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THE AVAILABILITY OF CAPITAL FOR DEVELOPING PHOTOVOLTAIC MARKETS

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ABSTRACT

Capital availability is not a problem in a well-functioning market. However, the market for photovoltaic cells is immature; in fact, the market for grid-connected photovoltaic applications (the primary concern of this study) does not yet exist. Therefore, the capital markets cannot easily evaluate the credit-worthiness, the economic attractiveness of the variety of photovoltaic production processes, research programs, or end-use applications currently being developed. Only when photovoltaic technologies converge to a roughly standardized set of mass production methods and consumer applications will private capital markets perform their job of allocating financial resources to the photovoltaic industry. Until then, investigations into the question of capital availability for this industry must focus on firm-by-firm "case" studies.

This paper examines capital availability for both the production and consumption sides of this young industry. The experiences of photovoltaic producers in obtaining and allocating capital are described for three groups: oil company photovoltaic subsidiaries, electronic firm subsidiaries, and independent producers. This discussion is based on telephone and personal interviews with officials of the companies described.

The capital availability problems of solar thermal consumers provide a basis for anticipating such problems for future photovoltaic grid-connected consumers. This basis is used to project the probable behavior of capital markets once mass production is economically feasible. Recent Congressional hearings on the creation of a Solar Energy Development Bank provide the primary backdrop for this discussion.

It is concluded that given no change in federal programs to support photovoltaic production and/or consumption, only "large," capital-rich firms will enter the mass-production of photovoltaic cells. Small independents can survive only if they are proficient in serving the specialty, or systems, photovoltaic market. Large firms not currently active in the photovoltaic industry will enter production through acquisition or accelerated research programs once the mass-production market develops and the profit potential is recognized. Finally, consumers will have difficulty in locating financing for their photovoltaic purchases for some time after the mass market opens up.

Recommendations include (a) no government subsidies until private industry defines the best photovoltaics technology, and (b) creation of a Solar Energy Development Bank after mass markets develop to dissolve the reluctance of financial intermediaries to lend.

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I. INTRODUCTION

> "It is not currently possible to define the socially optimal level of investment in solar technologies because neither the social benefits to be gained from solar utilization nor the costs necessary to achieve solar utilization have been adequately defined or analyzed."[1]

This paper addresses the following request as it appears in section 10(c) Part (4) of Public Law 95-590, the Solar Photovoltaic Energy Research, Development, and Demonstration Act of 1978.

> "(Report on) the availability of private capital at reasonable interest rates for individuals, businesses, and others desiring to establish commercial enterprises to manufacture, market, install, and/or maintain photovoltaic components and systems, or purchase and install such systems for private, industrial, agricultural, commercial or other uses..."[2]

Several problems arise in interpreting this request. These problems must be discussed so that we may clarify the purpose of this paper. The most troublesome language includes:

(a) availability: In a well-functioning market adequate capital will be available for all projects which are "economic;" that is, if the expected net cash flows of a project (investment) are discounted at a rate (or rates if an adjusted present value method is used)[3] which reflects the risk[4] of the project, and if the investment's net present value is positive, then capital will "flow" to the project as investors attempt to capture part of the positive value. To explore capital availability for the photovoltaic industry, one must examine risks and expected returns of specific applications of the technology; that is, the

type of photovoltaic investment should be specified, thereby identifying the investment being considered.

In this discussion we address the problems of capital availability for grid-connected photovoltaic arrays used by residences and commercial establishments. The development of these massive grid-connected markets implies a very large decrease in production costs from current levels. We assume that automated, mass-production techniques accomplish this reduction in cost, and that the level of production cost reached is $2.80/peak watt (all dollars in 1980 dollars). At this cost "the debate ends regarding whether or not a market exists for mass-produced photovoltaics," according to one leading independent producer.[5]

It is important to note that, in a well-functioning market, when producers and consumers "agree" on a price which assures an "adequate" profit for the producer, this producer's problems in obtaining capital are greatly reduced. This mass-production, $2.80/Wp event thus provides a "watershed" for capital availability to photovoltaics and the ending point of this analysis. Therefore, we will address the difficulties in attracting capital only until this watershed is reached.

