Solar Energy: Where Are We Heading?

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Predictions that the age of solar energy is imminent have tantalized the public for many years with the visions of cheap energy and independence from energy suppliers. Most recently, in April, 1978, the Council on Environmental Quality (CEQ) released a report that stated ". . . solar technology could meet a quarter of our energy needs by the year 2000." If one considers that the annual energy economy will probably be in the neighborhood of 100 quads[1] by that time, such a prediction implies the substitution of solar energy for the equivalent of 12.5 million barrels of oil a day! On what basis can such a prediction be made? How could so much energy be supplied from a source that is presently a minor contributor? If not the equivalent of 12.5 million barrels a day, what is a reasonable estimate of the contribution solar energy can make?

In order to address these questions, we must understand the types of energy systems presently included under the rubric of solar energy, or perhaps more correctly, renewable energy sources, and get a feel for where we stand in their development. And then, we must make some judgments on the potential of realizing the penetration of solar technologies into a large and complex energy marketplace not well attuned to accepting new technologies.

First, what technologies are we talking about when we say solar energy can make a major impact by the year 2000? Depending upon when you asked the question, you would find that the list has represented a moving target. The most popular concept, of course, is use of the sun as a thermal source to provide relatively low grade heat for space conditioning of buildings. This can be done, in a passive way, through such means as the proper orientation of windows and walls or by active systems that heat a working fluid that in turn transfers the sun's heat to the area where it is needed. Without too much effort, the energy arriving at the earth's surface can also be concentrated and very high temperatures, 1000 °F. or more, can be realized. Such high quality heat can be utilized for a variety of applications, from making steam to drive conventional steam turbine generators

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1. One quad is the equivalent of the energy contained in 180 million barrels of oil.

to industrial applications such as cement drying. Many agricultural applications are also possible using either the low grade or high quality heat.

Another way to use the sun's energy is through photovoltaic conversion, more commonly known as solar cells. This application takes advantage of the principle that photons striking semiconductor materials will free electrons that can be made to flow as an electric current. Silicon, one of the most abundant elements on earth, exhibits this property and is the key material used in solar cells that have provided power for many spacecraft. Solar cells can be used to provide electric power to homes, businesses, and other users by placing collectors on roofs or other convenient areas.

In addition to these direct methods of using solar energy, there are numerous indirect methods. The CEQ report included hydroelectric power as a solar contributor since it is the action of the sun on the earth's surface and atmosphere that creates rain that in turn is impounded behind dams. Hydroelectric power presently contributes almost 2.5 quads of energy, or about 3% of our total energy requirements. Most of this power is provided by high dams and large systems, but there appears to be a great potential for the use of small, low-head plants in the not too distant future. Wood, or plant materials, indirectly store the sun's energy and a variety of uses can be made of the handy molecules that the plants synthesize. Almost 2 quads of energy are supplied from plant (or biomass) material, primarily in the paper and pulp industries. Taken together, these last two forms of solar energy today provide over 5% of our energy needs.

Heating of the atmosphere by the sun also creates the force that drives the wind. Windmills, or wind turbines, are an ancient way to harness the sun's energy. Once common in rural America, modern wind turbines, both large (hundreds of kilowatts) and small (tens of kilowatts), hold the promise of providing significant amounts of energy in many parts of the country.

Another concept of using the sun's power is called Ocean Thermal Energy Conversion (OTEC). This concept takes advantage of the heat retained at the surface of tropical or near tropical oceans and the cooler water found at depth to power a conventional heat engine. Although the temperature difference between these two layers of water is not large, typically 30 ° - 40 °F., and therefore the Carnot efficiency is very low, there is sufficient heat to vaporize a working fluid, such as ammonia, and drive a turbogenerator. It is also possible to flash the hot water to steam in a low vacuum. This latter technique was used in the late 1920's to develop power in Cuba. Other concepts such as satellite power systems and those that generate power from waves and currents are also feasible and are being studied both in this country and abroad.

This then is the stable of solar energy sources. It is diverse; it can provide all the types of fuels presently in use (gaseous, liquid, solid); and it is ubiquitous. Many parts of the country can aspire to using several different forms of solar energy as we attempt to cope with our energy problems. Of all the major industrial nations, we are blessed with the greatest opportunity to use the sun because of our geographical location and climatic conditions. The important consideration in looking ahead and predicting which of the solar technologies will become realities is that we know they will all work. Scientific or technological breakthroughs are not required. Some, as we have just seen, are already making important contributions.

