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SOLAR ENERGY: HANDLE URGENTLY BUT WITH CARE

There is controversy, real controversy, over the extent to which solar energy will ever be a major component of U.S. energy. On the one hand, some of us see the many routes to tapping solar energy, and the current plethora of relevant ideas, and conclude that there must be some cost-effective methods in here somewhere — especially if energy prices continue to rise steadily. On the other hand, solar energy is diffuse and intermittent. These are fundamental characteristics and not easily surmounted. This leads some of us to strong pessimism.

We all agree, however, that the situation requires a high priority on solar research and development. Expenditures on R&D always have a high potential for cost-effectiveness. But in the case of solar energy, they represent an ever greater imperative.

Ironically, an energy crisis is afflicting those energy sources where we do not confront any problem of supply. Nuclear energy, a potentially limitless resource, is under increasing attack for its radiation. Solar energy, our only other limitless resource, remains of uncertain utility. Coal, while existing in America in enormous supply, is increasingly viewed with alarm for the CO_2 it contributes to the atmosphere when burned, CO_2 which can have a potential disturbing effect on the world climate.

With so few sources of energy available for the long run, and with solar energy seeming to possess so many desirable environmental and aesthetic advantages, it seems absurd to do less than to push energetically the state of the solar art.

Time is of the essence here. We could find ourselves, in a decade or two, with a campaign for a coal-burning moratorium and a dying or dead nuclear industry. And since solar, even if it works and works well, will require decades to take over a major share of the energy needs, we could find ourselves in a very unhappy situation indeed.

The research on solar energy must extend into two unusual dimensions thus far insufficiently pursued. In the first place, with solar energy, the problem is normally to reduce its cost, not to establish its technical workability. For this reason, the problem of cost-cutting technical advance merges with the problems of economic subsidy and incentives. The economic perspective of the problem is often harder to assess than the technical and, for this reason, needs more attention.

In the second place, we need more research on the weather and the climate, with special reference to the anticipated reliability of solar energy. Solar energy will require large capital investments. Some of these investments can only be made in relative certainty that the pattern of sunlight, wind, ocean current or agricultural production are suitable.

In the case of heavy dependence on wind and direct sunlight, for example, solar "drought" could be much more serious, and simultaneously widespread, than water drought is presently.

Perhaps the underlying dilemma in the solar energy field lies in maintaining public support without misleading the public. Thus far, the solar R&D program has grown, despite resistance in the Executive Branch, as a result of popular — and hence Congressional — enthusiasm. Maintaining that enthusiasm is, therefore, a major tactical goal. On the other hand, nothing could be worse for solar in the more strategic long run than to arouse unfulfillable expectations. At best, decades of research and commercialism are going to be necessary. In the inevitable devices that do not work to expectations, one can anticipate excesses of public discouragement.

While the general public waits for the economic analyses and technical developments to be sorted out, its involvement and contribution should be sought, not only in conversation, a *sine qua non*, but in applying the rapidly evolving and valuable notions of sensible solar architecture.

In summary, we are all quite sober about the possibility that our generation might bequeath to future generations, a technical-political situation in which energy is in painfully short supply. There are, after all, not really very many energy options and they all have problems of availability or side effects. We must not miss — or mishandle — solar energy if it can be made to work. On the solar energy bottle, therefore, it should read: "handle urgently but with care."

—Reviewed and Approved by the FAS Council

VOYAGE INTO THE SUN?

At the kickoff press conference for "Sun Day" — the day of celebration of solar power — its chairman, Denis Hayes, made a series of plausible remarks about the importance of eliminating subsidies from other kinds of power so that solar would be dealt with on an equitable basis. But he concluded by urging an effort to develop solar power comparable in intensity to the U.S. effort in World War II! Was this necessary — or politically possible? It seemed the time to find out.

It turns out to be hard to generalize about solar power because that phrase is taken to mean the exploitation of quite a few entirely different phenomena. A variety of technical articles having already appeared in leading science journals, a reporter-analyst concluded that the easiest way to lead the reader through the thicket of technology,

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economics, philosophy and ideology that constitutes solar power was to relate his learning experience at the hands of FAS officials and other experts and to let readers reach their own conclusions.

