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Photovoltaics Program
Technology Development and Applications
Lead Center

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Photovoltaics Program Utility Interface Southwest Regional Workshop Proceedings

September 9-10, 1980

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Prepared for
U.S. Department of Energy
Through an agreement with
National Aeronautics and Space Administration
by
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

(JPL PUBLICATION 81-32)

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FOREWORD

The Photovoltaics/Utility workshop reported in this document came about because of the confluence of several forces: By 1980, the technology status of photovoltaics had progressed to the point that its prospects and potential in major installations needed to be addressed. In this decade, partially because of the difficulties encountered with other options and because of some of the intrinsic qualities photovoltaics offered, the utilities in the sunbelt, and California in particular, became interested in photovoltaics as a possible generative option. In addition, the State of California had taken an aggressive posture toward adoption of renewable energy resources and encouraged utilities to avail themselves of any of these technologies that proved viable.

These factors led to a meeting in January 1980 of Paul Maycock, Director of the DOE Photovoltaics Energy Division, Jerry Yudelson, Director of the State of California Solar Business Office, and Bob Forney, Manager of the Jet Propulsion Laboratory, Photovoltaics Technology Department and Applications Lead Center. The meeting in turn led to a resolve to bring utilities in the southwest closer to a position that would allow them to capture the benefits of the rapidly developing photovoltaics technology. The first step was to inform them of the technology status, expose them to DOE plans for furthering the technology, and seek their reactions and guidance. This workshop was the result.

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ABSTRACT

The Photovoltaics Program Utility Interface Southwest Regional Workshop was held at the Huntington-Sheraton Hotel in Pasadena, California on September 9-10, 1980. This was the first of a series of regional workshops that will focus on the photovoltaic and utility interface, and the use of photovoltaics as a cogeneration option by utilities.

The Proceedings defines the needs and constraints of the utilities and establishes an understanding of the capabilities and limitations of photovoltaic systems as an alternative electricity generation option by utilities.

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PHOTOVOLTAICS PROGRAM
UTILITY INTERFACE
SOUTHWEST REGIONAL WORKSHOP

Prepared by: Irving S. Bengelsdorf, Scientific Writer

THE WORKSHOP

The U. S. Department of Energy (DOE) and the California Institute of Technology/Jet Propulsion Laboratory in collaboration with participating DOE Field Centers jointly sponsored a DOE Photovoltaics Program Utility Interface Southwest Regional Workshop. The workshop was held on 9, 10 September 1980 at the Huntington-Sheraton Hotel, Pasadena, California.

Of the 120 attendees, 33 were associated with utilities in the Southwest region. The presence of several top-management officers of utilities indicated an increased interest in photovoltaic systems on the part of utilities--a change in outlook from as recently as the past year. At this particular workshop, the participants generally found that photovoltaic development was progressing faster than they had previously been aware and that the program goals, when met, would put photovoltaics on a competitive footing with several other alternative electricity generation options.

This paper is essentially a summary of the proceedings of this Southwest Regional Workshop and in no way is intended to be a definitive document concerning the technical, economic or institutional aspects of photovoltaic energy.

Reasons for the Workshop

Photovoltaics (PV) refers to the process that directly converts sunlight into electrical energy. The basic sunshine-collecting and electricity-generating unit is a semiconductor material (usually silicon) fashioned into a solar or PV cell. Numbers of PV cells are combined together to form a PV module, and numerous PV modules, in turn, can be interconnected to form a PV array. The complete PV generating system--the PV array, the power conditioning equipment, the wiring, and the necessary auxiliary devices--is called a PV system.

Because of its modular construction, a PV system can be small, intermediate or large. But regardless of its size--whether it is a small PV system on the roof of an individual's home (2-10 kW peak power), or whether it is a large generating facility (2-200 MW_p)--a PV system can act as a power producer to feed electricity into the already existing electrical grid systems now operated and maintained by the nation's utilities.

The prospect of many thousands of individual homeowners with rooftop PV systems injecting a flow of electricity into a utility's grid system--a so-called reverse flow--introduces a new technical dimension for a utility. Traditionally,

utilities have been involved only in the one-way flow of electricity--from utility to customer.

Also in contrast to traditional utility operations involving central control of their capacities to supply power, utilities now must handle power from numerous small producers--each of which has a variable output dependent upon the variable nature of the sunlight falling upon its particular PV array. The additional need to convert the DC-power generated by a PV system into the AC-power carried by a utility's grid calls for some additional equipment at the interface between a utility and the PV-equipped generator.

