come in and begin steering us in a different direction.

Question:

The solutions that you mentioned at the end of your talk are policy changes. You would like to see a different approach to venture capital, guaranteed markets of different types, different farmer programs, solar access legislation, etc., as means for solving the energy problem. It seems that one reason, the major reason in my view, that we have an energy problem is that the institutions that we have created and that exist right now are set up to supply energy to an older America -- a 1940's America or 1950's America. In order to solve 1970's and 1980's America's energy problem the institutions are going to have to change; to some extent guarantees, different consumer incentives and other mechanisms are only playing with the symptoms of the problem. In other words, to really solve the energy problem you have to develop new institutions that will intrinsically solve the problem by themselves. One issue that you talked about is decentralized energy sources, but we do not have decentralized institutions. What role do you see for policy makers, and people who influence policy, to focus more on the institutions rather than on the symptoms? I do not see much of that happening. Is that a mistake in your view?

Answer:

It is a serious question as to whether you go for the technology first or the institutions that can embrace it, or whether you figure out ways to do it simultaneously. My remarks were premised on the topic of what the federal government should be doing. In terms of building the sorts of institutions you are talking about, I am not sure that the federal role is going to be greater than perhaps making funding available. To the extent that alternative institution building takes place, I suppose that it is due to people's frustration with what they see as the federal government doing the wrong things. Recent polls have shown an incredible and in some senses a very frightening falling away of confidence in the federal government, and even to some extent the perceived legitimacy of the federal government. Alternative institution building seems to be going up from the grassroots, as it necessarily must if you are talking about building neighborhood organizations, or if you are talking about towns that are trying to pull together to do something. But what the federal role should be probably requires a person with a different kind of background and knowledge than I have.

Question:

I have the impression that you believe that small is beautiful and that big is bad. And yet I think I hear you saying that because the federal government is heavily involved in research in such areas as nuclear power, that becomes a justification for federal involvement in solar research. It occurs to me that one of the advantages for solar research is that the research on individual units, which can be quite small if you have decentralization, can be conducted in private laboratories. Firms like AT&T, Lockheed, North American Rockwell, Dow Corning, are available and can do solar research. I'm surprised that you advocate that there be a larger solar research budget. Why not turn around and advocate a smaller research budget for other technologies? Then you would have a smaller government, and you would give solar energy the equitable competitive situation that I think you are seeking. Have you ever given any thought to that approach?

Answer:

As it turns out, I actually have given it some thought, although I do not know that I have come to any profound conclusions. I have a basic Adam Smithian belief in the capacity of a market to sort things out. However, there is some difficulty in getting a new technology running and up to speed. Since World War II solar researchers have received a little less than one five-hundredth of the federal research dollar whereas nuclear energy has received more than 50%. I would hope that there could be some kind of balance. Clearly you cannot put $20 billion a year into solar energy research for three years, but you could do something that would get it up to speed rapidly. Once that kind of counterbalancing has been done, however, I would be delighted to see the federal government get out of the R&D area. The kind of solar energy that I, in fact, do regard most highly, gives fantastic scope not only to the major firms that are involved in it, but also to backyard tinkerers and small firms. An individual or small firm may have a good idea or develop a technology that is particularly appropriate to their relatively narrow specific area, but which is unlikely to be meshed effectively into the marketing plans of a large firm whose marketing decisions are all necessarily national, or at least broadly regional. If one could come to an equitable balancing beforehand, I would be enthusiastic about less government involvement in energy R&D.

Question:

There are a few of us on Capitol Hill, at least, who believe that neither the Congress or the executive branch will come to any conclusion about solar energy or to any directions that you have been advocating because there has been no consensus among the people in this country on directions on energy. As a result, we are going to have a mishmash policy for many years to come. I would like your comments.