FAS Council Member Robert Williams, the guest editor of the *Bulletin of the Atomic Scientists* series, initially advised that government solar energy planning suffered from a "fishbowl mentality." Officials were afraid to innovate by subsidizing risky research. But this was what was needed and, indeed, it could be very cheap in a field that needed more old-style inventors at the workbench. The solar area was full of good ideas and very exciting. The problem was that, basically, there was no economy of scale with the collection of solar power, but was an economy of scale with its storage. As a result, intermediate size complexes of users might be the best beneficiaries of solar — big enough to permit supervision and maintenance of the facility and use of the waste heat generated (called cogenerated heat) but not so large that there were losses of energy through its transportation elsewhere. (But would intermediate size complexes mean a host of siting problems?)

Hot Water Heating

The next day, an FAS member, Harold Taylor, dropped by and provided some fundamentals. Hot water heating was the most feasible use. Sunlight was admitted through glass, and onto a black surface, which would capture its heat and, transmitting it through water, would warm a hot water tank. The key economic fact was that people used hot water every day of the year, hence the capital cost of the solar collector system could be offset by fuel savings throughout the year. By contrast, systems for heating the home (space heating) run up against the fact that fuel savings can occur only in the colder months and then only to the extent that there is offsetting sunlight. Thus they are economically more marginal.

The existing power grid based on coal or nuclear reactors would be used as backup. Its energy would be automatically switched on whenever the solar system lacked the warmth to maintain a constant temperature in the tank. Here one saw a fundamental problem with solar systems. If they require backup, how can one save resources by cutting back on the coal or nuclear plants they "replace." Won't such plants be necessary, in virtually full assortment, for those periods of "solar drought" when whole areas of the country are receiving less than adequate amounts of sunlight for periods of days and weeks? Obviously, one would save fuel, but fuel, especially in the case of nuclear, was not a major part of the cost. (Most solar enthusiasts are not considering nuclear as the alternative, but coal, and hence they do emphasize fuel savings.)

Problems with house heating seemed to be of various kinds of consumer uncertainty: the fact that consumers did not stay in the same house for the large number of years (sometimes 20 to 30) required to amortize the solar investment; uncertainty about the reliability of solar systems over such long periods; the question of who would provide suitable warranties; and the fact that installation did not lend itself to mass production — the orientation of the house and its roof, and the amount of sunlight it received, etc., were all quite particular. Since solar heating did not involve complicated technology, it was not likely to lend itself to important technological innovation.

William Shurcliff

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Later, reading Council Member William Shurcliff's writings, one saw clearly the enormous number of possibilities for home heating, and his conclusion that the critical issue was economics — doing it cheaply enough to be competitive with other fuel sources. He pleaded that standards not be promulgated on solar energy systems lest ingenuity on new approaches be suffocated. (But the fledgling solar industry is adamant about standards because it fears that the entire potential reputation of solar collectors would be destroyed if the generation of systems sold initially were to fail. The initial unreliability of devices called "heat pumps" — devices that pump up the outside heat and bring it indoors — caused their premature demise. The solar industry remembers this and, also, that there have been three or four different periods of solar enthusiasm in the last 100 years, each of which later dissipated.)

Windmills or Wind Machines

At a brown-bag lunch for interested public interest groups at the Department of Energy headquarters, wind specialist Lou Divone said economic studies were "surprisingly" giving DOE more problems than designing the windmills themselves.

The efficiency of the wind machines depends closely on the speed of the wind. It goes up with the cube of the velocity. (Wind being notoriously fickle, one wondered whether anyone could invest large sums in wind machines under these circumstances. The pattern or strength of winds could change to a degree that decisively undermined the economics of the investment. In few spots do we even have long records of past wind strengths.)

Wind, like solar heating, also needs some kind of storage element to compensate for the intermittent quality of the source. Reflecting this dilemma, enthusiasm was expressed for putting wind machines near hydroelectric dams so that one could use the electricity produced by the former when it existed, and use the hydroelectric power in greater or lesser quantity as a complement.

Asked how much "wind" was going to amount to overall, Divone said the various estimates ranged from "wind isn't going to amount to anything" to "18% of the country's electricity."

Another FAS member, Harry Davitian, dropped in and advised that, so far, people are buying solar for kicks or ideological reasons. Economically, it was much more sensible to insulate one's home to save fuel costs than to install solar (space) heating.