Furthermore, the Public Utility Regulatory Policies Act (PURPA), passed by Congress in 1978 as part of the legislative package known collectively as the National Energy Acts, requires the utilities to pay for the power that an individual homeowner or other cogenerator offers the utility's grid. The amount fed back to the grid can be appreciable; an example given at the workshop, which may not be typical, involved the output of an experimental $8kW_p$* PV system in Phoenix which was divided as follows: 37% of the electricity generated was used in the house, and 63% was sold to the utility.

*Because the power output of a PV system is variable, it cannot be rated in the same way (watts, kilowatts, megawatts) as can the output of a traditional thermal or hydroelectric power generating system. The output of a PV system is rated as peak, under standard conditions of sunlight (insolation) and temperature. Thus, a PV system will put out its rated power output--8 kilowatts peak ($8kW_p$) in the above-mentioned case---when the insolation is $1kW/meter^2$ at a temperature of 45°C.

The passage of PURPA has introduced a new set of <u>institutional</u> considerations that have not heretofore been required. Among these is the question of determining the price the utility should pay a cogenerator or homeowner for the electricity "sold back" to the grid.

In spite of these problems, there are countervailing forces toward adoption of PV in many applications. Among these are federal and state income tax credits and property tax exemptions that will work to hasten the proliferation of small residential PV systems. The desire for a tax shelter or tax benefits may work to introduce residential PV systems into our society sooner than if only normal market forces prevailed. In addition, the growing confidence that the DOE Photovoltaics Program will meet its 1986 cost-reduction goals--the reduction of the cost of a PV system down to about $1,500-2,000/kW$_p$*--should hasten the incorporation of large central PV systems. Such systems, if available now, would likely make PV systems cost-competitive in many Southwest applications today. So, whether utilities are comfortable with PV systems or not, several speakers at the workshop indicated PV systems are coming--and they are probably coming sooner than was originally expected.

For these reasons, the DOE Photovoltaics Program decided to sponsor a series of workshops--of which this Southwest Regional Workshop is the first--to encourage the utilities to

*All costs are given in 1980 U.S. dollars.

express their views, their reservations, their doubts and their questions about PV systems in general, and the DOE PV Program in particular. Conversely, the workshops offer an opportunity to utilities to become aware of the ongoing development and evolution of PV systems in America today.

It must be emphasized that it is not the intent of the DOE PV Program to restrict PV applications only to small systems or to large central utility systems. Both extremes may find use--along with a wide range of intermediately sized PV systems. The marketplace eventually will determine the actual mix.

PLENARY SESSION COMMENTS

Several workshop attendees presented their views on the future of PV systems. Remarks ranged from guarded pessimism to unbridled enthusiasm.

Speaking on the cautious side, Louis Winnard, General Manager of the Los Angeles Department of Water and Power, indicated that the high cost and low efficiency of PV systems would limit their use to special applications only--unless there was a major technological breakthrough in terms of cost and/or performance in the future.

In contrast, Russell Schweickart, Chairman of the California Energy Commission, in his keynote address, claimed that the only thing that will stop the coming of PV systems (particularly small, individually owned, rooftop systems) would be what he called a technological "breakdown." Schweickart believes that the interaction between "Big Dumb Silicon"--the PV array on the roof--and "Small Smart Silicon"--the home microcomputer controlling the flow of PV-generated electricity--will give rise to heretofore non-existent feedback loops between customers and utilities.

The ability of an individual customer to act as a small power producer--to inject his excess PV-generated electricity back into the utility's grid--will greatly alter the present one-way flow of electricity and monthly bills from a utility to its customers. It will be replaced by two-way interactions that will change the traditional role of

utilities and will blur the boundaries and distinctions between "customer" and "utility." Schweickart not only feels that PV systems are coming, but that they are coming faster than anticipated. We may already be too late in envisioning how to make the best use of the ongoing PV revolution.

According to Paul D. Maycock, Manager of the PV Energy Systems Division of the U. S. Department of Energy, the widespread skepticism among energy professionals towards the DOE PV program's goal of reducing the cost of PV systems to $\$2,000/kW_p$ by 1986 is rapidly being replaced by a belief that the goal is realistic and will be met. There apparently are no physical, technical or engineering reasons that preclude the use of distributed PV systems--small PV systems placed on rooftops. But before such systems are put on homes, detailed experiments are needed to show these systems are reliable, durable, efficient, and esthetically acceptable.

