No End To Conspiracy?-- The Solar Connection

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INTRODUCTION

The Nation of January 21, 1978, published an article by Bruce L. Welch, "The Reality of Solar Power," in which the author spends about two pages attacking me personally and the Nuclear Energy Policy Study (NEPS) Group collectively for our flawed performance in the analysis of the future of solar energy-- in particular, the future of solar cells. He ends with the sweeping conclusion

> "Finally, and viewing all areas of the nation's continued welfare, it is imperative that we evolve a more reliable science advisory system...it is increasingly essential, for the shaping of national policy, to have scientific advice that can be relied upon to be comprehensive, competent, and unbiased."

These are important questions. The substantive conclusions and recommendations of the Nuclear Energy Policy Study Group are contained in our book Nuclear Power Issues and Choices, but Welch criticizes the group for "superficiality, inaccuracy and lack of percipience..." and rather less directly for bias, incompetence, and lack of comprehensiveness. Let me reply.

Although granted by Dr. Welch a light cover of anonymity, I decline to wear this cloak, because it would not be difficult for a reader to divine my identity. I welcome the opportunity to explain how the Nuclear Policy Study Group actually operated in producing the book Nuclear Power Issues and Choices (Ref. 1). The NEPS group was selected to avoid individuals, no matter how competent, with a lifetime commitment to (or antagonism for) nuclear power. Our goal was not so much to recommend detailed decisions on nuclear power and alternatives as it was to understand how to approach such decisions. We were encouraged by the knowledge that the major decisions in any case were being made and would be made by decision makers in industry, government, and the public sector, who would have had less opportunity for analysis and for challenging their tentative thoughts than our format was to provide.

We did not propose to incorporate in our book finished chapters by individuals or even by small sub-groups of NEPS. Our proposal was to give primary responsibility for information gathering, analysis, and presentation of facts and alternatives to one or a few members in a given field, to provide specialized, devoted critical readership by still others, and then to decide on the responsibility for final writing of that portion of the book. Books written by committees tend to swell; ruthless editing by our chairman, Spurgeon M. Keeny, Jr., was to solve this problem, with the approval of the members of the study group. The NEPS meetings were far from a process of compromise and accommodation. Most of the members are well known to their colleagues as seekers after truth, with little tolerance for fuzziness and ambiguity, and none for falsehood. Our task was to clarify the nuclear debate. We heard pro-nuclear witnesses, anti-nuclear witnesses, and had a great deal of reading and discussion. Mostly, however, we were a group of severely critical individuals dedicated to saying something useful about nuclear energy in sixteen months, and relevant to impending decisions by the Administration.

We did not prescribe an alternative lifestyle for the nation or the world, nor did we foreclose it. We did not estimate future demands for energy, because we have little idea how the world will develop over the next fifty years or so, which was the period of our greatest interest. Our intent was rather to see whether reasonable demands for energy could be met by existing mechanisms for bringing supply and demand into balance-- primarily the market. Our analysis showed that although energy is pervasive, there is no reason to treat it differently from any other important economic good.

Our attention thus shifted to an attempt to understand the cost vs amounts of energy consumed from various sources-- oil, gas, coal, fission, geothermal energy, solar energy, and fusion. Our concern was with the major needs of the country, recognizing explicitly that some users of energy now pay extremely high costs and that these users could be an early and profitable market for alternative sources such as power derived from solar cells. We regarded as a virtue what Welch portrays as a vice--

> "that there is 'little value in demonstrating clearly noncompetitive technology,' and that it would be 'inefficient and unnecessarily limiting' to try to make alternative energy sources available 'prematurely.'"

This applied not only to our analysis of solar energy but also to our views on fusion, breeder reactors, plutonium recycle in light-water reactors, and the like.

