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PREFERENCES AND CONCERNS OF POTENTIAL USERS IN THE SELECTION OF SOLAR THERMAL SYSTEMS FOR INDUSTRIAL AND SMALL UTILITY APPLICATIONS

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PREFERENCES AND CONCERNS OF POTENTIAL USERS IN THE SELECTION OF SOLAR THERMAL SYSTEMS FOR INDUSTRIAL AND SMALL UTILITY APPLICATIONS

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ABSTRACT

To achieve widespread application in the industrial and utility sectors, solar systems must be economically competitive. Economic viability is, in turn, determined by a number of supporting criteria, ranging from system reliability to dispatch characteristics to how the system supports the main product line. In addition, solar systems possess some inherent attributes that may render some of the traditional supporting criteria inappropriate or require their redefinition. This paper discusses those criteria and their relation to the solar investment in three steps. First, the main concerns and preferences of the potential users, as identified in recent SERI studies, are identified. Second, the equitability of the resulting decision criteria for solar investments are examined. Finally, the implications of these criteria for solar energy's penetration into these markets are discussed.

INTRODUCTION

Since early 1978, SERI (the Solar Energy Research Institute) has been extensively involved in evaluation of the technical and economic feasibility of solar thermal power and process heat systems. Evaluations conducted in two recent studies have the common purpose of comparing different possible collector types and system configurations to help insure that the allocation of government funding supports the most promising concepts. Our primary purpose has been to judge the potential of these systems from the point of view of the end user. Two application areas and the appropriate user groups have been addressed. The potential use of solar thermal systems in the generation of electricity for utility applications was examined in the first study (1). The second study, to be completed this year, investigates the use of solar thermal systems to provide heat for industrial processes (2). During the course of these studies we have consulted with nearly fifty industrial and utility decision makers in order to obtain a comprehensive understanding of their concerns and preferences. The purpose of this paper is not to report on the results of the system evaluations, but rather to convey the results of our interactions with industry and utility decision makers. We feel that an understanding of their concerns regarding use of solar energy is an important step on the long path toward eventual commercialization. In addition to the background provided by our own work, we have drawn from several recent studies concerned with the problems of commercial acceptance of solar energy systems. The Gas Research Institute (3) addressed the integration of solar energy with existing gas fired systems, and the potential impact on the gas market. Insights West under subcontract from SERI broadly surveyed the attitudes of industry toward the use of solar energy (4). A concurrent study at SERI (5) has examined the dynamics of the decision process in industry, concentrating on the decision criteria surrounding the primary economic factors. Sandia Laboratory has explored the utility industry's acceptance of a particular solar thermal concept in a series of interviews (6). The major contributions of the authors' analyses has been the coupling of a comparison and evaluation of the most feasible systems from the technical, i.e., system design and performance viewpoint, with an evaluation as it is made in the market place.

The presentation of this paper follows in four parts: (1) general background material concerning the solar systems examined and the decision analysis approach exercised to model user preferences; (2) a brief schematic of the study's overall methodology, concentrating on the process used to elicit end user preferences; (3) results in the form of a summary of user concerns and preferences; and (4) an evaluation of these results with regard to their impact on the implementation of solar thermal systems. This last point at once raises questions pertaining to the appropriateness of often used decision criteria, and at the same time illustrates the impact of these criteria on the development of solar energy systems for commercial application.

BACKGROUND

Solar thermal systems directly use the heat in solar radiation, converting or concentrating it to provide useful energy. Several examples of the types of systems examined in our studies are currently being demonstrated throughout the country. Southern California Edison, in conjunction with the Department of Energy and the California Energy Commission, is funding a 10 MW_e pilot plant for the generation of electricity using the so-called "power tower" or central receiver system at Barstow, California. Georgia Power Company is constructing a field of parabolic dishes at Shenandoah, Georgia, to test the capability of that technology to generate electricity. Numerous examples of cost-shared and wholly owned solar thermal systems are currently providing process heat to a broad spectrum of industrial users. One of the more well-known applications is at the Campbell Soup plant in Sacramento which combines a parabolic trough and flat plate system to provide hot water for can washing. Many variations of the flat plate collectors, widely used for domestic hot water heating, are capable of providing low temperature process heat. Two systems using unconventional forms of collectors, the shallow solar pond and the salt gradient pond, have been examined for their potential to provide heat and generate electricity.