Levels of Solar Rhetoric

Lunching with Theodore Taylor, the nuclear bomb designer, a reporter witnessed the verbal labyrinth through which solar initiates must pass. To the question, "Is solar power here?" Taylor began to observe that the earth receives vast quantities of solar radiation. To an "of course," he admitted that to conclude that "solar is here," one had to include photosynthesis. Asked if this referred to "biomass" (the burning of refuse, agricultural waste and trees grown for fuel), he said, "No," one has to include cotton, wood, etc. By this standard, a visitor suggested, solar had been "here" since man had given up hunting and taken up agriculture. Taylor agreed and said that, if one did not accept this formulation, then one could not say solar was "here."

He emphasized, however, that one could use wood for fuel for all the world's energy by planting and harvesting forests on only 5% of all the earth's surface. After more cross-examination, it turned out that this would mean doubling the amount of land presently under cultivation — a clear impossibility.

Several FAS members had recommended a look at Taylor's paper on seasonal storage — storing summer solar energy into winter months. His paper began by stating present costs of energy with which one might compare solar: heating rooms and water for $2 per million BTU; delivering electricity to consumers at 5¢ per killowatt hour. With these benchmarks he had concluded that:

> "We have found no recent overviews of solar energy that suggest that such cost goals are likely to be met in the foreseeable future in the regions that account for the majority of the world's population."

Having decided that heat and storage might be the key to meeting the goals, and concluding that the only sufficiently cheap, and available, material for storing it in was water, he had proposed that communities consider pools of water covered with layers of plastic film that would absorb sunlight but not release heat.

It took only five minutes of conversation to see the associated problems. A hundred households would require a square pond that was a football field length on a side and 30 feet deep. Thus, as Taylor readily admitted, the ponds would become "as pervasive as roads." If one fell into the pond for some reason, one would die, since the temperature would get about 150 degrees Farenheit. The pond would be constructed with dikes, to save excavation, and the dikes might be breached — with hot water pouring out upon the town either by accident or sabotage. Repairing the plastic would be a problem because the pool would be so hot and leaks from the pond into the ground would be too. Taylor observed that, with all its difficulties, it was "the most promising seasonal storage scheme." (A well-informed solar enthusiast, who had recommended the Taylor proposal for study, on reviewing the proposal, admittted it seemed impractical.)

Photovoltaics

FAS member Henry Kelly had been looking into photovoltaics. The photovoltaic is a device that turns sunlight directly into electrcity. A product of the space age, it is used in satellites, has no moving parts, and is made of one of the world's most common elements, silicon. Here was the model solar idea. In theory, one could cover rooftops with silicon collectors and get one's electricity straight from the sun — circumventing the utility companies and everyone else — but relying upon the utilities during cloudy periods.

Unfortunately, these devices are presently 20 times too expensive. Could they be made cheaper and cheaper? "Yes." Could they become competitively cheap? Nobody knew. One idea was to exploit the possibility that a mass market in the underdeveloped world might exist. It would pay premium prices for the silicon collectors and, in so doing, prime a mass market in the United States which would bring down the price. (Were the poor to be subsidizing the rich by buying high-cost items until they became cheaper?)

Council Member Arthur Rosenfeld was interviewed in Berkeley. He has real doubts about solar energy except in his particular area, where he is most enthusiastic. What he advocates is, in effect, sensible solar architecture which is

Arthur Rosenfeld

called in the trade "passive" solar. Thus, because the sun is seen to the south in northern latitudes, one would build houses that "faced" south with windows letting in the warmth. They would have a great deal of "thermal mass," which is to say water or rock to absorb the heat so that the house would be long in heating up, and slow in cooling. Thus one would have a dwelling which, like a cave, would smooth out the temperature fluctuations induced by day and by night.

While the U.S. stock of housing was turning over, there were still many things to do that were, he argued, much more effective than solar space and water heating ("active" solar). One could insulate one's home, plug air leaks, use glass that had a panel of air between two panes, and so on. He and his colleagues at the Lawrence Berkeley Laboratory (LBL) had documented the very considerable savings available.

They had also observed that, if one assumed increasing energy prices, it would then become cost-effective to the consumer to go quite far down the road of weatherproofing his home. Under these circumstances of rising price, the State of California would therefore be justified in mandating standards that went comparatively further than would be cost-effective at today's prices.

That night, at an FAS member's Berkeley home, one saw the consequences of long-term changes in housing attitudes. A wealthy man, the host had a beautiful home built in the early 1920s with windows galore. But as a result of current energy prices, the living room could no longer be heated continuously and had, instead, a blower which would heat it up rapidly whenever it was to be used.