(b) reasonable rates: The rate of return on invested capital demanded by the investor reflects, as mentioned above, the perceived risk of the investment as well as the expected return. Investors are constantly digesting new information on the market portfolio of risky projects, and required rates of return are continuously reestimated based on these evaluations. It is reasonable to assume, therefore, that the market mechanism will set reasonable "interest rates for individuals, businesses, and others" desiring to produce or consume photovoltaic products. Using any other assumption would imply that we have better

information or judgment than the marketplace. In fact, market failures may exist (see below) which distort the evaluation of the market regarding photovoltaics. However, these failures, if they exist, should not persist for long. Therefore, our assumption that reasonable interest rates on capital for producers and consumers of photovoltaics is the most prudent assumption we can make. This assumption eliminates the need for us to provide some artificial methodology for defining reasonable interest rates for photovoltaics.

(c) individuals, businesses, and others desiring to establish commercial enterprises . . . or purchase and install . . .: The development of the photovoltaic industry and the evolution of new applications of photovoltaics technologies are being carefully watched by potential producers and consumers alike. Naturally, when the price of grid-connected photovoltaics is low enough to stimulate the demand which warrants large-scale production, "individual businesses, and others" who presently have no real interest in photovoltaics will "desire" to save or provide capital for the industry. However, evidence of the desire to invest in photovoltaics (or any venture) is reliable only after a price has been agreed upon and the transaction is made. It is, therefore, not a very useful exercise to search for those who may provide capital in the future and to try to estimate the degree of their desire for investing in photovoltaics. A useful estimate of this degree is available only at the time the producer or consumer exercises the right to buy into mass-produced photovoltaic products. We therefore focus our attention on currently-operating producers of photovoltaic arrays and those businesses committed to a serious program of research and development in photovoltaics. In our examination of consumers, we will use consumer

experience in solar space and water heating to provide information on their problems in obtaining capital.

In addition to the unclear language used in the directive presented in Section 10(c) Part (4), two further assumptions must be made to refine our understanding of the purpose of this paper. First, an assumption must be made regarding the future role of the federal government in channeling capital to photovoltaics. Second, a time frame must be assumed within which we will examine the problem of capital availability. We therefore employ the following assumptions to further refine the definition of purpose for this paper:

(1) Federal involvement with photovoltaics producers: We assume that no major change in federal policy occurs before the watershed technology is developed. (For example, no major federal procurement plan is implemented.)

(2) Federal involvement with photovoltaics consumers: Little (if any) federal funds are used to assist erstwhile consumers of photovoltaics products. However, the potential for such assistance is contained in legislation pending in both the United States House and Senate. These bills include H.R. 605, also known as the "Solar Energy Development Bank Act," and Senator Henry Jackson's "Omnibus Energy Bill," S. 1308. These pending schemes employ interest rate subsidies and therefore would affect the availability of "private" capital to photovoltaics. We will explore the possible effects of this kind of federal action in the private capital market.

(3) An estimate of the number of years required to reach $2.80/Wp is, of course, impossible to suggest with much certainty. The duration of the struggle to decrease photovoltaics production costs is a function

not only of the production and consumption technologies which are assumed, but also of the price of alternative fuels. The higher the price of substitutes, the sooner markets will develop for grid-connected photovoltaics. Most significantly, the price of oil is, of course, largely determined outside the marketplace in the realm of international politics. This greatly complicates the estimation of the approximate date of the development of markets for grid-connected photovoltaics and the price at which these markets will appear. However, it is reasonable to assume that these markets will develop some time during the 1980s and that the $2.80/Wp price is a reasonable prerequisite to successful photovoltaic marketing. Therefore, it is assumed that $2.80/Wp is realized in the 1980s.