A simple schematic of how a solar thermal system can be used to provide heat to an industrial process is shown in Figure 1.

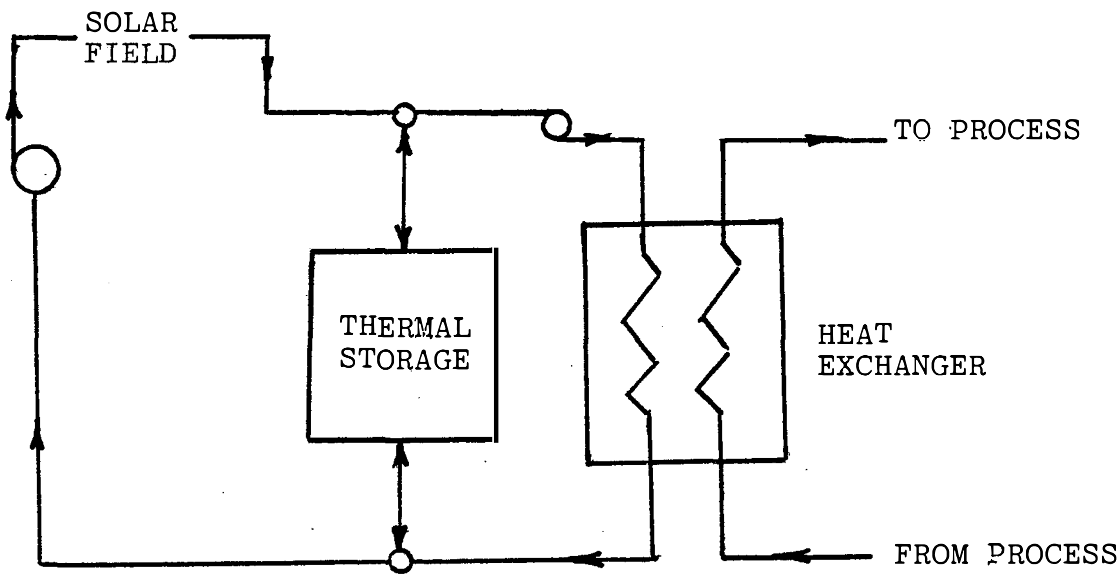

FIGURE 1. PROCESS HEAT SCHEMATIC

Sunlight concentrated via the solar collectors provides the heat source in place of or in conjunction with a conventional gas or oil fired boiler. A working fluid in the solar system is heated, then passed through a heat exchanger where the thermal energy is transferred to the process heat medium (steam, hot air or hot water). One unique aspect of the solar system is the optional addition of storage to capture excess or unused (e.g., weekend) energy. A simple example of storage is a hot water tank or a tank of high temperature molten salt. The schematic for generation of electricity is analogous, although somewhat more complex, since a variety of engine types were examined (the Stirling, Brayton, and Rankine cycles).

The solar thermal systems were examined in the fuel saver mode only; i.e., replacing the burning of conventional fuels. Alternate sources such as photovoltaics, wind energy conversion, biomass and synthetic fuels were neither examined nor used as a basis for comparison. An hourly simulation model was used to evaluate the performance of the various concepts. These simulations provided volumes of performance data. However, to effectively use this data in evaluating system acceptance, we needed to define quantitative and measurable attributes germane to the eventual end user's purchase decision.

The approach selected to methodically and quantitatively assess how a decision maker would evaluate a solar system was multi-attribute decision analysis (MADA). A straightforward and simple explanation of MADA is given in Appendix C of (1). The essence of the procedure as applied here is described from this Appendix:

> The problem was first reduced from an objective to a set of independent criteria that are measured by quantitative or subjective attributes. Because the complexity

of the formal analysis does not allow the consideration of more than ten attributes, it is necessary to select attributes that are: (1) important to the decision, (2) independent, (3) measurable, (4) differentiable characteristics of the options being considered, and (5) familiar to the decision maker.

During the second step, interviews were conducted with decision makers or their surrogates to obtain the proper data that could be used in a simulation of a decision maker's thought process. A simple method of questioning was developed for use in this study, permitting assessment of utility preferences over the scale of each attribute and the relative weighting of each attribute in a short series of lottery-type questions.