Before I go into the details of our conclusions and recommendations on solar cells, I want to note that the NEPS group was accused by the nuclear industry of an anti-nuclear bias (and of incompetence, etc.) just as we have been accused by Welch of a pro-nuclear bias. In fact, when Keeny, Landsberg, and the writer testified March 25, 1977 to the Breeder Advisory Panel of the ERDA, Dr. Chauncey Starr, one of the members of that advisory panel and head of the Electric Power Research Institute (EPRI), charged that no NEPS member had any "hands-on" experience on nuclear reactors, and that our conclusions and recommendations were therefore unsound. Presumably it made no difference to Dr. Starr that Albert Carnesale has a Doctorate in Nuclear Engineering, that Panofsky was in charge of the design, construction, and operation of the $100 million Stanford Linear Accelerator Center, with severe problems of radiation and the like; and that many of the panel had had previous experience in advisory roles in the nuclear power field. In fact, I am charged by several of my colleagues in the industry with having been responsible for the demise of at least three programs in space nuclear propulsion-- ROVER (to propel a spacecraft by reactor-heated hydrogen gas), ORION (the propulsion of a spacecraft by multiple nuclear explosions), and SNAP (Space Nuclear Auxiliary Power from isotope generators or nuclear reactors such as that contained in the Soviet satellite COSMOS 954 which fell on Canada in recent months).

The words of Breeder Advisory Panel member Carl Walske (President of the Atomic International Forum) at that same public meeting, for which a transcript is available, further show the warmth of reception of the NEPS book and its Study Group by the nuclear community.

Welch accuses NEPS of having no one on the committee with experience in solar energy; Chauncey Starr accuses NEPS of having no one on the committee with experience in nuclear energy. Starr's charge is the more serious one, but they are both readily refuted. Welch notes that I was in charge of the National Academy of Sciences Committee to advise on the organization and tasks of a Solar Energy Research Institute. Our NAS committee began work in March 1975 and produced its report October 1975, including a two-week summer study during which we met with dozens of individuals interested in solar power (and heard no advocates for nuclear power or fossil fuels). Although our primary task was not in the substance of solar power, it was necessary to pay considerable attention to the status of and prospects for solar photovoltaic devices, both ordinary silicon solar cells and those involving concentrators for the solar light.

Incidentally, Welch's charge that none of the NEPS members had ever worked in solar energy in my case turns out to be untrue. In 1958 I published an article which is generally regarded as the technical foundation for modern efforts to use solar energy (and the accompanying pressure) for propulsion of spacecraft (Ref. 2). In 1958 also I published a paper (Ref. 3) discussing a technique now regarded by some with enthusiasm as a means for concentrating sunlight inexpensively for conveying it to low-cost and high-efficiency solar cells. In a recent paper (Ref. 4), Henry Kelly of the Office of Technology Assessment says about the promise of this technique,

> "A concentrator system based on use of a plastic doped with fluorescent dyes has recently been suggested which may be able to achieve concentrations on the order of 100 times with no tracking at all."

I have not polled my fellow NEPS group members, but it is clear that Welch was wrong at least in charging that his primary target of criticism had no background in solar energy.

Procedure. How did the NEPS group so miss the boat on solar energy; how did I pull the wool over their eyes? When we first considered (when we first conceived the plot of?) putting alternative energy sources in a single section of the book, three such popular sources were identified and assigned to individual members of the study group for gathering data, informing their fellow members, and in general standing up to criticism. They were: solar energy to Member AA, geothermal energy to Member BB, fusion power to Member CC. I volunteered or was dragooned into doing the first criticism and combined presentation of these alternative energy sources, and eventually having the responsibility of responding to criticism and integrating the contributions and the comments into a single draft text.

As I have emphasized previously, our primary concern was with the problems and prospects of nuclear energy. We were concerned with alternative energy sources insofar as they could be expected to contribute a large fraction of US energy needs during the time period of interest.

In Particular: Solar Energy. The enumeration of the types of solar energy has not changed since the NAS SERI study of 1975. Member AA had somewhat different views, different data, and different units, but there was no problem in reaching agreement without compromise and in responding to criticism and questioning from the rest of the group. Member AA, after the study group session primarily concerned with solar energy, submitted another draft (and this is the first time that the challenged "$200,000/kw" appeared-- about which Welch comments, "...that price-- which was not a misprint...was almost twenty years out of date."). I shall now limit this discussion to solar cells for the production of electric power-- the focus of Welch's criticism of NEPS.

In our 418-page book we have approximately one page on solar photovoltaic power (eight on solar energy in general). This is, after all, a book titled Nuclear Power Issues and Choices. Nowhere in our assessment of solar energy did we make use of the data contained in our sentence on page 134:

> "Even if the theoretical limit of 22 percent (for single silicon crystals) for photoelectric conversion could be reached, current collector costs are about $200,000 per kilowatt of peak electrical capacity, several hundred to one thousand times what they have to be (about $1 per square foot of collector) in order to compete with nuclear or fossil plants."