II. DISCUSSIONS WITH PHOTOVOLTAIC PRODUCERS WHICH ADDRESS THE PROBLEM OF OBTAINING CAPITAL

The purposes of this paper are addressed by first discussing capital availability with existing producers of photovoltaics. These discussions, which took place in person and by telephone, explore past, present, and potential issues of capital availability for the photovoltaic industry. The conclusion of this section will address the longer-term capital availability issues as they will be affected by the probable composition of the industry. (In Section III we focus on consumers of photovoltaics.)

> "A limited amount of effort has been devoted to documenting the extent of current private investment in solar technologies . . . No information is collected on the extent of private investment on production facilities, research and development, or future private industry plans. This and other information are essential if the extent of current and future private investment in solar energy technologies is to be adequately described."[6]

It should not be surprising that information on the capital allocation process in the photovoltaic industry is scarce, for the industry is composed of a collection of closely held private organizations and wholly-owned subsidiaries embedded within larger firms. Neither of the photovoltaic industry subsets (the independents or the subsidiaries) is, in general, pressured by (a) private investors who are not also managers or (b) federal agency investor watchdogs (the SEC in particular) to defend management decisions at shareholder meetings, or in annual reports and 10K forms. Therefore, since (a) independents are managed or closely monitored by a few owners, and (b) subsidiary photovoltaic groups are currently "insignificant" components of the firms which own then, little information on the financial management of photovoltaics industry participants is publicly available.

The early stage in the evolution of the technology -- and therefore of the industry -- determines this current organizational configuration. Neither a photovoltaics production or generation technology has surfaced as the 'standard' for the industry. Therefore, research and development is a primary activity within the industry and will continue to be until a major decrease in cost is accomplished. This R&D function requires a secrecy which adds to the difficulty of completing a worthwhile study of the industry at this time.

The purpose of this section is to dissolve as much of this corporate secrecy as is possible in order to describe the problems, if any, of photovoltaic firms and subsidiaries in finding the capital required to reach the automated production stage. This purpose is accomplished by discussing the industry participants' (a) experience with the search for capital to date, and (b) projections of the future configuration of the industry and associated future capital allocation problems. This case study approach makes it difficult to form generalities which would tend to mislead observers of this young, rapidly changing industry.

We concentrate on three groups of photovoltaics producers: independents, oil company subsidiaries, and electronics company subsidiaries. These groups represent major factions in the competition for product development and markets, and therefore are an adequate sample for our discussion. However, we may <u>not</u> assume that these three factions will <u>not</u> be joined by other kinds of firms as the photovoltaic industry matures. No one can predict what types of firms will enter this business (especially through acquisition) once large markets develop and the business becomes profitable. This underscores the limitations of the assumptions used below regarding future composition of the industry.

A. Capital Availability Experience to Date

No one is sure of either the total number of participant organizations in the photovoltaic industry (estimates range between 14 and 20) or the number of those which are independents (up to 13).[7] This imprecision is characteristic of most new industries as new ventures spin off of old, firms succumb to competition for the few markets that do exist, and new, principally R&D, ventures enter the race without fanfare. Four independent producers, Solarex, Optimal Coating Laboratories, Inc. (OCLI), Solenergy, and Sollos Incorporated, were contacted for their insights into the capital availability issues which are pertinent to independents. These insights suggest that variety characterizes the subset of independents much as it does the entire industry.

The capital availability problem "does not exist" for Solarex, according to an official of this largest, and perhaps most aggressive independent. Two corporate European investors each recently purchased a one-sixth interest in Solarex worth over $3 million.[8] In addition, Solarex recently announced purchase of a similar interest by Standard Oil of Indiana. These minority positions were sold, according to this source, to provide the capital necessary to move into the "mass-production" phase of the business. It is clear that, for Solarex, "no problem" exists in raising private capital "for this purpose."