Answer:

The best polls that I have seen indicate that between 75% and 85% of the people in America would like to link our energy future to solar resources. I think there is a general public receptivity to solar energy, but the public views those energy decisions as basically decisions that should be made by other people on their behalf, rather than as personal decisions. You do not buy an automobile and then make a personal decision to run it on sunlight, you buy what is available. Recently a rather wealthy woman told me that she would like for symbolic reasons to power the active system in her new solar house with electricity from photovoltaic cells. She asked me where she could buy them, and I suggested three or four companies that I thought were marketing them. She has written to all of them and been declined by all of them. Even if she wants to make an uneconomical decision today, there is nobody making those cells available, at least in the quantities that she is willing to buy. I think that there is a broad public receptivity to the solar option, and people would like to have the opportunity to choose solar the next time the make a major purchase.

Question:

I have been working on a project in which we have been talking to solar consumers, manufacturers and the rest of the people in the technology delivery system in order to build the commercial incentive for solar heating and cooling. However, one of the things that the solar manufacturers said is that "the government is killing us by saying that solar is going to be useful in the year 2000. We are trying to sell a product now. Will you stop telling people that it will be useful in 25 years?" Now, how do you reconcile that with the prophets who are going around saying it is not worth anything now? Are we in a situation today where solar is reasonably competitive over a long haul and that it would be worthwhile to begin to invest now?

Answer:

It obviously varies from technology to technology. Some things make sense today; some thing do not make sense today; and some things may make sense today, but we do not know because it will depend upon how long they last and we do not know how long they are going to last. For example, we are making decisions right now about building thousand megawatt nuclear plants, even though we are not sure that these thousand megawatt nuclear plants have life expectancies of 30 years. None of them thus far has lasted 10 years. Until at least some of them have lasted 30 years, we will

will not know.

With solar technologies there are a variety of factors. Photovoltaic lifetimes are going to be largely dependent upon the techniques for encapsulation that one uses with photovoltaic cells. I think we can come up with a way of encasing calls in a material that will be resistant to sunlight and the elements over a very long peiod of time. The cell itself is going to be useful for as long as the encapsulation remains intact. It could, in theory, operate forever -- and will, in fact, if you put it up in space. Another of the things we do not know is what we are going to do in terms of storage. The degree to which you go solar for any particular application depends upon how inexpensively you can have substantial amounts of storage. Far more research should be done on storage technologies. For example, the private sector came up with what could be an important new finding in January of this year. General Electric announced that it had finally solved the principal problem that had been plaguing eutectic salts as a thermal storage mechanism. In the past, eutectic salts tended to cake on the inside of the container, stopping heat transfer in and out by providing basically a layer of insulation on the inside. General Electric found out that by putting the salts inside a cask and rotating that cask gently at about three revolutions per minute, caking did not take place. It was a very simple discovery, that nobody else had come up with in the course of 20 years.

I think it is clear to say that a lot of solar technologies today do make sense and I have faith that a lot more are going to make economic and technological sense shortly.

<u>Question:</u>

You said some very pejorative things about other technologies and fuels in the course of pressing your suit with solar, but you have not indicated to us if all these impediments to fulfillment of solar were removed, what part of the total energy mix of the nation, of the world, could solar provide?

Answer:

Eventually, I think, solar resources are going to be providing us with 100% of the global energy budget. You can make various decisions today that hasten that eventuality and make some that will not. Amory Lovins has come up with a very important concept that is too little used in energy planning. He suggests that once you have chosen where it is you want to go, you choose the year that you want to be there. You then start moving your projection backwards. If you say you want to be solar by 2025, what does that mean you have to have on line by 2010? Basically, how do you design a timetable? Nationally that is going to be very difficult; globally, for most sets of institutions, it would be impossible because of the different kinds of cultures and the different kinds of technical and resource potentials in different parts of the globe. But it is something that I think has to be done and I would think that is one more area of research in which the federal government could very well play a role.

I said some pejorative things about other technologies and I gave what I thought were a defensible set of reasons why I do not think those alternatives can play the kind of global role that is often postulated for them. If I am right, then I think it makes a good deal of sense to accelerate the solar transition very dramatically. If we did that, then it would be my judgment that the country could be largely dependent upon solar resources sometime around the year 2025. If we decided to make the solar transition the financial equivalent of war in addition to being the moral equivalent of war, we could come up with a series of realistic targets that could get us from here to there. At least then we would be able to apply at least some standards of judgment -- we would have some benchmarks, and we could say "if we fail to meet the target, we are behind schedule."