Even though the largest PV system built and operating today is only 250 kW_p, Maycock feels a large-scale, central PV system could be economical in California as early as 1986. A 1-10 MW_p, grid-connected test system is needed to provide performance data to utilities to make large-scale PV systems credible. Perhaps such tests and demonstration systems could be financed by a trilateral partnership of federal and state agencies and utilities.

An analysis of the key technical and institutional problems involved in the DOE PV Program's goals of technology

readiness (by 1982), systems readiness (by 1984), and commercial readiness (by 1986), and their impact on utilities, was outlined by Donald G. Schueler, Manager of PV Projects at the Sandia National Laboratories. The six key issues in the development of PV systems were identified as: the interface between PV systems and the utility grid; sellback constraints and rate structures; institutional barriers; technological developments; government policy options; and the strategy of the commercialization of PV systems.

The idea of having millions of dispersed, small PV systems generating electricity and feeding their excess power into a grid is an alien concept to utilities, who think in terms of a few large, central generating systems. New technology has to be developed for a mutually compatible integration of the existing utility grids with the many small, individual power producers. J. Charles Smith of DOE described the DOE program underway to achieve this technology integration. From his experiences, Smith indicated the utilities have expressed a desire for greater communication between DOE and utilities concerning technological developments.

Roger D. Bourke of JPL substituted for the ill and absent Robert F. Riordan of the University of Kansas Center for Research, Inc., and reported on a national conference held in Topeka, Kansas, in May 1980, entitled "The Integration of Solar Energy into Utility System Planning and Strategies:

1980-2000."* One of the recommendations of this Kansas conference--that more discussion and workshops are needed--was coincidental with the decision to hold several regional workshops, of which this Southwest Regional Workshop is the first.

The key issues that have to be considered by utility planners before a utility accepts any new power-generating technology were reviewed by Edgar DeMeo, Program Manager of the Solar Power Systems Program of The Electric Power Research Institute (EPRI). That utilities are interested in solar energy is borne out by their research activities during the last five years. The number of utilities involved in solar research projects has increased from 52 in 1975 to 220 in 1980, and the number of solar research projects has also increased from 125 projects in 1975 to 781 projects in 1980. Although the bulk of the research activity is involved with solar heating, this activity has leveled off for the first time in 1980. The greatest increase in solar power-generating alternatives involves wind power because the utilities are encouraged by results in this area. A good deal of the information developed from the wind program also could apply to PV systems.

DeMeo's own thoughts concerning PV systems are that the interest of utilities in this form of power generation will grow commensurate with the progress of PV systems in the

*Copies of the proceedings of the Kansas Conference can be purchased from Mr. Riordan at $25 apiece.

field. It does not make sense for utilities to commit large amounts of money for as yet unproven and emerging technologies. More field tests and operating experience with PV systems are sorely needed.

One of the key issues involved in a utility's acceptance of a new power-generating technology is proof of reliable operation. Hundreds of MW-years of experience were required of gas turbines before they were accepted by utilities as part of their conventional power systems. Because PV systems are a long way from such detailed and cumulative experience, efforts must be made to start to get experience with large-scale PV systems. DeMeo feels that when the economics are ripe for the proliferation of rooftop PV systems, utilities will become heavily involved with all aspects of their use.

VIEWPOINTS OF UTILITIES REGARDING LARGE-SCALE CENTRAL PV SYSTEMS

Large-scale, central PV systems are attractive from a supplier's standpoint because they can result from a single decision and represent the largest potential PV market. They are attractive from the utilities' standpoint because they are a non-oil-consuming generating capacity, and operation and maintenance can be controlled by a single entity. From a convenience view, large-scale central PV systems are also attractive since there are minimal social and institutional changes necessary in a society that already uses central, large-scale electrical generation.

There are many advantages of using large-scale PV systems to generate electricity. Compared to conventional power plants:

a. PV systems should be relatively trouble-free to operate (no moving parts) and maintain (straightforward procedures).

b. The solar energy is independent of railroads, pipelines, and highways--although it does vary greatly with time.

c. Air pollution should be at a minimum; no effluents at the power plant site.

d. PV systems use little or no water--a big plus in their favor.

e. PV systems are silent.