While the original investors in Solarex could have "retired as millionaires" had they accepted one of the several buy-out offers from major firms proposed over recent years, Solarex is "determined to remain independent." A similar resolve, perhaps varying only in degree, is characteristic of other independents and provides the only deterrence to

continued evolution of the industry towards an entirely "subsidiary" composition. (It is apparent that solicitation of further corporate investment would probably reduce the ownership of the original Solarex investors to a minority position.) The possibility of changes in this resolve clearly exists and should be monitored since such change will determine the fate of the major independents in the photovoltaic industry.

The Corporate Controller of OCLI[9] states that equity capital, such as that successfully won by Solarex, is currently the only reasonable source of capital for the photovoltaic industry. Major debt positions are "out of the question" because lenders do not believe independents are good risks for their money. It is too early in the development of photovoltaics markets to seek debt support for plans to expand to a mass-production phase because reliable rates forecasts are impossible to construct -- the markets do not exist.

OCLI has solved this problem in a manner different from Solarex. Having spun off its photovoltaics subsidiary as Applied Solar Energy Corp., (ASEC), ASEC sold out an underwritten public offering of 770,000 units at approximately $10 per unit. Each unit consists of one share of newly issued common stock of ASEC and a ten year warrant to purchase another share of common.[10] (It is not clear at what price the warrant may be executed.) This public offering is a major event for the photovoltaics industry since it provides a signal of the public's perception of the commercial potential of photovoltaics. The offering's success could well spark more widespread interest in further financings of this kind. A major source of capital would then be available to other reputable independents.[11]

Solenergy was formed in the spring of 1978 with three partners contributing a total of $10,000. The president and founder of Solenergy, Robert Willis, was no newcomer to the industry.[12] For five years he headed Solar Power Corporation, a wholly-owned subsidiary of Exxon Enterprises.

Willis realized he needed a "small" line of credit to get started and support his operation. He composed a detailed business plan to support his case with the banks. However, he failed to secure his line of credit with the first ten "so-called venture capital firms" which he contacted. He claims that most venture capital suppliers are not interested in risky new ventures, but rather focus on established but fast-growing concerns (e.g., Wang Corporation). (Willis finally received a line of credit from U.S. Trust.).

The banks he contacted had two principal concerns. First, they were completely unfamiliar with photovoltaic technology, and were unwilling to spend the time necessary to understand its production and application. Willis claims that only U.S. Trust actually read his business plan. Some bankers complained that a business plan for a new firm in a new industry was obsolete before printed. Second, the banks were worried about Solenergy's considerable competition. They wondered how a small business could compete with subsidiaries of Mobil, Exxon, Shell, Arco, Motorola, and Texas Instruments. Willis was not successful in convincing the banks that the survival of a small photovoltaics business would be possible if it offered specialized products to be customized to the consumers' needs. This latter point emphasizes that the nature of the competition is critical to the question of capital availability. Banks want to back winners. It is therefore necessary for undercapitalized industry

newcomers to demonstrate to banks their ability to prosper, perhaps by serving specialized markets which larger firms may not want to serve.

Sollos Incorporated, a small independent headed by Milo Macha, survives in just this way. Macha produces small photovoltaics orders for specialized, mostly foreign markets (i.e., wire-fence electrification in Sweden).[13] He has been approached by several foreign firms and governments (from Greece, Sweden, and Switzerland) who are interested in larger orders than Sollos is now able to produce. Although Macha has "avoided seeking outside capital" to date, he believes that such external capital will be necessary to permit him to expand production and win these lucrative potential contracts abroad. However, Macha is concerned that obtaining the contracts will be "very difficult" at best.

It is therefore clear that among the industry's independents are firms with vastly different approaches and attitudes towards securing private capital for their businesses. As we turn our attention to subsidiary photovoltaic operation, we will see this range of characteristics broaden.