In the third and last step, results of the interviews were used to calculate the coefficients of a multiplicative form of the utility function. Given the actual attribute values of a system, the value of this function is an absolute and quantitative measure of the utility or preference of the system to the decision maker. An ordering of these values then provided a ranking.

A more comprehensive explanation of MADA is contained in (7). Details of how utility functions quantify user preferences and how the relative importance of each attribute was assessed is also given. One point worth stressing here is the weights assigned to the attributes depend not only on the importance of the criteria being measured, but also on the range of values to be judged. For example, cost is significant to the purchaser of a car, but if all models under consideration are within $100 of each other in price, then cost becomes a second order consideration. This point is crucial in avoiding misunderstanding of the relative importance of environmental concerns as mentioned later.

Preliminary to discussing the results of the interviews conducted during our studies, we will next describe how the interviews were structured and with whom they were conducted.

INTERVIEW METHODOLOGY

The first step towards defining the decision process to be used in evaluating the system is, of course, to define the users whose viewpoints are to be modeled. Although representatives of large utilities were among the interviewees, the electric power study concentrated on sizes (.1 - 10 MW_e) more appropriate to smaller utilities. Thus, the majority of interviewees were from small to mid-size utilities, including small investor owned, public and municipal utilities and rural cooperatives. To gain overviews and inputs from special interest groups we also interviewed utility consultants, trade journals, public utility regulatory bodies and R&D personnel. The smaller size systems (less than 1 MW_e) were more relevant to a different end user group in need of an independent source of electricity because of unreliable or high cost sources. Such users include small communities, the minerals industry, military bases, small or dispersed government institutions (e.g., the National Park Services) and the agriculture industry. For thermal applications in industry, the relevant end user group includes any industry with significant thermal needs occurring below 1100°F. Three major categories of industrial users, differentiated by varying degrees of knowledge concerning the decision to purchase solar energy were sampled. The first and by far the largest group includes those who have little familiarity with the possibilities of solar energy related to their operations. The second group consists of five companies currently in the throes of assessing alternative solar thermal systems. These companies are vying for participation in a DOE-sponsored demonstration program. The final category includes companies who have installed solar thermal systems, usually cost-shared with the government. This last group has actual hands on experience and indeed may become the prime source of information for other companies considering solar energy.

Initial contacts with these end user groups were used to evolve a working decision model appropriate to each group. This model was fine tuned to final sets of criteria through preliminary interviews. Three models were developed: one for the utilities (1-10MW_e plants); one for the small electric power users (.1-1 MW_e); and the final for process heat users. Table 1 summarizes, in descending order of importance, the criteria selected for each group. Also included is the "bottom line" or overall criterion most often used as the best single gauge for acceptability.

Utilities	Small Electric Users	Industry
Capital Cost	Payback	Payback
Capacity Factor	Capital Cost	Rate of Return
O&M Costs	Capacity Factor	Reliability
Safety		Capital Cost
Environmental Effects		Availability
R&D Costs		
Application Variety		
	Bottom Line Criterion	
Levelized Bus Bar Energy Costs (BBEC)	Payback	Payback/ROR

TABLE 1. DECISION CRITERIA

The variation of decision criteria reflect not only a shift in emphasis for the user group, but also our experience in weeding out unimportant criteria and those difficult to deal with in a quantitative manner. The MADA models built to include these criteria provided the basic structure for the interviews. While such rigid models were not appropriate to all members of each group, the models did provide a focus for the interviews and were necessary to establish a consistent basis for comparison from one decision maker to another. Most interviews started with a discussion of the decision we were trying to analyze and an untethered description of how this decision was currently being made. Interspersed throughout the interviews and summarized at the end were qualitative or subjective concerns which did not fit into the decision model, but certainly were significant, and often gave us information on attributes which for one reason or another we could not assess. A prime example of this last category is the general area of risk. However, enough has been said of a general nature; now to the actual results uncovered.