Question:

Of course we have no example in history of this kind of technological planning except in controlled economies where they have often taken wrong turnings like starting having a passion for coal at a time when you would have been better advised to have one for oil and gas. One of these recurring features of Western Europe in the past 25 years has been politicians and people of the intellectual bent falling in love with technologies and not allowing them to have a natural evolution so you have the Concorde and the Hovercraft and a whole series of prototype short-take-off aeroplanes and many other wonderful things such as the ground nuts scheme in central Africa that was going to feed everyone all over the globe with protein. If you started in 2020 and worked back, is there not a great danger that you would lose the dynamic of flexibility and choice that you were advocating earlier this evening?

Answer:

If, in order to get through the solar transition it means we have to move to an authoritarian society that could destroy the pluralism that that in the past has been part of the American society, then obviously it is a choice that I would not be willing to make. I mean, small is beautiful but small fascism is not beautiful. What I am saying is that if your publication, the Energy Daily can come out very strongly in favor of governmental subsidies to synfuels and to the nuclear program, very strongly behind the Clinch River breeder and very strongly behind massive federal efforts in areas of questionable desirability to people whose values I share, it is not unreasonable to support a similar kind of program with regard to the other technologies. One way to measure the appropriateness of that program and the effectiveness of it is to set a series of benchmarks and say are you progressing at a reasonable rate.

Question:

I am concerned mainly with energy in a form that can be used by people in their cars. I would be very interested in your conception of how solar energy can provide the energy requirement for mobile users of energy -- transportation, cars, trains, planes -- where you cannot plug into a solar panel.

Answer:

It is pretty clear that you are not going to fly any jets directly on sunlight. You are going to have to come up with some mechanism to store the sunlight that strikes a large area and then convert it into a form that can be stored and transported easily, if you are going to continue to have jets. However, I suspect that our transportation system is going to undergo some fairly major alterations. The current transportation system was a creature of the petroleum era -- it did not look at all like that before the petroleum era and it is probably not going to look at all like it does now after the petroleum era. For example, I think that in the future it is possible that we will be doing something other than flying jets between Washington and New York, and we will be doing something other than flying Concordes for any kind of purpose.

The greatest consumer use of petroleum in the United States today is personal transportation by individuals. Hazel Henderson once suggested that the amount of transportation in a given society may be the best single index of the degree of dysfunctional organization in that society.

That is to say, if you build a society that is fairly intelligent, you do not have to travel as much as if you build one pretty haphazardly. I think it is safe to say that you can come up with communities that have a bit of forethought, that are designed in ways so that you do not have to have long trips for each person between her home and her office, a different trip from her home to her recreational area, a different trip from her home to where she buys her food, a different trip for practically any purpose. As energy costs go up, and as the particular fuels that are appropriate to our current transportation system become less available, I suspect that such reorganization is in fact going to take place, just as the concentric ring pattern of cities took place spontaneously in the past as we moved into an automobile culture. There is going to be an increase in the substitution of communication for transportation as well. I think that some of the research that is being done now on improved modes of communication may well be some of the most important energy-conserving research that is being done in America today. Nonetheless, people are going to want to travel and for a lot of purposes it is going to be most convenient for them to use individual vehicles. It would be at least as easy to tap into solar resources as it is to tap into nuclear resources for electric vehicles. You can come up with different benchmarks for the amount of liquid fuel that you derive, in a sustainable fashion, from the solar resource base. If you subordinated every other national interest -- from home building to paper making and getting food to growing energy, you could produce large volumes of liquid fuels from biomass. If population levels off in the U.S., as it seems to be doing, and if we move to fuel-efficient vehicles, we can design a personal transportation system that would be able to do quite well on energy available from solar resources.

Question:

There seems to be a popular presumption that the choice that faces us is between having more oil, gas, and electricity on one side, and altering life styles on the other. Could you talk about that a bit?