There are, however, disadvantages. Compared to conventional power plants:

a. Some participants claimed PV systems use more land than other options. There was a difference of opinion as to whether land would be easy or difficult to obtain. Some felt it was a serious consideration. There was no agreement as to how much PV power could be generated from a given land area. Although there are calculations indicating the expected watts/area, the utilities feel actual performance tests are needed to establish these values.* There also may be an esthetic problem. No one knows the degree to which environmental changes may be caused from the photovoltaic arrays.

b. PV systems have a variable output from the solar position and are greatly dependent upon the weather. Thus, some utility spokesmen considered PV systems without electrical storage to be "losers." Yet, other participants from the PV Program felt that the

*Ed. Note: From the operation of existing PV experiments and commercial systems, the land area requirements for flat-plate, fixed tilt, silicon PV Systems are well-known. A system with 10% efficient modules in the Southwestern U.S. requires approximately 5 square miles (3200 acres) per 100 MW_p. Land area requirements for tracking or concentrator systems may differ and are not as well understood. Changes in device efficiency also clearly affect land area requirements.

storage of electrical energy was not necessary for PV systems. During a discussion period, it was pointed out that the cost of electricity storage from a PV system (or any other electrical generating system) is about 10 times greater than the cost of heat storage from a solar thermal plant. Proponents of PV emphasize that a major advantage of PV is that it generates peak power output at roughly the same time of day there is a peak demand of power from the utility. But even in Arizona, there is not an exact fit between the curves of peak solar insolation and that of peak load; the load peak continues after the solar peak declines. A spokesman for the Arizona Public Service utility claimed that for his particular utility a storage time of three hours would make a PV system much more valuable than without storage. Some participants from utilities felt that the question of storage should receive serious consideration and be a major effort in the DOE PV Program.

c. PV systems are currently too expensive. PV systems now run about \$15,000-30,000/kW_p (although it was recognized that the 1986 goal of the DOE PV Program is to bring this down to about \$2,000/kW_p). This is partially offset by the low operating cost of PV, but it is not yet clear that the PV combination of high capital costs and low operating costs is

superior or inferior to the conventional combination of low capital and high operating costs. It was repeatedly emphasized during the workshop that the cost of PV systems must compete not only with oil, but also with other energy sources--including other solar alternatives. It was felt by many that some sort of solar power--PV or others--will be competitive with the various alternatives. A recent poll of utilities has revealed they currently favor wind turbines as the nearest-term, competitive, large, renewable power generator.

d. The performance of PV systems is both intermittent and variable. Because of this variability and intermittency, utilities feel they would have less control of their generation and dispatch of PV power. PV systems are "free-running;" there is no way to turn sunshine on or off on demand. Similar, but much less severe problems sometimes are faced in the hydroelectric generation of power.

There was a great deal of complex controversy as to whether PV systems offer capacity credit to a utility (and if so, how much), or whether they should be considered only as fuel-savers. The question was raised in the Workshop as to how one places a value on a PV system that is not operating all the time, yet is statistically reasonably reliable.

Utilities are also concerned about the long-term service qualities of PV equipment. Materials must not only have long

lifetimes of 30 years or more, but a base of reliable suppliers must be in place before many utilities would consider PV systems. The question was raised as to whether or not there was enough silicon manufacturing capacity available upon which to base a large PV industry capable of furnishing PV systems in the hundreds-of-megawatts range. Spokesmen for the manufacturing industry responded that, while there may be near-term capacity limits, they did not see any problem in the long-term.

The utilities repeatedly emphasized the need for more information concerning the long-term installation, performance, operation and maintenance of large grid-connected PV systems. Unless data are forthcoming from at least one 1-10 MW_p plant, utilities will have no good basis to evaluate PV systems. It was pointed out that although a $10MW_p$ PV system now is a large system as far as PV is concerned, its electrical output is rather inconsequential to a large utility. There also is insufficient information on the optimum size of PV modules and power conditioners for a $100MW_p$ central PV system.

When asked if they could help fund a large-scale PV demonstration project, the utilities responded that most of them are strapped for funds and that their ability to fund large systems, that cost more than the value that can be derived from them, is small. It was suggested, however, that a utility might pay that portion of a large-scale demonstration project that provides value to the utility in the form of

added electrical capacity, but that the utility looks to the federal government to provide the capital for those portions of the project beyond its value to the utility and those stemming from technical and cost risks.

Some workshop attendees not associated with utilities chided the utilities for their slow-to-move attitude and general disinterest in the DOE PV Program. The utilities were encouraged by a California State Government representative to be leaders in the development of new power-generating technologies rather than followers.

Many utility personnel said they found the workshop educational, and they now want to stay abreast of PV developments.

VIEWPOINTS OF UTILITIES REGARDING SMALL-SCALE DISTRIBUTED PV SYSTEMS

The advent of numerous, small, residential PV systems raises many technical questions including 1) how these individual systems will be tied into a utility's grid, 2) how the grid will accommodate the numerous small inputs, and 3) how the necessary DC-to-AC conversion affects a utility's power system. The utilities are particularly concerned about the performance of power conditioners--the devices that change a PV system's DC into AC.