Pointed to a key review article on energy, one saw that Melvin K. Simmons and Frederick H. Morse had concluded it was "uncertain and controversial" whether we now have the means to collect economically, and to convert, solar energy into useful forms. But they believed that 1985-2000 would be the "coming of age" of solar power and, after that, it would become "one of the conventional power sources used in many regions of the world."

Central Plants for Solar Electricity

Next morning, at the Radiation Laboratory, the possibility was discussed that centralized solar plants for making electricity might combine with, or compete with, nuclear or coal plants. Here many mirrors would track the sun rather precisely, and focus the concentrated rays of sunlight on a mounted boiler of water so as to create steam and then electricity. Because the peaks of electricity demand come at the beginning, and end, of the daylight hours, this method needs storage — at least to extend the solar power a few hours on each side of usable sunlight. (Unfortunately, for solar power, if there *were* cost-effective ways to store electricity, they might help the economics of nuclear power as much or more. This is because the nuclear plant could then be run vigorously during off-peak hours with the output going into storage that would smooth out the peaks of the next day.)

Later a researcher on solar thermal electric systems said flatly (but not for attribution) that such plants would never be competitive for electricity. The feasibility of these systems, he felt, was in separating compounds which when transported elsewhere and rejoined would generate energy. Asked what substances he had in mind, he said the chemists were working on it.

Researchers on OTEC came next. This is a method of getting energy from the fact that the ocean has different temperatures at different levels. An enormous pipe ten football fields long and 50 feet in diameter would be placed vertically in the sea and large amounts of water would pass through it, giving up energy in the process. There were a number of possible environmental problems and a need for demonstration. But OTEC was clearly one of the more imaginative approaches.

One researcher commented that "Solar can be thought of as an insurance policy and an upper ceiling to energy price rises." He thought it would play an important role in the next century in freeing up electricity and was the "most viable long-term solution to our energy problem." He raised the problems of coal. If we continued to burn it, the world would become overheated as a result of the CO_2 concentrations in the atmosphere and this could be disastrous.

At lunch, waiting for Donald Glaser, an FAS Sponsor, one read his secretary's sign: "You have to kiss a lot of frogs before you find a prince." Perhaps this was the allegory for solar power techniques. Glaser was no expert on solar but said he has "an enormous aesthetic preference for it."

Waiting for another interview, one saw the many solar industry periodicals displayed: *Solar Age, Solar Energy Report, Solar Engineering Magazine, Solar Energy Digest, Solar Energy, Sun-Up.* Obviously, a modest industry was underway.

The solar section of the Berkeley Lab is chaired by Mike Walig. He said economics was the most important factor, that bad initial performance could destroy solar, and that photovoltaic cells were a "big question mark." Passive solar had just become more popular in the last few years, was getting a late start but was very promising and it looked like it was cheaper than active solar. With good insulation and passive solar systems, today's hot water needs alone would heat the home.

Inside FAS, no one speaks with greater authority and precision on general questions of energy than Council Member John Holdren, who had just completed his new book (with Paul and Anne Ehrlich), *Ecoscience.* He supported Rosenfeld's enthusiasm for passive solar. By investing only 5% more in a $40,000 house in Indianapolis and by using such architectural advantages as double thick walls, triple glazed windows (three panes with air between each), good insulation, lots of internal thermal mass and 85% of the glass facing south, it had been possible to reduce the fuel needs of a house, which had already met HUD standards, by 80%.

The next easiest thing was heating hot water. Since the collectors need not be too large, the roof itself need not be at the right angle to the sun for the latitude in question — instead, the relatively small collector could be propped up. It might cost $1,000 for a collector of 100 square feet and it might save 2/3 to 3/4 of the hot water heating energy. Still, the biggest gains for the next 15 to 20 years would come from insulation and plugging of leaks and architecture.