All solar technologies, however, will benefit from engineering, manufacturing, and materials improvements since essentially all find it difficult to compete against conventional fuels. There are a number of reasons why this is so, but the primary reason is dictated by the energy source itself. The radiant energy arriving from the sun is so diffuse that large collectors, regardless of the conversion process used, must be deployed to collect or intercept the incoming energy.[2] This, in turn, translates into capital intensive investments that can only be justified, at this time, on a life cycle costing basis. Even on such a basis, most solar technologies, such as solar cells, cannot compete today except in very specialized applications.

The challenge in attempting to further widespread use of solar energy is to bring about cost reduction, accompanied by reliability and all the other considerations that must be met to produce acceptable energy technologies. Cost reduction has been the focus of private and federal research and development over the past years.

Where do we stand in the development of solar technologies? A short history of the federal program would be useful in order to understand how we have arrived at our present position, since, to date, the majority of development work has been funded by the federal government.

In 1952, the President's Materials Policy Commission predicted that the nation's energy demand would double over the next quarter century.[3] The Commission's analysis concluded that although conventional sources such as coal, oil, gas, and hydropower could fill this demand, intense competition could be expected for these finite energy sources from both the developed and developing countries.[4] The Commission also stated that two new energy sources, atomic and solar energy, stood on the horizon as tremendous possibilities.[5] As a result of their analysis, the Commission recommended that the most important step the government could take at that time was to develop a comprehensive energy policy and bring all the energy programs under a single roof.[6] Although such a comprehensive policy was not forthcoming and no federal programs of any magnitude developed for solar energy as a result of the Commission's recommendations, the National Science Foundation (NSF) provided a small amount of funds over

2. Consider for a moment that, to collect the BTU (British Thermal Unit) equivalent of one barrel of oil per day, 12,000 square feet of solar collectors must be in place. At today's prices, such a collector field would cost between $120,000 to $250,000.

3. THE PRESIDENT'S MATERIALS POLICY COMMISSION, RESOURCES FOR FREEDOM (June 1952).

4. *Id.* at 122.

5. *Id.* at 37.

6. *Id.* at 130.

the next two decades to carry out research programs.

By the early 1970's, the energy problem so clearly forecast by the 1952 Commission and others became a reality, and sooner than predicted. On June 4, 1971, the President issued an energy message calling for a program to ensure that adequate supplies of "clean" energy would be provided in the years ahead. Under the direction of the Office of Science and Technology (OST), panels were formed to study the complete spectrum of energy sources, including controlled fusion and solar energy. The objective of the panels was to recommend research and development goals for all the energy technologies.

For reasons that remain somewhat obscure, the only panel report that was published dealt with solar energy.[7] The OST panel recommended a fifteen-year program be undertaken that would cost in excess of $3.5 billion, including funds to be spent by the federal government and private sources.[8] If such a program were to be carried out, it was predicted that solar energy could provide seven percent of the nation's energy by the year 2000.[9] Working with the solar panel, the Research Applications Directorate (RANN) at NSF developed and sent to the Office of Management and Budget (OMB), in October, 1972, the first comprehensive Terrestrial Solar Energy Program.[10] It preceded by two months the formal OST panel report and, although reduced in scope from the program called for by the panel, outlined a research, development and demonstration (RD&D) program that would cost $196 million from fiscal 1974 through fiscal 1978.[11] Compared to ongoing R&D programs for other technologies, the admittedly modest NSF plan called for a tripling of expenditures to more than $12 million in fiscal 1974 and projected growth to $56 million in the last year of the plan. It is clear from the funding pattern that it was the intent of RANN that this was to represent just the beginning effort in a major program to develop the many potential uses of solar energy.

In 1973, prior to the oil embargo, this proposed program went essentially unnoticed. The many solar lobbies that today are making themselves heard throughout the country did not exist, for the most part. Somewhat surprisingly, OMB accepted the proposed program and steps were begun to implement it.

Following the release of the OST report, and when it became known that an expanded program of solar development was forthcoming, interest blossomed in the research community. Unsolicited proposals began to pour into RANN. It became very clear that new ideas abounded and the chance

7. NATIONAL SCIENCE FOUNDATION/NATIONAL AERONAUTICS AND SPACE ADMINISTRATION SOLAR ENERGY PANEL, SOLAR ENERGY AS A NATIONAL ENERGY RESOURCE (Dec. 1972).

8. *Id.* at 11 (table 4).