B. Photovoltaics Subsidiaries of Oil Companies

The five major oil companies which house photovoltaic subsidiaries are among the most liquid and most creditworthy of private institutions.[14] For their photovoltaics subsidiaries, therefore, the capital availability problem is not one of locating and securing capital outside the firm; it is one of competing among other new-product subsidiaries within the firm for internal funds. This internal capital allocation process varies among companies and is generally not public information. Moreover, the process is subject not to the rules of the

open market, but rather to the strategic program of the oil company.

While it is true that the behavior of the debt and equity markets responds to investors' perceptions of a corporation's strategic program, even if the investor's perceptions of the managers' total corporate strategy are correct (and they may not be), it would be very difficult to identify those investor responses which are motivated solely by the photovoltaic component of the strategy. Factors other than the isolated capital-worthiness of the photovoltaic subsidiary enter into the oil companies' allocation process. These considerations include managements' (a) estimation of the public relations value of participating in photovoltaic research and development; (b) evaluation of longer-term options to proceed with marketing photovoltaics (capital-rich firms have the luxury of using longer-term planning horizons than do firms which are less well-endowed); and (c) assessment of the "strategic fit" of photovoltaics in their specific oil company. Intra-firm competition for funds is intense, but the game is played by the rules established by management--rules which are not necessarily public information. This section discusses some examples of these rules as they affect photovoltaic subsidiaries.

Solar Power Corporation, as a wholly-owned subsidiary of Exxon Enterprises, must meet certain criteria established for all new businesses in Exxon. Performance is measured using after-tax return on investment on a discounted cash flow basis. The required return varies according to the estimated risk of the project. In general the weighted average after-tax cost of capital for Exxon new ventures is 12%. But Solar Power Corporation "in the long run" will have to earn more than this 12% because of its greater risk relative to other Exxon ventures.

The ROI for Solar Power is not yet defined because the subsidiary is still "on a negative cash flow basis." Exxon Enterprises will allow a longer period of negative flows for Solar Power than for other new product ventures because of the "early stage" of the industry and the "potential size of the market." In other words, the expected return in the long run justifies taking the greater risk inherent in the venture. According to an Exxon spokesman, "We would not get into any business that we thought would would turn out to be a loser." However, the spokesman stresses that Solar Power must become profitable before the advent of domestic grid-connected markets, an event which he believes is "well into the future." He suggests that foreign grid-connected markets will open before their domestic counterparts.

In 1975, Mobil Oil Corporation allocated $30 million to Mobil-Tyco with a mandate to "produce a net positive cash flow within approximately seven years," (that is, by around 1982). According to Jim McNeil, president of Mobil-Tyco, this goal is somewhat flexible. He defines a two-pronged corporate strategy which, if adhered to, will assure Mobil's continued allocation of capital to Mobil-Tyco. First, in the "near-term," Mobil-Tyco must be competitive in the markets for existing photovoltaic applications. Second, Mobil-Tyco must produce at 70¢/watt (in 1980 dollars) in line with the goals of JPL's low-cost photovoltaics array program.

McNeil believes that Mobil-Tyco's participation in the Low-Cost Solar Array Program (and other photovoltaics programs) is crucial to its continued support from Mobil. This participation conveys a sense of long-term potential of photovoltaics--a conveyance which reassures Mobil of the legitimacy of its investments. Therefore, the existence and

visibility of a national program to support the photovoltaic industry in its early stages is crucial to the provision of internal capital to the photovoltaics subsidy by a major oil firm.

Shell's photovoltaic subsidiary, SES, (SES does not produce photovoltaic cells yet, but is on the threshold of doing so) must eventually be competitive and profitable in a "very large" market for Shell to retain its interest in the firm, according to a very reliable source within Shell. "With no mass market for photovoltaics, our interest would go to zero." For Shell, therefore, photovoltaics must be big business. The prospect of profitable operation in the small, specialized markets of today is not attractive for Shell management. If it appears that the firm could survive and prosper in specialty markets, Shell will seek an appropriate buyer.