Answer:

If you do not want to alter life styles, you should put your funds into conservation. You can go a long distance without changing anything except the efficiency with which you are doing things. You can do it economically for a while, but then you start paying more for it because you are willing to pay a premium not to alter your life style. On the other hand, I think a fairly compelling case can be made that we have not yet arrived at Nirvana in the American society and that in fact there may be ways to enhance our life styles. If you change to alcohol fuel, you have a very high octane fuel which does not need lead in it. Levels of lead found in young children are now at the point where people in the public health agencies are worried about them; the only explanation they seem to come up with is that it somehow comes from the automobiles. The alcohol fuels you would be burning produce a much less noxious set of byproducts.

In the next few hundred years, our largest metropolitan areas may evolve out of sight just as they evolved into sight. With a fundamental change in energy source, society begins to undergo the kinds of major changes that one cannot extrapolate from past experience. We know technically how to do everything today that we need to do to power the American society on renewable energy resources. There is nothing that we do not know how to do. It may be too expensive, it may not have benefitted from research advances, and many of its elements have not benefitted from economies of mass production. We know technically, though, that we can do it. We do not yet know what it will mean for the shape of American society and for the nature of our life styles.

Question:

I would like you to gaze into a slightly different crystal ball for a minute in your role as an interest group organizer. It appears that your constituencies are becoming very, very frustrated with big government's inability to deal with the energy problem. This growing frustration in my mind is much like the growing frustration of people with the government's inability to deal with Viet Nam. I think few people realize that since 1969, almost a decade, we have had zero energy growth invested in production in this country. Our entire energy growth has come out of imports. With the exception of the Alaskan Pipeline there have not been many big federal steps forward in bringing forth new domestic energy supplies. Do you see that decade long trend holding? And if so, where is this frustration on the part of your constituency going to lead us?

Answer:

I think that that is a profoundly important question and the dimensions of it are ones that you have to worry about if you have the audacity to try to get into organizing things and if you have a degree of conscientiousness. It is part of a much broader issue, which is basically the issue of "growth" in the American society and the American economy.

In the energy realm I suspect that we are going to have our decisions forced upon us, and we as a society are going to have to accommodate ourselves to them. We do not have a choice as to whether or not we are to make a transition out of the petroleum era. We are going to make the transition -- either we are going to plan for it and do it smoothly, or else we are not going to plan for it and we are going to continue to increase oil imports and we are going to find ourselves really up the creek without a paddle. But we are going to make the transition one way or the other. As a public organizer, I think everyone has a responsibility to make sure that the coalitions that are going to be pushing for policies that bring that transition into focus are broad coalitions. They need to involve organized labor, and poor people and farmers and they must be sure that they follow through every step of the reasoning to determine the implications of their choices.

Question:

I think that in talking about development, and certainly the aspirations of a range of people around the world, not only our society, we clearly need to be thinking about growth. These people are not going to live with an aspiration of merely the status quo. I wonder why you characterized the inevitable aspects of transition as automatically translating into a growth versus no-growth issue?

Answer:

I was talking about the United States. One of the reasons that I think that we are going to find ourselves forced into that transition has nothing to do with energy, but with a series of realities that are going to assert themselves because of the growth imperative in other parts of the world. One of the good things about societies and their economic systems is their capacity to grow in a closed cycle system. Once you a resource out of the ground, you can use and and reuse it. You do it with your sewage, your glass and newspapers, your water, all metals... You can recycle everything except energy. You do it by taking a lot of cycles that are long-term cycles and shortening them a little. Growth then becomes a function of how rapidly that cycles goes around, rather than of the size of the flow. That kind of growth becomes much more do-able with an ample energy supply that it is without one. One of the good things about solar energy is that it gives the world a much larger potential capacity to tap into energy resources than does any competing technology. The overwhelming preponderance of all of the energy that we are ever going to have the potential to use is energy that we are getting from the sun. If we can figure out ways to harness that, then we have got a lot more prospective potential for a well-developed energy system and for overall well-being.

Question:

You speak of a total solar economy as a goal, and speak about it as if one must move inevitably and inexorably in that direction. But you do not really consider the mixed case in which we would move in a more gradual transition to a major reliance on solar but still retain the flexibilities of the mixed energy production system. In this way we would not undergo the very sharp dysfunctions in the system of energy institutions and the system of financial institutions that has evolved over the country in the last 200 years. Do you not think that, even though your goals are very dramatic goals, a more realistic target to a pragmatist might be this type of mixed energy economy that evolves toward solar?