RESULTS

Although these results were illuminating, they were not surprising. Overall, decision makers were receptive to the possibility of solar energy. There was broad agreement that solar energy might ultimately play a large role in providing energy to all sectors of our economy. However, it is not surprising that few agreed that long-run potential provides a defensible basis for making near-term investment decisions. As is evident from the ordering of criteria in Table 1, economic factors dominate the ultimate decision. The utilities stressed that capital cost and capacity factor were most significant, with O&M costs close behind. These three criteria determine the BBEC, utilities' bottom line criterion. Reluctance to pay more than $2000/KW_e$, 1990 installed cost (1980 dollars) often removed many of the solar systems, ranging from $1500 to more than $3400/KW_e$, from consideration for utility applications. The more subjectively quantified attributes, safety, environmental effects, R&D costs, and range of application were relatively unimportant. The first two attributes (as in the case of the $100 difference in car prices mentioned earlier) did not vary significantly from system to system, hence they did not attract a great deal of attention. R&D costs and variety of applications were simply not of significance to utility decision makers. Small power users and industry both used payback (simple, after taxes) as the primary criteria. Capital cost was more significant to the small power users because it reflects how they traditionally assess their investments and also because it is not well reflected in their primary attribute (payback period). Industrialists place a greater reliance on a combination of rate of return and payback that internalizes the effects of initial costs. Further, the small power users often either do not directly control their own funds (as in the case of government institutions) or have severely limited capital (as in the case of farmers). If we generalize from the three sets of decision criteria, user concerns seemed to cluster about three issues: risk, system performance, and economics.

No criterion addressing risk appears in our first two models because we were unable to effectively differentiate between the advanced systems (not yet built), the performance of which we were predicting into the 1990s. Reliability was included in the last model in an attempt to quantify its role in the purchase decision, even though data is still not available to defensibly differentiate between the systems based on that criterion. As applied here, risk includes not only the issues of whether or not a solar system will perform as expected, but such problems as permit requirements or pricing policies by gas or oil suppliers to customers no longer using large and predictable volumes of fuel as well. First, we treat the risks of this last category.

Risk is a factor to be minimized for almost any investment decision. A high-level of risk implies a high degree of uncertainty which, in turn, implies a greater potential for disaster. If only because they are new, solar thermal systems are associated with a large amount of risk. Every aspect in which the solar thermal system differs from the conventional system increases the level of perceived risk. The reduction of that risk can, in turn, only come about through experimentation and experience (preferably hands-on).

For decision makers, risk can encompass a wide range of possibilities, ranging from institutional arrangements to the economic effects of environmental problems to technical problems of system integration. On the institutional level, a key consideration of risk for industry stems from the fact that it often purchases natural gas at a reduced price as an interruptible customer. Were a firm to make a large commitment to solar energy, the gas utility would become what might be termed an interruptable supplier. That in turn could result in the firm losing access to gas at the cheaper rate.

Electric utilities are justifiably concerned about environmental problems (witness nuclear power plant construction delays) from the standpoint of risk management. Although solar energy is generally considered an environmentally benign technology, the case is far from proven, and the reaction of agencies like the EPA to a large solar thermal power plant is yet to be observed. Specifically, the impacts of a large solar collector field on runoff or local plant ecology may affect the ability to speedily obtain permits.

At the technological level, risk takes on the guise of system reliability. The distinction between risk and performance blurs somewhat and in reality system performance is part and parcel of the risk concern. It is such a large concern that we treat it separately here. Questions of system reliability usually must be answered at the engineering department level before any serious consideration will be given a new system. Feelings about this issue were very consistent across both industry and utility decision makers. A typical comment was, "First, our engineering ensures that the design will meet our reliability standards and only then do we examine the cost effectiveness of it." Questions about whether a cheaper but less reliable design would be considered seriously often produced a negative response. While utilities plan for a given amount of unscheduled down time for each generating unit, industrial plants often do not. The question of what constituted an acceptable level of unscheduled down time generally brought the response,"None!" Instead, preventative maintenance might be scheduled during plant down times. An oft voiced comment from manufacturers was that an unnecessary energy investment was generally peripheral to their main production, hence of lower priority. The possibility that such an off-line system could interrupt production was viewed as a distinct negative point. "We produce widgets, not BTUs" capsulized this sentiment.