This desire for participation in a future massive market encouraged Shell to pursue a cadmium sulfide photovoltaic technology rather than a silicon-based method. Cadmium sulfide cells are more easily produced using mass-production techniques.

Cadmium sulfide, however, presents some unique risks which adversely affect the chances for eventual profitablilty of SES and therefore adequate allocation of Shell's capital to it. Cadmium sulfide cells are less efficient and the material is less chemically stable than silicon.

Normally, Shell uses a discounted cash flow method to evaluate its new ventures. However, SES "is a very long-run and high-risk project, so that return on investment is not a very meaningful parameter--there are too many uncertainties. We are looking at a market that does not really exist." Eventually, however, SES will have to earn a return higher than other Shell ventures because of its "unusually" risky characteristics.

Shell is so uncertain about the future economics of photovoltaics that is has not projected prices for its photovoltaic products or estimated Shell's penetration as a fraction of those prices--the process which Shell normally uses to estimate revenues. It is simply to early to do this for SES.

C. Photovoltaics Subsidiaries of Electronics Firms

According to a reliable source, the photovoltaics division within Motorola competes for internal funds with other new ventures based in large part on one corporate-wide rate of return on invested capital. In general, therefore, those new ventures with ROI's greater than this corporation standard survive, and those that fail to earn the specified return are eliminated. This policy is softened for photovoltaics, however, since "so little money is involved." Otherwise, the high risk of photovoltaics and its recurrent negative cash flows would cause Motorola to eliminate the project from its corporate budget.

The chances for photovoltaics survival in Motorola are smaller than in oil firms because (according to this source) (a) the rate of return of Motorola (and other electronics firms) is higher than that of the oil industry, and (b) ideas for new ventures are more numerous in Motorola than in the oil industry in general. Photovoltaics, therefore, is less of a "standout" technology in the electronics industry than in the oil business. This point illuminates the competitive internal environment at Motorola. It further demonstrates that while large pools of capital exist for photovoltaics in large firms, the internal capital allocation process may be more rigid and unforgiving than the market in demanding an invariable return from photovoltaics. However, the continued existence

of a photovoltaics group within Motorola verifies that management recognizes potential profit in photovoltaics and is willing to modify corporate policy (at least for a while) to sustain the option to capture these future profits.

Texas Instruments (TI) funded internally its research and development in photovoltaics for five years before the Department o Energy recently allocated $14 million (in a four-year contract)[15] to TI to encourage the development of a promising new photovoltaics technology. Photovoltaics in Texas Instruments is purely a research and development activity at this stage. A required rate of return has therefore not been fixed. Until the DOE grant was made, TI was "purchasing" an option to capture profits later in the event that its research and development led to commercializable technologies.[16] Their successful R&D effort led to further infusion of internal and external (federal and private) capital. An uncertain amount of private capital flowed to the publicly held firm from the publicity given to the DOE grant. The $14 million dollar grant must have tended to increase the enthusiasm over (and therefore the price of) TI's stock to some small degree. However, it is difficult to isolate the specific effects of the new technology and the grants on the stock price.[17]

D. Capital Availability and the Future of the Photovoltaic Industry

The experience in obtaining capital gained by photovoltaic producers which was discussed above suggests two themes on which to focus in our examination of future capital acquisition. First, the capital structure of the firms which will make up this industry in the long run must be identified. Subsumed in this task is the requirement of making the

assumption, given the current level of government involvement, of whether independents, oil firms, electronics firms, or some other generic industry type will dominate the photovoltaic industry. In a related matter our task involves questioning the future role of "small business" in this industry. If we cannot make a reasonable guess regarding who will be asking for capital in the future, then we cannot conclude much about whether they will find the capital they seek in the long run. (However, if we know the industry composition we want, federal programs can be designed to encourage that composition.)