Solar Partly Waiting for a Cost Rise

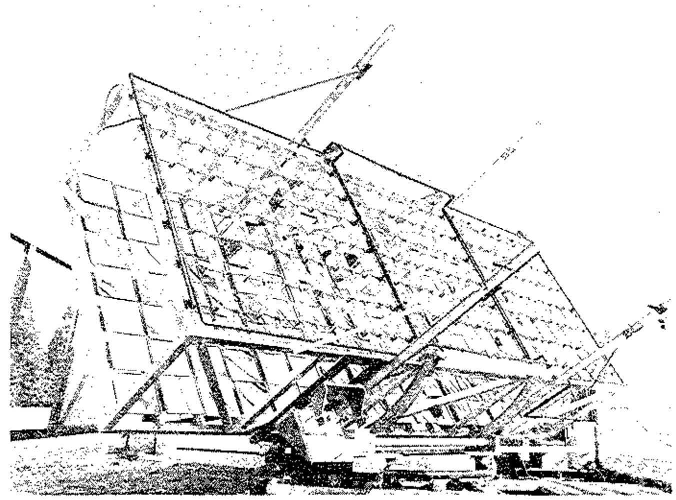
Active solar for heating space in homes and buildings would not compete until heating oil went up by about 200% and gas by 300%. (Deregulation of gas might provide a factor of 200% but not 300%.) On the basis of his work on a recent study group, he was able to provide me with a sense of the informed consensus. Evidently, even with prices two or three times those at present, only a few quads (quadrillions of BTU) of fossil fuel would be replaced by various forms of solar electricity (wind, thermal electric, etc.) in a total of about *100* quads needed. Another few quads of heat would be delivered by domestic water heat, industrial process heat and passive solar. (A leading solar enthusiast absorbed these numbers and said, "If that's all we can do by the year 2000, we might as well cancel "Sun Day.") In short, only about 10% of the energy in use in the year 2000 would be solar even if prices go up by a factor of three — unless solar is mandated in some way that goes beyond a free economic system.

One could imagine a big breakthrough in photovoltaics, but not in the other fields. Unfortunately, in photovoltaics, one *needs* a big breakthrough. Still, all in all, Holdren thought it was just a question of time before solar would play a major role. It was unlikely that solar would be cut off by some other source, as gas had driven solar out of Florida in the 1920s. That would require massive oil or gas discoveries or very successful technologies for coal or oil shale gasification.

The next morning, in Palo Alto, a reporter stopped at an industrial firm working on photovoltaics. While most of the government effort was focused on silicon collectors, Varian was working on systems that tracked the sun, concentrated the sunlight with plastic lenses, and then focused the concentrated rays on a small gallium arsinide receptor. At first researchers had been pessimistic about this system working in the northern latitudes because it only worked when the sun was strong enough to cast a shadow. But they later learned that the precise tracking of the sun — when such sunlight *was* available — made up for the longer operating periods of those non-tracking systems that picked up diffuse sunlight but did not track the sun.

John Holdren

The working model was rotating rather perceptibly. The escort wasn't sure why, unless it had lost the sun behind a cloud and was searching for it. Finally, he



Varian photovoltaic

realized it had been laid falt on its back for protection ("feathered") because of rain storms the night before. Because it could not possibly find the right angle to the sun in this posture, it was rotating aimlessly while it tried. Obviously exposure to nature and the "elements" was going to be a problem for all solar systems. Wind machines, active solar systems, OTEC devices or whatever, could hardly be expected to have the reliability of machines working inside buildings. Fortunately, most of the devices were fairly simple in nature.

Electric Power Research Institute (EPRI)

Nearby, there is the research institute of 500 electric utilities called EPRI — Electric Power Research Institute. There Piet Bos is head of the new-energy resource program: fusion, solar and geothermal. He was authorized to spend about $14 million each year, of which solar got $5 million. Bos complained about instant experts and the inability to trust what one read in this field. (Several solar observers spoke in similar terms to me at other times.) He wanted controlled experiments and rarely found them. But EPRI was designing suitable housing experiments.

Electric energy must be generated when it is needed, so if demand is especially high in some part of the day, generating equipment must be built and then stand idle simply for that one part of the day. One important goal of EPRI was to get greater use out of the existing investment; in particular, this meant smoothing out the peaks in the demand curves for energy.

Solar power tended to create a new kind of peak problem. After all, if solar devices were widespread, they would all work when sunlight was available in a region but all would demand backup services when it was not.

Bos thought that a heat pump would have a phenomenal and guaranteed future. If shortage methods were available, heat pumps might be combined with such storage to provide an even more phenomenal future. He felt that, if the utilities played their cards right, people would, in time, switch from gas and oil to an all electric system combined with heat pumps and solar power.

The utilities feared that nuclear might be lost as an option. Initially they had resented solar, but were now learning to live with it and trying to see if there was something to it.

Bos thought wind too fickle and said it gave the utilities fits thinking of how to "hook it in." Still he liked wind better

Piet Bos

than OTEC. Nevertheless, he was looking at everything — including biomass through growing kelp in the ocean.