9. *Id.* at 10 (table 4)(estimate of seven percent did not include hydro-electric power).

10. RESEARCH APPLICATIONS DIRECTORATE, NATIONAL SCIENCE FOUNDATION, NSF TERRITORIAL SOLAR ENERGY PROGRAM (Oct. 20, 1972).

11. *Id.* at VI.

to advance solar technologies based on new developments in many fields was real. In June, 1973, building upon this new awareness, RANN reexamined the October plan and submitted an expanded program. The new program called for the expenditure of $1 billion over the five years ending in fiscal 1978. This time, not surprisingly, support from the Administration was not forthcoming.

Less than one week after the expanded program was submitted to OMB, the President announced that he was initiating a $10 billion program for research and development in the energy field to extend over the next five years. The Chairman of the Atomic Energy Commission (AEC) was directed to implement this program and sixteen sub-panels began work in the fall of 1973 to develop the necessary background. The Solar Panel, Sub-Panel IX, chaired by the NSF, recommended two alternative programs, one designated the "Minimum Viable Program" and the other an "Accelerated Program."[12] Both programs started in fiscal 1975 with the minimum program requesting $50 million in the first year and totalling almost $500 million over five years.[13] The Accelerated Program started at $100 million and spent over $1 billion by fiscal 1979.[14] Unfortunately, the recommendation sent to the President in December, 1973, over the AEC Chairman's signature endorsed neither program, but included one for solar energy of only $200 million.[15] The majority of the $10 billion was designated for the various nuclear technologies. When put into its proper fiscal context, this recommendation represented a solar program smaller than that earlier approved by OMB.

By this time, support for solar energy was mounting in Congress and release of the report marked the beginning of the confrontation between Congress and the Administration over priorities for energy R&D dollars. At one point early in the debate, the Administration was accused of suppressing the Sub-Panel IX Report. And to heap BTUs on the fire, the Chairman of the AEC was quoted as saying that solar energy could be thought of as the fleas on the back of the nuclear elephant when comparing the contributions that the two energy sources could make. Needless to say, such actions led many to believe that it would be extremely difficult for nonconventional energy sources to get an honest share of the R&D pie.

Over the ensuing months the debate grew in force. The oil embargo brought home our vulnerability to interruptions in our fuel supplies and demonstrated, in a graphic manner, our dependence on energy for every activity in our daily lives. In a few months of shortage, the GNP dropped almost $20 billion, and 500,000 workers became unemployed. Pictures of small children sitting in classrooms with hats pulled over their ears were

12. *Id.* at 3.
13. *Id.* at 4 (figure 1).
14. *Id.*
15. ATOMIC ENERGY COMMISSION, A REPORT TO RICHARD M. NIXON, PRESIDENT OF THE UNITED STATES: THE NATION'S ENERGY FUTURE (Dec. 1973).

seen in every newspaper. Stories about people coping or not coping with the energy crisis became commonplace and the clamor for government action intensified.

While the report, *The Nation's Energy Future*, was being assembled in final form, the President announced, in November, 1973, a new energy program called Project Independence.[16] The stated goal of Project Independence was to meet the nation's energy needs by the end of the decade (1980) without depending on foreign energy sources.[17] With the intervening oil embargo, development of this program, under the direction of the newly formed Federal Energy Administration (FEA), did not begin until the spring of 1974. Almost all agencies of the Executive Branch participated in the task forces set up to define the enormous job to be done. Toiling through the summer, the task forces, including one for solar energy, finally reported to the President in November, 1974.[18] Although unstated, it became clear that energy independence by 1983 was a hope gone aglimmering. Once again, however, the Project Independence Solar Task Force recommended an aggressive RD&D program and detailed the job that needed to be done.[19] Based on this recommendation, NSF submitted to Congress, in December, 1974, a five year program plan requiring over $1 billion to implement.[20] The plan was not endorsed by the Administration.

In the meantime, and almost in spite of all this relatively nonproductive activity, solar energy was making solid gains. Early in 1974, the NSF was designated the lead agency for solar energy development. The necessity of designating a lead agency was evidence of the intense pushing and tugging in the federal bureaucracy over who would play the major role in what was sure to be a growing federal involvement in developing new energy technologies. By the spring of 1974, the first large scale solar installations were up and operating at four schools in the midwest and east. A windmill program had been initiated with NASA and the world's largest windmill was being designed. The fiscal 1974 budget was almost $15 million and the 1975 budget was coming in at $50 million. Work was quickening in all areas. The small but growing band of solar advocates was finally being recognized.