Answer:

I suspect that you arrive at a pragmatic target such as you discuss by having each of the individual energy sources with relatively strong proponents pushing us as aggressively as they can with their sources. That is really the political marketplace operating at its best, if in fact the ideal curve is your pragmatic mix. I am not doing that. I am not outflanking people in the hopes of saying something outrageous so that

that gives the people who are middle of the road types a better chance of getting what they want than if we are not out there flanking them.

I have discussed what I consider to be intractable reasons why a nuclear powered world or a coal powered world are not sustainable. It was a simplistic model, but it does yield certain useful insights. If one moves away from that model and talks pragmatically about different kinds of energy levels in the United States, one still runs into serious problems with other energy sources. I believe that we would be well advised to have in mind a way to get from here to there that is largely solar in terms of its incremental growth. What bothers me most at the moment is that that kind of planning does not seem to be taking place, even on a contingency basis. It seems plausible to me, for a variety of political reasons, that a nuclear moratorium is a genuine possibility in this country. If, in fact, the CO_2 problem is as unavoidable and dire as it appears to be, with continued fossil fuel combustion and if the growth in many other parts of the world is going to be as dependent upon fossil fuels as it shows some signs of being, a vast reduction in American coal use may become sort of an imperative, because of our global reponsibilities. If we find ourselves in a position in which solar energy is the only viable alternative, I hope we are able to use it.

Question:

Where does the potential for nuclear fusion fit into this picture you have drawn?

Answer:

The first generation of fusion reactors will use relatively easy fusion, "easy" compared with more difficult types of fusion. Deuterium-tritium fusion requires a substantially lower ignition temperature than does deuterium-deuterium or hydrogen-boron or the other cleaner fusion cycles. One of the things that happens in a deuterium-tritium reaction, which is what everybody is now pushing for, is that you create a high neutron flux. Among other things, this will bombard the inner walls of the reactor, structurally weakening them so that you have to replace them every year or two and leading to a substantial amount of radioactive waste. I have seen estimates as high as 250 tons of radioactive waste a year for a large D-T fusion reactor. That has to be disposed of somehow. The more difficult problem, I think, in the short-run with deuterium-tritium fusion, (presuming that it can in fact work and be commercialized and be economical, and that the technology is something that in fact enough people can be trained in rapidly enough to build) is that with that high neutron flux one of the things you can do with it is breed uranium 238 into plutonium 239. You can use the fusion reactor as a substitute for a breeder reactor. In fact I am told that the first generation of Soviet reactors are going to be designed to optimize plutonium production rather than to optimize power production.

While I support the development of clean, advanced fusion cycles, I suspect that it is going to be a very long time before they are ready to make a substantial contribution to the American energy budget and I suspect it will make a contribution here far earlier than it will in most parts of the world.

Question:

You have such a great faith in technology for solar and yet you lack such a faith in the development of technology to overcome the hurdles of nuclear. The sun has been around since the creation of the earth, and we have only worked with what makes the sun what it is since World War I or World War II. Why don't you put a little more faith in our technologists?

Answer:

I have a good deal of faith that technology can solve a number of problems. There are some problems in nuclear power that I personally do not see as amenable to solution, especially with wide-scale development. I think that it is probably technically possible, if we decide that we are going to do it, to operate some number in the United States within acceptable margins of safety for some substantial period of time. But doing this would require a technology that is so expensive that it would not be able to compete at the margin with other technologies. We have probably already invested, in current dollars, in excess of $100 billion in nuclear technology. I do not think that we have a lot to show for it, despite the fact that we have had many of the best minds in America working on the problem for decades. What I would like to see is a sufficient commitment to renewable energy resources to entice all of those bright young minds that a few years ago, were still choosing high energy physics as their field because that was where the intellectual excitement was, and that was where the money was. I hope we can create a climate in America in which some of those bright young minds will apply themselves to some technologies that do not even require much money.

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