SERI — Solar Energy Research Institute

After Congress approved SERI, a competition among almost 20 proposals was held which was won by the Midwest Research Institute (MRI) with a proposal written by its present deputy director, Michael Noland. SERI is currently preoccupied by efforts to negotiate its relationship with the Department of Energy. It is also fighting off efforts of its former fellow competitors to recoup by becoming regional SERIs but with open-ended charters that would allow them to fulfill their initial aspirations. SERI is in the process of growing bigger than MRI although, in principle and partly in fact, it is simply a government contractor whose contract is managed by MRI. By October 1979, SERI should have almost 500 workers and will grow to 600-900 subsequently.

SERI's real problem is heavy responsibility without authority. Congressman George Brown had suggested SERI was to be the "trustee for the solar age." In fact, one researcher complained, it was simply a research extension of DOE, responding to DOE queries but not able to initiate its own projects in response to its own sense of what was needed. In short, the most activist staff thought that SERI should have been set up with greater independence and autonomy as a public body, rather than as a private organization under a government contract.

SERI Staffers

A sizeable fraction of SERI staff are "with it" environmentally. In discussing the cost-effectiveness of solar collectors, one staffer said they could be made cost-effective if Americans would come to adopt a measure of "do-it-yourselfism" — but he granted that this constituted a "change in lifestyle." He kept his house at 55 degrees.

We discused an experiment in Mississippi County Community College, which had assumed, in its construction, that classes would be run in the evening if it became too hot — a form of lifestyle change that made the college solar methods cost-effective.

Another young staffer felt citizens would come to enjoy having some rooms cooler than others, just as we enjoy the change in seasons — that this was not a diminution in standard of living but just a change. We would all feel better at lower temperatures anyway. She said this did mean "actively making it harder for ourselves in a sense" as a way of making life more interesting.

An expert on wind thought one needed "a different vision of the whole society." I asked what the difference was between the "soft path" and the "hard paths" emphasized by Amory Lovins. He said, "We discuss that often." Apparently, the difference is not easy to pinpoint, e.g. is a space station beaming solar energy to earth "soft?" One staffer described the choice simply as the brilliant political stroke of a skilled polemicist.

A lecture was being given at SERI by Lawrence M. Murphy, supervisor of the Solar Research Office of the California State Energy Commission. Solar, he felt, was "where the action is" politically and environmentally and would "make it" if it's done "right." Electricity from solar power was the area where things might be mishandled partly because the utilities tend to goldplate, and electric is what they're interested in. The utilities could be helpful in retrofitting and in providing the funds to overcome the barrier of initial costs, but public and environmental sentiments won't permit the utilities fully into action.

Hearing him speak, one realized that California was the obvious test site for solar. It had everything: wind, sunlight, moderate temperatures, an environmentally conscious population, a tradition of experimentation, a large fraction of the scientists interested and proficient in these matters, and a good deal of money. (It even had the aerospace companies that liked high technology, and they had apparently influenced Governor Brown to encourage the notion of beaming solar power down from enormous space stations, despite obvious environmental hazards.)

The state was offering large tax incentives to help solar along. But Murphy had some information that people are treating relevant regulations as they did "Prohibition." Would people someday put a cheap solar collector on their roof to indicate compliance, but really be relying upon their backup sources for all their energy? (Later, a leading environmentalist suggested that, if necessary, regulations might require that homes got a certain percentage of their energy from solar sources. But he had no answer as to how one could draft such regulations in the face of the crazy-quilt national pattern of differing homes and differing availabilities of solar energy.)

At lunch the conversation turned to solar's problems of gaining acceptance. Did one need warranties for as long as the payout period (the period at which the installed system paid for itself)? Had New Mexico passed the first law on sun rights to protect the installers of collectors against interference with "his" sunlight? Could solar collectors be paid for by taxes as one paid for streets and sewers? The lunch table economist, Michael Yokell, scored a number of times with the economist's perennial: "It depends upon details."

Melvin Simmons is the assistant director of SERI in charge of analysis assessment. In an interview he warned of a "mismatch between expectations and realities." People did not realize how hard it was to develop and implement a new energy source. Congress could get unduly disappointed. There was some concern that the experience of the 1920s and 1950s, when solar power had been anticipated but failed, might happen again. If this happened again, it could be serious for solar.

Another SERI official is so worried about this felt-to-be-inevitable backlash that he feels SERI is virtually being set up for it and will be held responsible! He felt that SERI would be judged by events beyond its control: *viz.* the rate of commercialization. Most of solar was, after all, a "systems problem" in which many people had a say in how fast it grew. He felt Congress talked solar because it got votes, but did not really put its money where its mouth was. Solar was waiting another crisis. And it needed some kind of solar czar, a solar Admiral Rickover.