A "consensus" of opinion--not all participants agreed--rated technical issues high, medium, and low, according to the potential troubles they are perceived to present. These issues are collected by degree of difficulty below:

Technical Issues With a High Rating

a. Power factor: More discussion was spent on this subject than any other. In an AC-power system, the utility supplies power (measured by the product of RMS voltage and RMS current, volt-amperes). Of this power supplied, the amount actually used to do work is that which has potential and current in phase and is called watts. If the amount of useful power (watts) is the same as the amount of volt-amperes supplied, then the power factor is unity (the ratio watts/volt-amperes=1).

If the power factor, however, is less than unity, then the utility must put out more volt-amperes than is actually being consumed by the load. These additional, out-of-phase, volt-amperes, supplied by the utility, are called volt-amperes reactive (abbreviated as vars) and represent power pumped into the grid that is incapable of doing work. It costs money to generate reactive power, but it is of no use to the customer and produces no revenue.

A utility may be able to operate with a power factor as low as 0.85. But, to date, the limited performance data of power conditioners used in small, residential, experimental PV systems indicate the equipment known as line-commutated inverters puts out electricity at power factors in the range 0.35 to 0.60. Hence, a large fraction of the power fed by this system to the grid would not be useful to the utility. To boost the power factor nearer to unity, some type of power factor corrector is required.

If a PV system were to feed electricity into the grid with low power factors, it would not only contribute to high line losses, poor voltage regulation, and oversizing of distribution transformers, but it also could require that the utility supply compensating vars. If the utility does so, then who will pay for these vars--the utility or the

homeowner? And, since currently used meters do not record reactive power, how will they be measured? This was recognized as a problem amenable to technical solutions. One suggestion was to put a var-meter into each PV system-equipped home or otherwise specify the power factor quality of utility purchased power.

One possible solution is for the utility to provide a DC power line or bus to a group of PV-equipped homes. A group of homes then could share a single, large power converter that would have an improved power factor and result in a lower cost to each homeowner.

Some attendees felt the power factor problem was greatly exaggerated.

b. Harmonics: The waveform of the AC-electricity current or voltage put out by a power conditioner of a PV system-equipped residence may be distorted compared to the waveform already in a utility's AC-grid. This could lead to a degradation of the grid's power quality and to many potential problems as: overheating of motors, interference with telephone operation, malfunctioning of relays, etc. Some attendees felt the amount of distortion was low and could be easily corrected. But others felt there was a potential for constructive harmonic injection from several homes tied to the same grid

transformer such that their effects are directly additive. This was one of the issues identified for further action.

c. Equipment Protection: How does one insure adequate protection of both the utility's equipment and the homeowner's PV system? What happens if, in the absence of an isolation transformer, a fault in the power conditioner dumps the PV system's DC output onto the AC grid? The situation is worse if the PV system also has battery storage. And what happens to the PV system if there is a fault in the grid's AC-line? It was felt that various devices and techniques were necessary to isolate the two systems from each other. There remained a question as to how their costs would be borne.

d. Personnel Protection: In case of required maintenance, utility personnel must have access to the PV system to shut it off while necessary inspections or repairs are made. This means the PV system's outlet may have to be housed in a specifically colored box, and a padlock mechanism to insure that the PV system is off may be required. Or, radio-controlled switches may be required.

e. Utility Feeder Regulations: What sort of changes (if any) may be required in the utility's feeder lines that run from distribution substations to homes?

Technical Issues With a Medium Rating

a. Radio Interference: Will the DC-to-AC conversion interfere with radio reception?

b. Sizing of Utility Equipment: Will the addition of numerous PV system power producers require changes in the sizing of utility grid equipment?

c. Reverse Power Flow: A utility's grid-distribution system is designed for unidirectional electrical flow. Will a utility's grid system be able to handle the reverse flow of electricity from numerous generators? Suppose many residents are away from their PV-equipped homes on a particular day. There is little load demand from the utilities at precisely the same time that home PV systems would be putting out peak power. The incentive to keep the PV system on is to earn money from the power sold back to the utility. Some attendees felt this issue should be labeled low instead of medium because reverse flow apparently is not a problem until it gets to be twice the line- rated capacity. It could become a problem if there is a high penetration of residential PV systems. Reverse power flow can affect a utility's voltage regulation equipment and its requirements for protective relays.

Technical Issues With a Low Rating

a. Interface Boundary: What are the problems involved in connecting individual PV systems to the grid?