The burden of our discussion was to consider the cost elements and method of analysis for evaluating the potential of electrical power from solar cells, including those aspects which would assume importance only after solar-electric power was contributing a substantial fraction of electrical energy of the nation. Thus, it was inappropriate to consider only peak-load shaving by the provision of solar power to industry and residences (on sunny days) without storage and without considering the "demand charges" which would economically be levied against such users on days when the sun did not shine. I did prepare a chart showing the capital costs of various electrical energy and alternative energy sources and their dependence on capacity factor (whether they were in use to meet peak load a few hours per day, for base load, etc.) Unfortunately, shortage of space and the inevitable comparative value decisions which accompany final editing of a book eliminated this section. We do say, "Photovoltaic methods are far less competitive at present as economic sources of energy but, since large improvements may be possible with new ideas, economically competitive designs might emerge within a few decades."..."For the longer term, one or more of the solar energy methods may provide a significant fraction of energy in the United States, but not until rather far into the twenty-first century, and with a price premium over nuclear or coal power."..."It is important to recognize that society can depend on the availability of solar energy for the long run, at a cost it can afford, even though it would prefer to pay less."

When I testified March 31, 1977 to a House of Representatives Committee, Representative Richard Ottinger asked very emphatically why our results for solar energy were far less favorable than those which he had learned from Dr. Harry Hovel of my own IBM Thomas J. Watson Research Center. I responded that I did not know but that I would find out and send him a comparison of our two views, which I did for the Hearing Record. I reported,

> The difference arises very largely because Hovel was assuming that there was a market for energy produced currently while the sun was shining, and that base load would be provided in some other way. He used a figure on the order of $55/kw for the concentrators, a figure which has not been achieved but one which is at least possible in the referenced time period of 1986.
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> As I indicate in my submission for the Hearing Record, such a power source becomes <u>much more expensive</u> if it is used to provide power off-peak.
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> As we emphasize in our book, and as I note in my reply, peak power is <u>very</u> expensive if one has to pay true system costs, including transmission and distribution. There is no way in which solar-photovoltaic power can compete (at Hovel's costs) with nuclear power in general.
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> But I am not at all negative about solar-photovoltaic power in the long run. In the enclosed copy of the Report "Establishment of a Solar Energy Research Institute," 1975, you will find our views on page 28:
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>> 'Systems analysis is necessary to compare the potential of flat plates with the potential of photovoltaic systems using concentration of sunlight and to determine the economic gain of increased efficiency of the cells, improving reflectivity, mirror tolerance, tracking, and the like. Thus, SERI will need an experimental, theoretical, and analytical capability in solid-state technology and fabrication.'
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> <u>and</u> on page 38:
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>> 'On the other hand, the primary problem with solar-energy plants is their high capital costs. If the capital utilization can be more efficient in the sunny desert, then it <u>may</u> prove economically advantageous to generate a large fraction of electric power at such sites and to transmit it over long distances. What matters here is the cost of transmission, and it matters much more than with nuclear power plants of lower capital cost and less sensitivity to siting...'
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> I wish that ERDA had followed the recommendations of our SERI Committee and created a SERI on a scale and with the mission adequate to the overall job.

"Enthusiast Nuts." Where Welch wounds me most is in his direct misquotation from our telephone conversation where he has me calling some solar energy proponents "enthusiast nuts." Intemperate I may be; in error once in a while; but ungrammatical rarely. Bruce Welch telephoned me, identified himself somewhat hesitantly as being from Yale Medical School and asked for details on how the "solar energy section" of our book had been prepared. He requested the drafts of the chapter and other information of considerable interest and value to a historian of science but of no relevance to the conclusion and recommendations of the NEPS group which were contained in our final manuscript and which did not exist before that. In particular, he challenged me on the "$200,000/kw" figure in the book. I acknowledged that that was our figure in the manuscript and that it was not a misprint in the publication. I pointed out to him that we had nowhere made any use of that number, since it was clearly decreasing rapidly, so it was irrelevant how big the number was-- what counted was how large it would be when it became level with time or with purchase of solar cells, and that was not dependent on the present size of the number. He asked whether we had checked these numbers with the solar energy people at MITRE, and I said that we had maintained our intellectual independence both from the Ford Foundation (which supplied the money) and from MITRE (which supplied the administrative support). He asked how we could have arrived at a reasonable conclusion without having incorporated in our group people who were expert in solar energy or having checked our conclusions with those who were working in the field. I told him that I personally had had six months of relevant experience just one year previously in my role as Chairman of the National Academy of Sciences SERI panel, and that I thus knew many people in the field. Furthermore, I was not responsible for the introduction of the number in question, the notorious "$200,000/kw," but since it did not figure in our conclusions, I had not verified it. Finally, the solar energy section had indeed been read by other knowledgeable people. He pressed as to why we did not consult those expert in solar energy, and I cautioned that I had found in the field quite a few who were "technological enthusiasts or solar nuts," more interested in means than in ends. Would that Mr. Bruce had taped our conversation; his notes were fragmentary.