Utilities, on the other hand, produce power as their business, so alternative energy investments are given considerable attention. Reliability is a problem of utmost importance because the solar system becomes part of their main line product. Further, utilities typically must work with state PUCs, who tend to take a dim view of speculating rate payer's money on unproven technologies. We found a consistent concern about several of the unique and as yet unproven concepts associated with some of the solar thermal systems (for example small distributed Brayton and Stirling cycle engines, each located at a separate collector). The utilities felt far more at ease with central generating concepts using conventional steam cycle turbines.

While questions of risk and technical performance generally must be answered first, there is no doubt that economic considerations are premier. In each of our three decision models, economic measures carried the most weight by far. Generally, one of two evaluation approaches is used. Small power users and the majority of industry use simple payback (see also (3) and (4)). The remainder of industry and the utilities use some form of rate of return analysis. Levelized bus bar energy cost, rate of return, and life cycle costing techniques are similar in that they involve the time value of money and the entire lifetime of the system. These techniques contrast with payback, and herein lies an important distinction. A simple example of this distinction is illustrated in Table 2.

	Scenario 1	Scenario 2
Cost	$1,000,000	$1,000,000
Economic Life	20 Years	20 Years
Escalation in Income (or Energy Savings)	0%	20%
First Year Savings	$100,000	$39,000
Payback Period	10 Years	10 Years
Rate of Return	7.75%	15.75%

SIMPLE (NON-DISCOUNTED) PAYBACK VS. RATE OF RETURN

TABLE 2.

This table could well illustrate the difference in results between an alternative energy investment in the decades of the 1950s and 1960s (0% fuel escalation) and one in the 1970s (20% fuel escalation.) Payback is the same for both investments, rate of return has doubled in the 20% escalation case. The comparison is an extreme example of current comparisons of energy saving investments to other investments where income may track inflation (6-8% over the 1970 decade). The point is still valid: payback does not take into account the full economic implications of an investment. However, payback does give an idea whether the money invested is returned to the company before it has gone bankrupt or in time to invest in other near term opportunities. Keeping in mind the dichotomy of these thoughts we move to the next section.

INTERPRETATION

One important result of the industry/utility consultation has been the gradual emergence of two related but distinct conclusions. First, solar thermal systems embody, as energy delivering technologies, some new and unique aspects that must be considered in any complete evaluation. Decision makers should be made aware of these aspects and how some traditional outlooks should be changed to accommodate them. Second is that industrial and utility decision makers have developed evaluation procedures that are generally reflective of and well suited to their particular needs and that any ultimate commercial acceptance of solar technologies is dependent upon satisfying those procedures in the near term. In other words, it is necessary that, through education and increased familiarity, decision makers come to understand some of the unique factors of solar technologies. On the other hand, it is vital that the solar equipment manufacturers and government agencies realize solar systems must conform to industrial standards of achievement before commercial acceptance can occur.

How are solar systems unique? There is no doubt that solar thermal systems mark a departure from traditional energy conversion systems. The first, and most obvious difference, is that these systems do not "burn" fuel. Instead, they redirect and concentrate thermal radiation from the sun. This leads us to the second difference: because solar systems are fueled by sunlight, they do not (without some form of storage) operate at night or during overcast periods and, hence, are not naturally suitable to be a base load type of system. Third, because sunlight is the fuel, variable costs consist only of operation and maintenance. Fourth, because a solar collector array must be distributed over a large, outdoor area, the systems integrate somewhat differently with existing equipment. Fifth, based on the above differences, ideal uses for solar thermal systems may be somewhat specialized (for example, preheat water for a boiler). A sixth, and most basic difference, is that solar thermal systems are new to industrial/utility decision makers and, as such, must gradually earn their confidence.

This section examines how these unique solar aspects relate to the rationale behind the three primary concerns of risk, performance and economics as discussed in the previous section. We also speculate on how these concerns can be accommodated by changes in R&D and commercialization strategies.

To this point we have noted how risk works to the detriment of solar energy. There are some risk reducing aspects to be noted briefly. A 10 MW_e solar power plant could be constructed in as little as 1-2 years (of course, the permit problems alluded to earlier must be solved) as compared to 6-12 years for nuclear or coal-fired plants. Admittedly, 10 MW_e is a small plant, but the capability to construct small and modular plants may be a distinct advantage. The modular idea was particularly appealing to industry. The ability to start with a small plant and, if the results proved encouraging, move to larger systems was seen as a good way to minimize economic exposure. Another risk reducer is the perhaps overworked reminder that fuel supplies may be interruptible. But a more tangible point for industry may be that fuel prices are so uncertain that long range plans are impacted by this variable. Once performance records are established, solar systems will have a more stable impact on cash flows, though the initial impact might be large.