Who bears these interconnection costs? What will the various switches look like? Utilities now have few specifications for these interconnections and there are no national standards.

b. TV Interference: This is not considered a difficult issue.

c. Installation and Maintenance: Many participants felt there would be fewer utility problems associated with the installation and maintenance of a single, large, central PV system than with distributed, roof-top systems.

d. Metering Requirements: This is a technically solvable problem even though special metering arrangements involving added costs may be necessary to measure both input to and output from a home. Are DC KWh-meters needed? Or, time-of-day meters?

e. Phase Unbalance: Since residential PV systems are single-phase, what are the problems if PV systems load up one phase compared to others?

f. Line Fluctuations and Load Following Capability: Are there any dynamic problems associated with transients in the grid if a large cloud suddenly masks the sun?

And if there is a high penetration of small, residential PV systems, will the grid be able to adjust to various changing loads as the amount of sunlight available fluctuates? How fast can an electrical

reserve, represented by spinning machinery, be spun up or down to meet these changing conditions?

It was repeatedly emphasized that most of these problems would not exist if PV systems were central rather than distributed. It was claimed that central PV systems were simpler and less costly even though a large-scale PV system also has the problem of DC-to-AC conversion.

Several utility spokesmen complained that haste and pressure in pushing residential PV systems are detrimental to the orderly, intelligent incorporation of new technologies into utilities. For example, the Arizona Public Service Company recently decided to build a PV-equipped home as a test bed for investigating utility interface questions. However, before they had even started, John F. Long, a developer in Phoenix, built a model PV home, announced the planned construction of 100 more homes--to be followed by thousands. From the Arizona Public Service Company's viewpoint, the electrical output from the J. F. Long model home is troubled with low power factor and harmonics problems.

Homeowners who decide to install a PV system to save money often can accomplish the same end--for one-third the cost--by insulating the home. Some attendees proposed doing both--insulating the house and installing a PV system. It also was pointed out that the better a home is insulated, the greater the discrepancy becomes between the time of peak solar insolation and peak load demand by the home; this will act to shift the total peak demand from the utility.

Some attendees felt that one advantage of residential PV systems compared to large, central utility PV systems is that no land acquisition is necessary--the home rooftops already are in place. There also is a question as to whether a PV system on a roof will increase the resale value of the house. If it does not, then the economics for the homeowner in installing the PV system are questionable.

Finally, it was pointed out that we should keep in mind that no matter how many rooftop PV systems there are distributed throughout an area, the back-up power--when the sun isn't shining--comes from a conventional utility grid system.

ECONOMIC, LEGISLATIVE, AND REGULATORY FACTORS AFFECTING PV SYSTEMS

The introduction of a new technology often is plagued with institutional problems that may be far more intractable than the technological problems. Consider PURPA, the Public Utility Regulatory Policies Act passed by Congress in 1978. Its three purposes are: 1) to encourage conservation of electricity by the utility's customers; 2) to encourage more efficient use of fuel and capital resources by the utilities; and 3) to set equitable rates for non-utility generators of electricity. Section 210 of PURPA, aimed at encouraging development of alternative energy sources, is important for PV systems because it governs the rates that owners of PV systems will be paid for the electricity they sell to utilities.

There are mixed reactions to PURPA. Some utility spokesmen referred to PURPA as a poor compromise that has satisfied nobody; other workshop participants spoke of the legislation as beneficial.

In response to PURPA, the Federal Energy Regulatory Commission (FERC) has published a set of rules aimed at attaining PURPA's goals. The FERC rules and the PURPA legislation do not set rates directly, but they require the individual states, through their Public Utility Commissions (PUCs), to set rates that comply with the FERC rules.

So, state PUCs must act by March 20, 1981, to set rates that comply with the FERC rules. These PUC decisions, as to what rate a utility has to pay to "buy back" electricity from PV system owners, could lead to numerous legal appeals by the utilities.

Traditional rate setting, with only one-way flow of electricity from utility to customer, has always been difficult. PV systems must function in this complex arena with the added feature of two-way electricity flow.

Despite the PURPA legislation there is no straightforward technical or economic solution to dividing the costs of electricity production among many users. It requires a regulatory solution implemented by each state. Because of this, much uncertainty exists in the design of rates for PV systems. Obviously, these rates may determine whether PV systems are economically attractive.

Not only are there problems in deciding the buy-back rate from a PV-equipped customer, but how does one deal fairly with the customer who has no PV system? He has no home-generated electricity either to reduce his inflow of electricity from the utility, or to sell his excess electricity back to the grid. Yet, regardless of these difficulties, PUCs have to make rate decisions soon. It was suggested that the beclouded issue of rate setting is what is keeping utilities from getting involved in distributed PV systems.