What’s Left? At the time of final editing of the manuscript, our chairman, Spurgeon Keeny, interrogated me mercilessly regarding the plausibility and accuracy of the figures in the chapter for which I had assumed responsibility (but which had been provided in large part by others and which had been subject to the criticism and reservations of the entire group). I traced many of the figures back to their source (U.S. Geological Survey, and the like), recalculated others which were a matter of analysis rather than primary data, and ended with one for which I had no data. This was the notorious "$200,000/kw". Clearly, we failed to check this number adequately; a more current figure for terrestrial solar cells would have been $15,000. My own concern with that number was somewhat limited, since no conclusions, recommendations, or judgments derived from it. My previous quotations from our book make clear our rather optimistic views on the affordability of solar power.

A Word of Caution. I can assure Bruce Welch and the readers of The Nation that every member of the NEPS group would have been overjoyed to have been able to conclude that solar cells had a substantial probability of becoming competitive with coal or nuclear plants for the production of energy over the next few decades at a cost of 2.5›/kwh. I know of no member who, had the facts been different, would not have done his part to establish that nuclear power was unacceptably hazardous by the criteria we normally apply to the utility sector or to industry in general (not that we had any prejudice against nuclear power, but it would have saved us a lot of work in cost comparisons and the like). I myself (as the public transcript of the Federal Energy Administration Environmental Advisory Committee will show) have been a strong supporter of dispersed generation of electrical power and of "cogeneration," in which an individual home, shopping center, or plant produces its own electricity and uses productively the waste heat (whether electricity is generated from fossil fuel, by gas turbine, diesel, or steam turbine, or produced from solar sources, garbage, and the like).

But the promise of solar cells is not to compete with the 13›/kwh was now charged by Consolidated Edison of New York for home electrical energy. Solar cells may very well be competitive at that price, as are conservation, peak shaving, and all of the improved efficiencies which will arise automatically from time-of-day pricing, system-demand-dependent pricing, and the like. An entrepreneur of modest size may get rich selling solar-cell electricity at 13›/kwh but when off-peak electricity sells for 2›/kwh (as is the case in the Consolidated Edison time-of-day pricing experiment) there will not be a very big market for this premium electrical energy. Welch notes,

> "The rate at which solar cells will actually spread throughout this and other industrialized countries will depend upon the development of adequate low-cost ways to store the electrical energy. It is in the administration's tepid encouragement of new storage technologies that its reluctance to promote solar energy really shows. The budget authority for fiscal 1978 provides only $48.4 million for all aspects of energy storage research, development and demonstration-- less than 3 percent of the amount provided for nuclear fission....It is no exaggeration to say that the Department of Energy has not set up a crash program to find better ways to store electrical power. For nuclear power, storage of electrical energy is not particularly important; for distributed solar systems it is crucial.
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> "The federal government should withdraw its multifarious supports from the nuclear power industry and remove remaining institutional obstacles to the rapid development of distributed solar energy systems."

What does our book say?

> "More rapid progress can and should be made in the transmission, transport, and storage of energy. Such progress would permit more effective and flexible use of existing energy resources at reduced social costs. Technological developments also improve the competitive economics of alternative sources of energy and hasten their introduction." (Page 155.)