In order to make the product attractive, sponsors of solar technologies are forced to come to grips with the individual issues such as risk. For the utility market with its lengthy planning horizons and need for large scale demonstrations, resolution will be a lengthy process, and there are few prospects for near-term commercial inroads. The industrial market offers better near-term prospects. The key is to concentrate on systems and applications that do not entail a big transition from current ones. Systems that embody a large number of established concepts (low technical risk) will be far more readily accepted. Advertising solar technology as being a "whole new way of doing things" may be useful for a residential market. However, in an industrial market, a better approach is to make the new idea appear as much like the old one as possible. One advantage of a system which uses simple, recognizable technologies (e.g., steam as a transport fluid instead of molten salt) is that a lower risk premium may be assigned. This is important because often a company may assign a premium in the form of higher required rates of return to projects perceived as risky. Therefore a costlier, but more straightforward system, may be a preferred alternative. This point was established in (6) where utilities preferred water and steam cycles in the near-term even if other fluids were more economical in the long run.

Regarding the performance issue, the prime concern stems directly from the intermittent nature of solar energy. This is an issue which is not as well understood by industry as it is by the utilities. While they are quick to ascertain that a 100% backup is necessary, industrialists still require stringent reliability standards. To wit, a system that allowed individual collector lines to be shut down while the rest of the system remains functional has obvious advantages. However, even if the solar system does not provide energy continuously, as long as the economic requirements are met and control problems are manageable, interruption may not be a show stopper. The place of storage in mitigating this problem should be mentioned here. Although energy cycled through storage is generally more expensive than that used directly from the collectors, storage can be used to even out transients in energy supply. The use of waste heat recovery tanks in common with solar storage will lower the costs of storage and at the same time effect a useful conservation measure. Cogeneration is an analogous situation for the utilities.

But the bottom line is still economic feasibility. As mentioned previously, rate of return calculations are economically more correct (see (8)) than payback. Sponsors of solar technologies are well aware of this fact and of the advantage of using ROR to show the economic possibilities of solar energy. However, a communication barrier often arises when they attempt to convince a firm that relies upon payback that solar energy can be a useful option. The problem is to show that an after-tax return on investment calculation is neither especially difficult to perform nor understand and is not merely a numerical trick designed to enhance the promise of a solar system. Rather, it is a reliable method that can easily account for all measurable influences on an investment and evaluate their impacts represented as a single number: percentage rate of return.

It is not our attempt to dismiss payback as short-sighted, hence incorrect. The necessarily short planning horizon that confronts capital poor industrialists and small power users provides ample rationale for using payback as an important economic indicator. Perhaps it is more a burden on the solar manufacturers and R&D community to recognize and adapt, than to expect this decision criteria to change. We can only make limited suggestions here. Is it possible to make a system which may not last as long (say 10 years), but is cheaper and yet reliable and has a quick payback? The question has not yet received sufficient attention. In the initial stages of commercialization, is it important to provide systems with lifetimes exceeding the expected lifetime of many of the potential applications? Will we fall into the trap into which pocket calculator manufacturers have run? Potential buyers hesitate to purchase because a new model, cheaper and more powerful, will come along well before the current model is no longer useful.

CONCLUSION

What can be learned from reading this paper? Three major points can be culled from our work. First, we sketch a procedure for evaluating solar technologies stressing the importance of incorporating user concerns. By referring to the brief list of references, the reader may gain valuable insights into how to perform a comparative evaluation of innovative technologies. Second, the paper provides a summary of important concerns and the insights we gained into the decision process used by utilities and industry in evaluating alternative energy concepts. This information should be valuable to manufacturers, proponents and government R&D centers because it will help define the atmosphere they will encounter as they venture into the marketplace. Finally, and most importantly, the decision criteria are examined critically. We hope decision makers will reassess their decision process in light of what has been said here. We also hope that some of the suggestions made will be useful to those firms trying to design and market solar systems. Herein lies a common ground of unbiased (at least not intentionally biased) information for use in the interaction between the suppliers and the users of solar energy.

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