Simmons felt there was too much early demonstration and eagerness to bend metal. Congress had a good political sense in pushing for demonstration programs, but this was, unfortunately, where the "big bucks" got consumed. The real competition with solar was not with coal but with conservation.

In the evening, Yokell, an FAS member, discusses the key question: Could solar flop and how? We discuss some ways: if products are oversold and without warranty; if they have a warranty but the warranty backer starts to take a big loss; if solar requires excessive tampering with the economic system to make it competitive; if sonar requires improving the efficiency of a whole industry (e.g. housing) to make it effective; or if it should require inappropriately high expectations of future fuel rises.

Apparently a lecturer at SERI had argued, recently, that the cost of flat plate collectors (for hot water and space heating) was already small in comparison with the costs necessary to sell and distribute the product. This means reducing the price of the solar gadget itself could have little effect. For example, Yokell's fuel bill was $30 a month. If people required a five-year payout to motivate them, as they often do, and if one assumed that the interest rate, the inflation rate and the rise in energy prices were about the same, and that the collector saved 70% of the fuel bill, as is often assumed, then only $1,260 could be afforded.

At dinner with FAS member Steven Schneider, the climatologist, we discussed solar "drought." In the first place, he said, one must calculate the number of solar days with great care and over long periods. A change, for example, in "persistent cloudiness" could be disastrous for such calculations and the variability of the weather was typical and notorious.

A visitor asked whether we were coming to depend on the climate at just the time when mankind was worrying about climatic instability. Would we know if the climate were changing or would we be unsure whether anomalous weather was simply an aberration? Apparently this would depend upon whether we rolled the new emerging calculations in with the old, long-term ones, or alternatively recognized them, *a priori*, as signifying more than an isolated change.

What, one wondered, if a whole region of the country sized its solar collectors and backdrop inappropriately? (Presumably one would — as one does with water management — prepare for, say, the 20-year "drought" and suffer through the bigger droughts that occurred less frequently. But what if 50-year solar droughts started coming every 10?) After years of independence from the weather and the climate, were we planning to return to it?

Clearly this is not a near-term problem because solar is moving very slowly and we are at a low level of dependence. Also, in time, as we come to recognize the problem, we are likely to hedge heavily against it to prevent prolonged "brown out." But such hedging is an economic drag on solar's progress since it undermines the savings that would otherwise result from reducing backup.

The CO_2 problem, Schneider said, had escalated over five years from a question that would not go away to a troubling concern. What, one wondered, if a movement arose in the next few decades calling for a coal-burning moratorium? Solar would certainly not be ready. □

—JJS

PESSIMISTIC ABOUT SOLAR ENERGY

I am very pessimistic about solar energy. Heating water seems all right at present. Space heating is marginal: Under the best conditions (cheap price, long life of solar, best climate for solar application) it may compete with the prospective price of synthetic gas (of course not with natural gas). Solar heating may possibly improve by new ideas like those of Ted Taylor, using seasonal storage for a large complex of about 100 houses; but the engineering has not yet been done and there is no reliable cost estimate. In any case, only 10% of the total energy consumption is for domestic heating. Large-scale solar energy (e.g., electricity production) seems hopelessly uneconomical; even the best known method, the power tower, appears to cost at least three times nuclear power. Research for better method is in order, but solar energy is unlikely to make a substantial contribution in the 20th century. *—Hans A. Bethe*

Physics, Cornell University

DISASTROUS DECREASES IN SOLAR ENERGY POSSIBLE

I would urge a very high priority for research on solar energy, but I am quite unqualified to discuss the engineering problems involved. Obviously, since solar energy is diffuse, the initial capital investment, in money and energy, must be large in proportion to the power output for a given design; but the equipment, once in place, should operate a long time with little need for replacement, and relative freedom from pollution is a great asset. For solar electric power I would favor many small plants, operating locally, rather than a few big ones. Occasional big ones could be placed in desert areas, provided the energy can be converted into forms that can be stored and transported, e.g. liquid hydrogen (though there may be better ways to do it).