Toward the end of the Ninety-Third Congress, two important bills were passed that showed the increasing desire of Congress to push solar energy.[21] Both these bills clearly detailed the intent of Congress to speed up the

16. Address to the Nation About Policies To Deal With the Energy Shortages, 323 PUB. PAPERS 916 (Nov. 7, 1973).

17. *Id.* at 920.

18. FEDERAL ENERGY ADMINISTRATION, PROJECT INDEPENDENCE (Nov. 1974).

19. NATIONAL SCIENCE FOUNDATION, PROJECT INDEPENDENCE BLUEPRINT: FINAL TASK FORCE REPORT, SOLAR ENERGY (Nov. 1974).

20. NATIONAL SCIENCE FOUNDATION, NATIONAL SOLAR ENERGY PROGRAM (Dec. 4, 1974).

21. Solar Heating and Cooling Demonstration Act of 1974, Pub. L. No. 93-409, 88 Stat. 1069 (codified in 42 U.S.C.A. §§5501-5517); Solar Energy Research, Development, and Demonstration Act of 1974, Pub. L. No. 93-473, 88 Stat. 1431 (codified in 42 U.S.C.A. §§5551-5566).

development of all solar technologies,[22] and in a somewhat unusual action, attempted to mandate a schedule for the significant accomplishments expected.[23] Finally, in the waning days of the Ninety-Third Congress, a twenty-two years after it was first recommended, Congress established a single agency to conduct a comprehensive energy research, development, and demonstration program aimed at practical applications.[24] This was the Energy Research and Development Administration (ERDA) born to live out a short, eventful and controversial life.

ERDA inherited, in January, 1975, energy programs from AEC, NSF, the Department of Interior, and several other agencies. The fiscal 1976 budgets were already locked up and on their way to Congress; thus, the new agency was forced to start business with its programs, in large measure, predetermined for the next eighteen months. Since the AEC was, by far, the dominant partner in this amalgamation, the history of ERDA shows the disproportionate emphasis on nuclear energy that existed until it was finally absorbed into the Department of Energy (DOE).[25]

But all was not black for solar and other nonconventional energy technologies in the new agency. The budget was growing, and as is usually the case in federal agencies, those directly involved in the programs became advocates to increase the size of their programs. ERDA presented a unique opportunity for advocates to push goals for energy technologies. Since ERDA now included the old AEC, budget data made available to Congress was based on procedures initiated in 1958 for the AEC. In that year, Congressman Holifield of California requested that the AEC provide Congress with a comparison of the budget request sent to OMB and that proposed to Congress.[26] Based on this request, the so-called Holifield tables became a matter of record in all ensuing years, thus allowing Congress to question, in great detail, discrepancies between the two submissions. These tables included not only the final agency request to OMB, but original division requests from which the agency made its choices. Armed with this information, Congress was able to selectively increase programs with a reasonable assurance that the funds could be spent productively. And this is precisely what Congress did in the two and one half years of ERDA's existence, in some cases going beyond even the expectations of the program divisions.

This process led to a natural conflict between ERDA and OMB, and continues with DOE. In years of tight budgets, it has been, and will continue to be, difficult for the Executive Branch to present a monolithic

22. 42 U.S.C.A. §5501(a)(1977); 42 U.S.C.A. §5551(a)(1977).

23. 42 U.S.C.A. §5501(b)(1977).

24. Energy Reorganization Act of 1974, Pub. L. No. 93-438, 88 Stat. 1233 (codified in 42 U.S.C.A. §§5811-5814).

25. Department of Energy Organization Act of 1977, Pub. L. No. 95-91, 91 Stat. 565 (codified in 42 U.S.C.A. §7101).

26. Letter from the Honorable Chet Holifield to Chairman, Atomic Energy Commission (May 2, 1958).

energy face during the annual budget showdown. The existence of the Holifield tables has in recent years exacerbated the normal budget debates that go on between the Executive and Legislative Branches. As a result, the real goals of the programs become obscured in the rhetoric and there is a danger that tax dollars will be spent on poorly conceived programs. Although the foregoing applies to all energy technologies, in the past few years it has been solar energy that has witnessed the widest variations in budget requests versus budget authorizations and appropriations.