Suspicions were aired that the effect of PURPA may be to prevent the customer who cannot afford a PV system from benefiting from the new technology. PV systems may mostly benefit those in high income tax brackets who will use their residential PV systems as a tax-shelter. An interesting question is whether the money a residential PV owner earns through sell-back of electricity is taxable.

Some attendees wondered whether the incentives that encourage small, residential PV systems act to discourage large central PV systems? Does it make economic sense to have numerous small-scale PV systems? Which costs more--a single 100 MW_p central station or 10,000 residential PV systems each of 10 kW_p? A detailed assessment of distributed PV systems has been completed for EPRI by the J.B.F. Scientific Company of Boston. The results are to be published shortly. Several members of the workshop session suggested that the assumptions that went into this assessment be carefully evaluated.

In a discussion of economic models, it was pointed out that it is not too difficult to set up models to calculate the economic aspects of electricity-generating systems, in general, and PV systems, in particular. But are these analytical models credible? There was also discussion as to whether these models could be used to provide informational feedback to PURPA so that FERC possibly could change its rules. Several participants emphasized that PURPA is not set in concrete; the regulations that have stemmed from it should be changeable.

Some attendees considered regulation to be a political rather than an analytical process, and that analytical models are not useful. Furthermore, utilities are not uniform; each utility must be considered on an individual basis. The economics of a utility in the Northeast is not like that of a utility in the Southwest.

Finally, with respect to PV systems as an alternative source of energy, it was asked that if it was in the national economic, political, and military interest to reduce the nation's dependence on oil, then how is this value determined and who pays? How much is this worth? And what is the value of the social benefits accrued in having a more environmentally benign source of generating electricity?

Other institutional problems associated with PV systems may be zoning--neighbors may object to "ugly" blue-colored, reflecting roofs. There also are the questions of sun rights, building codes, and defining and meeting standards such as those of the Underwriters Laboratories.

The liability question was raised: with whom does liability lie--particularly at the utility-PV system interface? The utility or the PV owner? Installation problems could arise if interjurisdictional disputes grow up among unions. Responsibility for maintaining numerous, small, individual home PV systems is not currently clear--it could be either the utilities or private maintenance companies. Access to home PV systems could be a problem since they are on private rather than utility property. Even now, utilities have a difficult

time gaining access to customer's meters. Building codes may also be a problem for residential installations although this was seen as minor from a utility's viewpoint. But there is tremendous inertia in the building industry.

THE STATUS OF PV SYSTEMS TODAY WITH RESPECT TO THE DOE PV PROGRAM

Essentially, one can think of the following four categories of PV systems:

a. Stand alone: These are power-generating systems located in remote regions removed from utility grids. There now are a million Diesel or gasoline engines that generate 100 kW or less for about 200 days per year. These engine systems, although relatively cheap to install, use expensive fuel at up to $2.50 per gallon. Some of these systems can be replaced by PV systems costing $4,000-5,000/$kW_p$ as early as 1982. The already existing demand for remotely located PV systems is running ahead of expectations of the DOE PV Program.

b. Residential: The development of residential PV systems is proceeding with one-of-a-kind experimental homes equipped with rooftop PV systems. Although the DOE PV Program now does not have an economic and reliable product, it may turn out that a favorable combination of federal and state tax credits could accelerate the early purchase of home PV systems in numbers beyond those expected by the DOE Program.

c. Intermediate: Since potential commercial and industrial users of intermediately sized PV systems

receive substantial rebates on the oil they burn, their motivation to turn to PV systems was considered low. Thus, it was thought that this particular PV market had lots of time to develop. But universities and colleges--who run the risks of power outages during the day because they are not high on the list of priority customers of a utility--now can borrow money at 4% interest to construct buildings equipped with PV systems. This also may accelerate the installation of intermediate-sized PV systems.

d. Central: Some prominent solar energy studies have concluded that central PV systems would not be viable until the year 2000. But the manager of DOE's PV Program feels they will be here sooner than that--even though we now do not have a PV system upon which we can put a 20-year warranty, or even a power conditioner that works well. But these things are coming, and when they do--combined with performance data obtained from the operation of large-scale demonstration plants--central utility PV systems will be on their way.

SOME RESULTS AND RECOMMENDATIONS OF THE WORKSHOP

The workshop pinpointed numerous technical and institutional problems associated with the introduction of central and distributed PV systems into American society. Yet, most participants agreed the workshop represented a valuable first step in the exchange of views and information between the representatives of utilities and those involved in the DOE Photovoltaics Program.