However, there may be occasional disastrous decreases in solar energy. In northern New England they still talk of 1816, "the year without a summer" or "eighteen hundred and freeze-to-death." Actually it was a disaster throughout the western world, and probably everywhere, with widespread famine and starvation in Europe, and seething political unrest. It followed the great volcanic explosion on Tomboro, east of Bali, in 1815, which poured hundreds of cubic kilometers of dust into the air, and dimmed sunlight throughout the world for the next year. Such a catastrophe is something we have to think about, in planning for the future. This should not diminish our zeal in planning for the development of solar power, but we have to bear such extreme contingencies in mind. *—John T. Edsall*

Biology, Harvard University

ONLY SOLAR PATH LIKELY TO BE VIABLE

Solar power will make it or humanity probably will not. Sooner or later, to survive, *Homo sapiens* is going to have to learn to live within a rather severe set of ecological constraints. To do so there will have to be a constant low level of throughput and an aggregate level of energy use not much different from that of today. While long-term energy needs of a sustainable society might conceivably be filled by fusion reactors or even fission breeder reactors the advantages of the "soft" path to solar are overwhelming —

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so much so that the choice of a different path would in itself be a sad omen for our species' future. —*Paul R. Ehrlich*
Ecology, Stanford University

VAST SCOPE FOR INNOVATION

Every essential energy need of modern society can be met using existing technologies that consume no fuel, produce no net CO_2, and employ no bomb-grade materials. Vast scope remains for technological innovation and cost-cutting, but the basic viability of solar, wind, and biological energy sources is not under serious question.

Because all renewable sources *combined* have received less than one five-hundredth of post-World War II federal energy funding, they have not developed vested interests in the private sector or strong champions in the research community. This situation will change sharply if Congress boosts the solar program into the billion-dollar range for fiscal year 1979. —*Denis Hayes*
Worldwatch Institute

SOLAR IS THE BEST BET

There are only three energy sources that might be able to support a high-energy civilization essentially indefinitely: fission breeders, fusion, and solar energy. Of these, solar is the most accessible, the most certain to work, the most readily matched to a wide variety of end-use forms and scales, the least threatening environmentally, and the most compatible with the needs, resources, and capabilities of the developing countries. Yet some say we can't afford it. I say that, when social and environmental costs and risks are counted along with economic ones, we can't afford to pass it up. —*John P. Holdren*
Energy Resources, U.C. Berkeley

RICH VISTA FOR HEATING AND COOLING

I am enthusiastically for solar energy, my primary focus being on what the sun is already doing for us: photosynthesis and other indispensable contributions to man's genesis and survival. The very last of them however will be the use of sunlight for electric power utilities. In between there is a far richer vista of small scale devices for controlled heating and cooling but also for mechanical energy and electricity generation in special circumstances and locations.

I hope that the obsession with sophistication and bigness of the DOE bureaucracy (ex-ERDA, nee AEC) does not inhibit vigorous development of a variety of small solar devices, including the electrolytic photovoltaic cells which may deserve strong efforts. —*George B. Kistiakowsky*
Chemistry, Harvard University

PREMATURE SOLAR REGULATION CONDEMNED

Solar heating of new buildings is economical right now — if the solar architects chosen happen to be among those who are familiar with the latest trends in passive-system design. Adding solar heating to existing buildings is much more difficult, but many inventors are working on the problem, trying to find lower-cost solutions, and they may succeed. What worries me is the escalation of intervention by well-meaning federal and state governments: their 100-page books of performance standards for solar heating equipment tend to discourage inventors and small, innovative manufacturers. —*William A. Shurcliff*
Physics, Harvard University

WITH EFFORT, SOLAR BREAKTHROUGHS POSSIBLE

No single answer applies to the future of solar power because many ideas and forms are involved. On the everyday level, architectural and home practices to utilize sunlight are ancient; they can be effective and need increased attention. On the out-of-this-world level, a space station for collecting sunlight and beaming energy to earth is uneconomical under presently predictable conditions. Between these extremes are solar heating of water, which is increasingly attractive and should be commonplace in many climates, and various not-yet-economical systems for converting sunlight into electricity. Some attractive devices such as efficient solar cells are expensive at present. However, there is no fundamental reason this or other forms of direct conversion of solar photons into electrical or chemical energy cannot be cheap, as is illustrated by the low cost of green leaves. Such important potentialities warrant extensive research, the outcome of which is not predictable except that with effort mankind usually finds ways of doing needed things if they are not against basic physical laws. For success, serious national efforts and wise choices, including giving both scientists and entrepreneurs adequate scope for efforts in this field, are critically important. —*Charles H. Townes*
Physics, U.C., Berkeley

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