We also say (in our three-page introduction to the section on solar energy (pages 130-133):

> The amount of solar energy falling on the United States is enormous: 44,000 quads per year. The present annual U.S. consumption of electrical energy could be supplied by 0.15% of this solar energy, if it could be used at 10% efficiency.
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> There is no doubt that solar energy can be used to generate heat, electricity, and biomass or other fuel, but it is not certain how much it could cost to collect and use it for such purposes. The energy intensity of sunlight is much lower than that in the heat-generation portion of a nuclear or fossil fuel plant. In the United States, sunlight provides an average of 190 watts of energy per square meter throughout the year, compared with nuclear or fossil fuel plants operating with energy intensities of hundreds of kilowatts per square meter. The problem is to find a way of utilizing the low-density energy of sunlight at a capital cost low enough to outweigh the benefits of "fuel" which is essentially free.
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> Methods of using solar energy directly include water heating, space heating and cooling, heating the working fluid of a heat engine, or using the photovoltaic effect to generate electricity. All of these suffer from the variability with which solar energy arrives at the earth's surface and the mismatch between time of production and time of use. Solar energy is available during only a portion of the day, and weather and seasonal variations greatly affect the amount available. Both contribute to a low load factor (fraction of time plant can operate) for solar plants. The fact that consumption is not limited to times when direct solar energy is available implies a need for large-scale storage.
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> When the bulk of a system cost is in capital expenditure, as it would be for solar-electric plants, the cost per kilowatt hour of energy produced is almost inversely proportional to the percentage of the time that the system is putting out power (except to the extent that components wear out with energy through-put rather than with time). Thus, a hypothetical energy plant with a capital cost of $1,500 per kilowatt peak electrical output (and a 15% annual capital charge rate) would have a capital charge of 26 mill/kwh at a 100% load factor, 43 mill/kwh at the 0.6 load factor typical of coal or nuclear plants, and 86 mill/kwh at the 0.3 load factor enforced by daily variation of insolation (the rate at which the sun's radiation is received at the surface) even at a favorable site.
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> Even apart from variations in power generation throughout the year (owing to changing lengths of days, sun angles, and long cloudy periods), the variation of insolation during each day even at a cloudless tropical generating site would make energy storage necessary for solar energy systems to compete in supplying power for normal uses. Peak electrical consumption, summer or winter, comes in the late afternoon or early evening when solar flux is low or even zero. Thus, without storage, solar energy cannot provide for peak load periods so as to save the fuel otherwise

consumed in low capital cost plants such as those fueled by gas turbines, which might be used during times of high demand. Without energy storage, the generation of off-peak electricity by solar energy would have to compete in cost with nuclear or coal-fired plants, which however have a great advantage in not being limited to periods of sunlight.

Solar energy could be more widely applicable if energy storage was provided, and several techniques for storage are in various stages of development. Examples are thermal storage in hot oil or hot rocks, electrical storage in batteries, and mechanical storage using pumped water or compressed air. Storage systems thus consist of a reservoir, the capital cost of which is proportional to energy stored (in the case of electrical energy, a cost per kilowatt hour), together with devices for transferring the energy into and out of the store (the capital cost of which is stated per kilowatt for electricity). Up to one-third of the energy is lost in the transfer to and from storage. A reasonable figure for capital cost for storing six hours of generated electric power might be $300-$500/kw, plus an additional 50% capital cost increment on the primary solar thermal-electric system to make up for losses. Thus a plant costing $1,500 per kilowatt of peak capacity could have a capital cost element of 86 mill/kwh if the electricity were used currently; if six hours of generated energy were all stored for later use, the capital cost element would rise to 150 mill/kwh.

An alternative to storage is to use another energy system as standby capacity to augment the solar plant. However, this alternative would increase the effective cost of solar power by the additional capital cost of the auxiliary system plus the value of the fuel it used. Storage (thermal or electrical) could also be used with nuclear plants, another low-fuel-cost system, to allow load-following operation without consumption of fossil fuel. Thus the availability of storage may not improve the competitive position of central-station solar-electric plants versus nuclear reactors.

It may do so, however, in small-scale systems. Indirect uses of solar energy avoid the storage problem by utilizing a fuel which has stored the sun's energy. Examples are the growth of plant matter for fuel (biomass), or the more hypothetical artificial photosynthesis and the solar photodissociation of water to produce hydrogen. Alternatively, solar energy can be extracted from the ocean (where, in the tropics, the temperature varies by 20~ C between the surface and a depth of 1,500 meters and where this temperature difference can be used to run a heat engine), from waves, or from the atmosphere, where solar energy is stored in the wind. In each of these cases, the energy reservoir is independent of whether the sun is shining, though the energy available may be periodic or otherwise variable for other reasons, as in the case of wind and waves.