Because it was felt that this information exchange is important and should continue, it was proposed there be increased and improved dissemination of the written reports put out by the various projects of the DOE PV Program. Upon request, these reports readily can be made available to the utilities. It was also proposed that a calendar of the meeting dates of the various conferences, symposia, workshops, and seminars dealing with photovoltaics should be distributed to all interested parties.

In turn, the utilities proposed the construction of a large-scale PV system to study its performance, to obtain information to serve as a guide for the construction of future, central station PV plants, and to disseminate the results of their testing.

And, finally, the topics discussed and questions raised at this workshop could serve as guidelines for the planning and organization of similar regional workshops to be held in the future.

APPENDIX A

AGENDA

AGENDA

PHOTOVOLTAICS PROGRAM UTILITY INTERFACE
REGIONAL WORKSHOP

Sponsored by:
United States Department of Energy, and
California Institute of Technology,
Jet Propulsion Laboratory

Huntington-Sheraton Hotel, Pasadena, CA

TUESDAY - SEPTEMBER 9, 1980

7:30 a.m. - Registration

9:00 a.m. - 12:30 p.m.:

Session 1 - Plenary Session

Chairman - Louis H. Winnard
General Manager & Chief Engineer
Los Angeles Department of Water & Power

1.0 Keynote address

Russell Schweickart
Chairman, California Energy Commission

1.1 DOE Photovoltaics Program Overview

Paul D. Maycock
Department of Energy

1.2 Photovoltaics Systems Development

Donald G. Schueler
Sandia National Laboratories

1.3 DOE Utility Interface Activities

J. Charles Smith
Department of Energy

1.4 Summary of Conference on Integration of Solar into Utility System Planning

Robert F. Riordan
University of Kansas Center for Research, Inc.

1.5 Utility Viewpoint of Requirements Involved in Incorporating Alternate Energy Sources

Edgar DeMeo
Electric Power Research Institute

12.30 p.m. LUNCH

2:00 p.m. - 5:00 p.m.:

Session 2 - Parallel Workshop Sessions
Identification of Critical Issues

Chairman - Donald G. Schueler
Sandia National Laboratories

2.1 PV/Utility Interface Issues

Chairman - John Wells
Pacific Gas & Electric Company

Organizer - Masood Hassan
Jet Propulsion Laboratory

2.2 Economic, Regulatory, Legislative Issues

Chairman - Albert Robison
Public Service Co. of New Mexico

Organizer - Richard Tabors
MIT Energy Laboratory

2.3 Engineering Design and Operational Issues

Chairman - Donald Penn
L.A. Department of Water & Power

Organizer - Gary Jones
Sandia National Laboratories

5:00 p.m. - 6:00 p.m.:

Session 3 - Plenary Panel Discussion:
Summary of Parallel Workshop Sessions

Chairman - Donald G. Schueler
Sandia National Laboratories

Panel - John Wells
Pacific Gas & Electric Company

Albert Robison
Public Service Co. of New Mexico

Donald Penn
L.A. Department of Water & Power

6:00 p.m. - 7:30 p.m. RECEPTION

WEDNESDAY - SEPTEMBER 10, 1980

8:30 a.m. - 11:30 a.m.

Session 4 - Parallel Workshop Sessions
Evaluation of Current DOE/Photovoltaic Plans

Chairman - Neil H. Woodley
Solar Energy Research Institute

4.1 Photovoltaics Central Station Power Plants

Chairman - D. L. (Bruce) Broussard
Arizona Public Service Company

Organizer - Stan Leonard
Aerospace Corporation

4.2 Residential Photovoltaics Systems

Chairman - Wayne R. Schmus
Southern California Edison Co.

Organizer - Charles Cox
MIT/Lincoln Laboratory

11:30 a.m. - 12:30 p.m.:

Session 5 - Plenary Summary Session:
Summary of Parallel Workshop Sessions

Chairman - Neil H. Woodley
Solar Energy Research Institute

Panel - D. L. (Bruce) Broussard
Arizona Public Service Company

Wayne R. Schmus
Southern California Edison Company

12:30 p.m. LUNCH

1:30 p.m. - 3:00 p.m.:

Session 6 - Plenary Session
Workshop Summary and Future Plans

Chairman - Robert G. Forney
Jet Propulsion Laboratory

APPENDIX B

LIST OF ATTENDEES

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UTILITY INTERFACE
SOUTHWEST REGIONAL WORKSHOP
September 9-10, 1980

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