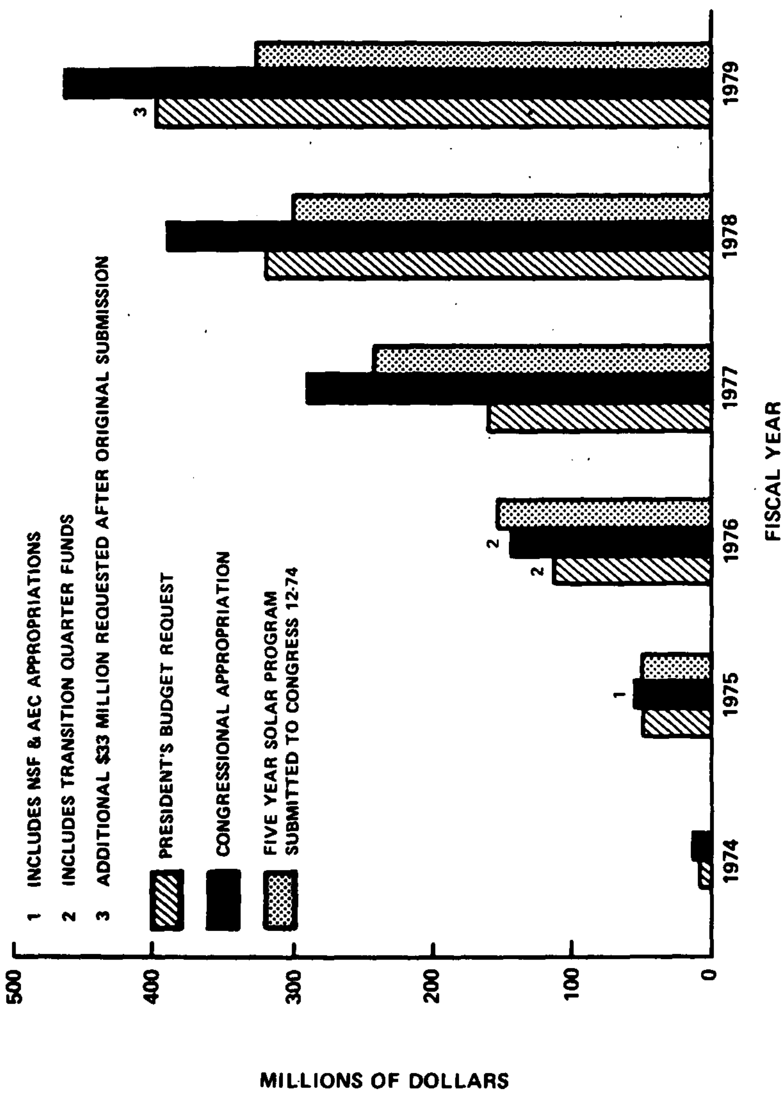
The final outcome of all these budget manipulations has been severe management problems for the solar programs. Because of the budget cycle, program personnel were unsure of funding levels in fiscal 1976 and 1977 until well into each year. Because major increases were provided after planning had gone forward at much lower levels, it necessitated quick catch-up actions. To some degree, this has continued in the last two years where planning proceeded at one level of expectation only to be modified by substantial budget increases just as the new fiscal year began. Table I (below) plots the progress of the budget from fiscal 1974 to the present and shows the great disparity that has existed between the official requests and appropriations. The Table also shows that if previous administrations had elected in the early years to embrace one of the billion dollar R&D plans put forward by the several task forces and panels, they would have proposed programs in close harmony with those finally supported by Congress. Much of the acrimony that has characterized the energy debate over the past few years would thus have been spared and the initiative for the programs would have remained in the Executive Branch (see Table I).

One might imagine that an agency would welcome appropriations in excess of requests. To some degree this is true, but it also creates the problem of gearing up the ponderous bureaucracy to spend funds wisely at an unexpected level. Requests for proposals and other types of solicitations must be generated for new projects, usually without the additional planning, manpower, and other resources required. Other complementary activities also increase and add to the overall workload. In the solar program, because of its rapid growth, management resources never caught up with the job to be done.

As one looks back over the last six years of the solar program, major accomplishments are evident. Public awareness of solar energy is high. Repeatedly, solar energy rates first when polls are conducted of energy likes and dislikes.[27] A major contributor to this awareness is the demonstrations of solar energy equipment sponsored by the government in all fifty states, Puerto Rico, and the Virgin Islands. From the beginning, open workshops on all aspects of the programs have been emphasized with attendance coming from business, academia, and the general public. Although attendance has never been totalled for the hundreds of meetings

27. *See* Harris Associates Survey, Sources of Energy for the Future (June 1, 1978).