Transmission of energy may also be a more severe problem with some forms of solar energy than with nuclear or even fossil fuel energy. Energy is consumed for the most part where people live and work. Insolation is about 40% higher in southern Arizona and

New Mexico than the average over the continental United States, but the bulk of the nation's population is 1,000 to 2,000 miles away. For solar-electric plants, for which the contribution of energy-collector capital cost to the cost per kilowatt hour is inversely proportional to insolation, the cost (perhaps a cent or so per kilowatt hour) required to transport electrical energy will probably prove economical, but there will be a substantial incentive to reduce electrical transmission costs for very large blocks of power (10,000 MWe and up) by developing devices such as cryogenic superconducting underground cables. Converting and transporting energy from regions of high insolation in chemical form (e.g., as hydrogen) is likely to prove more expensive unless the process is such that energy is generated originally in such form. Small-scale applications of solar energy, such as for space heating and cooling, have an advantage over other sources in requiring no transportation or transmission.

Comparisons of solar-thermal, solar-electric, or ocean-gradient energy costs with those of nuclear power rest on capital cost judgments, since fuel costs are nonexistent in one case and low in the other. Cost comparisons between biomass and fossil fuel plants are even more straightforward; since the generating plants are similar, the comparison is a question of fuel costs. Cross-comparisons between capital-intensive and fuel-cost-intensive methods are more difficult since they depend on the assumed cost of money, amortization times, construction times, the differential rate of inflation between the cost of construction and that of fuel, and load factors.

In fact, emphasizing the importance of storage to the economic success of solar energy, (we note page 135) "...the competition with nuclear or coal plants would depend upon the existence of storage. Thus, it seems possible that concentrated photovoltaic systems may have some application (with storage), in sizes of kilowatts to megawatts, in situations where fuel costs are very high." It is of interest also to note that inexpensive storage would also reduce the cost of electricity from nuclear plants, thus further lowering the permissive cost of solar photovoltaic energy if it is to compete effectively. It is not true that storage of nuclear electrical energy is unimportant; if we had it, solar energy might have a still more difficult time in emerging.

CONCLUSION

So,

- NEPS was not in any way opposed to solar power, either for technical or ideological reasons,

- We noted that some applications of solar energy are economically viable now-- space heating, the use of by-product biomass for crop drying, steam raising, and the like, that some applications of solar cells are economical now (in remote places, where the cost of alternative energy sources is very high),

- but that the test of alternative energy sources in the market place is (and should be) a severe one.

Proponents of many technologies over the years have sought government subsidy for their cause. There is nothing inherently good or bad about government subsidy for research and development (or even for implementation), but it is a very real cost. It is conventional (and economically sound) to ignore all previous expenditures on a project in taking a decision as to whether to continue the project beyond the current status. One thus looks at the benefits in comparison with the costs still to be incurred in comparing nuclear energy with solar energy or fusion; it is irrelevant economically that billions of dollars have been spent by the federal government in the nuclear energy fields (some to advance nuclear energy and some which has had in fact the opposite effect). What counts is how much has to be spent now to obtain energy from the alternative sources. Incidentally, the end of government subsidy was widely hailed with the first commercial sale of a power reactor by General Electric at Oyster Creek in 1963 at a price near $150/kw. Unfortunately, even economies of scale in going to the present much larger plants have not held nuclear energy costs (even allowing for inflation) to that level.

Welch demands reform of the science advisory system. Richard Nixon agreed and abolished the President's Science Advisory Committee, in large part because of its lack of support for various administration programs such as the SST, the ballistic missile defense, and the war in Southeast Asia. I received the first Public Service Award of the Federation of American Scientists for my analyses of the SST program and my willingness to testify to numerous Congressional committees about this important and costly program. Other members of the NEPS group have served on the President's Science Advisory Committee-- Doty, Goldberger, and Panofsky, and several others of the group, including Keeny, have had or now have high positions in the Administration. Only a small fraction of their contributions are known to me, but those are enormous. If Mr. Welch could recommend a better system to provide "scientific advice that can be relied upon to be comprehensive, competent and unbiased," we should all be in his debt.

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