TABLE I- SOLAR ENERGY PROGRAMS FUNDING HISTORY



held in the past six years, it is clear that tens of thousands have participated. A recent workshop in Philadelphia on passive solar energy attracted over a thousand participants.[28] At this time, with a number of the technologies at or approaching economic competitiveness, public awareness is the key ingredient that will assure acceptance of solar energy. But, it must be awareness without oversell or overdevelopment of expectations.

As to the technology itself, where do we stand? Passive heating and cooling can be economical today, especially if designed into a building from the beginning. Active space and hot water heating can also compete in most parts of the country depending on the type of energy displaced, but anyone contemplating the installation of such equipment must be cautioned to do a careful analysis, both of the costs involved and the equipment to be purchased. In six short years, supported by the federal program, an industry has developed. Recently passed tax benefits are expected to help that industry grow.[29] Biomass and hydroelectric power are already competitive, but significant expansion of their use will not come quickly since many unanswered questions exist. The federal programs in these areas have been slow to develop but, hopefully, they are now getting on track.

Windmills, except for special applications, are still higher priced than competing equipment by at least a factor of two. The present program, however, clearly envisions a time when wind turbines will be able to compete based on technology improvements in the pipeline. The other technologies—solar thermal, OTEC, solar cells, and satellite power systems—are even further removed from being competitive. But, compared to where they were when the program started, important gains have been made. Solar cells, for example, have been reduced in cost from almost $200 a peak watt in 1973 to approximately $10 a peak watt this past year. The goal of 50¢ a peak watt still appears achievable. Research, development, and demonstration must be continued on all these alternatives, at least for the next several years, until their state of development allows a fair comparison to be made. Some will undoubtedly drop by the wayside or be relegated to a minor role and then develop at their own unique pace.

How much energy can we expect solar sources to provide by the year 2000? There are a great many "what ifs" and assumptions that get involved in making such a prediction, some almost sure to come true, others less sure. What is sure is that the economics of energy supply do not lend themselves to simple analysis. The study commissioned by ERDA in late 1975 with the National Academy of Sciences brings this dilemma home graphically. Originally promised in twenty months, the final report will

28. Department of Energy, Proceedings of the Second National Passive Solar Conference (U. of Pa. March 16-18, 1978).

29. *See* Energy Tax Act of 1978, Pub. L. No. 95-618, 92 Stat. 3174 (codified in 26 U.S.C.A. §44C).

probably not be released in less than twice that time. The Academy has explained the delay by stating "the subject was damn hard." Replacement costs, distribution costs, subsidization, marginal costs, environmental costs, and the like make it difficult, if not impossible, to set a true value on a BTU delivered or a kilowatt hour of electric energy consumed. To make a reasonable prediction, all these factors and many more must be played against each other and an overall scenario selected. Such a universally agreed-upon scenario does not now exist. The Domestic Policy Review (DPR) of solar energy requested by the President last May has also been wrestling with this problem.[30] The final options sent to the Pesident call for increased tax benefits, low cost loans, major overseas efforts to develop markets, vastly increased RD&D, and a host of other subsidies.[31] Depending on how the parameters are used, the DPR analysis shows a potential solar contribution in the year 2000 ranging from ten to twenty-eight quads.[32]

Clearly, if the nation is willing to pay the price, solar energy can be brought on line at a rapid rate. Twelve quads is probably within reach if we include wood burning and hydroelectric power; this is a sizable amount of energy by any reckoning. The Domestic Policy Review will not, however, resolve the question of how much we must spend to get *X* quads of solar energy on line. Since the answer to this question is not needed at this time, if ever, the rush to supply the answer is misdirected. Rather, we would better utilize our resources to define a window in time when solar energy should be making a positive contribution and push the technologies in hand vigorously so that their advantages and disadvantages can be fairly assessed before the window closes. Considering our present lack of knowledge of the economics of most solar technologies, premature assessments of which ones will be able to compete in the marketplace could result in the rejection of important alternatives.

We have made large strides in the last six years toward developing a new energy source, a process that past experience tells us takes twenty or more years to complete. Evolutionary progress must be continued if we are to make rational decisions in the future.

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30. Remarks at the Solar Energy Research Institute on South Table Mountain, 14 WEEKLY COMP. OF PRES. DOC. 824 (May 3, 1978).

31. DOMESTIC POLICY REVIEW OF SOLAR ENERGY, A RESPONSE MEMORANDUM TO THE PRESIDENT OF THE UNITED STATES (Dec. 1978).

32. *Id.* at table 8.