The second focus provided by the discussion on past experience is on the identity and origin of the technology which will provide the 'standard' for the industry. We will call this the "watershed technology," for its emergence will simultaneously signal a drastic reduction in production cost, the rapid expansion of markets, and the flow of capital to the photovoltaic industry (for originating the watershed technology in particular) because of the positive present values which are associated with the new technology. The firm which originates this technology will have no problem attracting capital, nor will firms which purchase the license to use the technology and which have their own markets for it, nor will firms which develop variations and/or improvements on the standard to remain competitive with the originating firm. If a watershed technology emerges, the firm with the flexibility to adapt will remain in the market or enter it for the first time. Thus, the evolution of technology affects our first focus--the composition of the industry.

There is a consensus among "subsidiary" solar producers in the industry today that only large, capital-rich firms will survive in the

long run. They suggest that small firms will survive (and even prosper) not as producers of cells but as "systems" producers. That is, existing and future independents will purchase cells from the subsidiary manufacturer, and use them in photovoltaic systems which they construct and customize for the end user.

Although Solarex, the largest independent, and OCLI disagree (at least publicly) with this forecast of industry composition, Solenergy and Sollos do expect to survive in the future by filling rather small orders for specialized applications. Further, it is clear that Solarex has no dearth of offers for the purchase of its business. Perhaps the primary obstruction to its acquisition would be the development of the 'watershed technology' by Solarex. Solarex would then become more attractive as an acquisition, while at the same time the resolve of its owners to become preeminent in the industry would also probably increase also. One can only guess at the outcome.

We may conclude that, given present government attitudes and programs, it is not unreasonable to expect the photovoltaic cell production industry to consist in the long run entirely of wholly-owned subsidiaries of large conglomerates. The "long run" will begin once a watershed technology is developed and the economic wisdom of investing in the production of photovoltaic cells for grid-connected applications is recognized. At this time, firms with large internal capital and easy access to external capital markets will study photovoltaic cell production for grid-connected markets in light of their corporate strategy and spend their own funds to expand photovoltaics operations or to acquire either an independent photovoltaic business or a multiproduct firm for which photovoltaics is a promising component. Under this

forecast there will be no capital availability problem for the photovoltaic industry.

III. PV CONSUMERS AND THE AVAILABILITY OF CAPITAL

No market currently exists, either in the United States or abroad, for grid-connected, residential and commercial application of photovoltaic devices. We shall therefore study the analogous experience in attracting private capital of those who have purchased, or wish to purchase, passive and active solar space and water heating (we abbreviate this as "solar heating") systems for their homes and residences. Unlike photovoltaics, the solar heating business is well-entrenched in a few concentrated areas of the country. The existence of these markets for solar heating suggests that both the economics and consumer awareness of solar heating are several years ahead of photovoltaics. We may therefore use this solar heating example to gaze into the future to the time when the first grid-connected photovoltaics markets develop. Caution must be exercised in using this analogy. We cannot assume that capital attraction for photovoltaic consumers will present problems which are identical to those of solar heating. The product--electricity in photovoltaics and heating in conventional solar--is different, as is the nature of the production process and the technology used to deliver the product (heat or electricity). That is, solar heating is a form of advanced plumbing, while photovoltaics is a more complex technology.

The similarities between the two technologies, however, outweigh their differences for our purposes. First, the homeowner (or the owner of a commercial establishment) is the end-user of both. It is he or she who must be convinced of the wisdom of purchasing each of these technologies. Second, the issues which must be addressed by the homeowner prior to deciding whether to purchase a solar heating or a

conventional system are similar to the question which a prospective consumer of photovoltaics must answer. For example, how will the cost of alternative fuels behave over the twenty-year life of the system? And is this new type of system reliable? Third, since capital cost "up-front" is very high relative to operating costs, the principal obstacle to the growth of markets is obtaining all or some of the capital to cover this up-front cost. Fourth, the source of that capital will come from local lending institutions; these local lenders must be satisfied that their loans will be repaid. They will price these loans based on their estimation of the expected savings on energy bills and on their interpretation of the risk inherent in these technologies. The argument is therefore persuasive that studying the availability of capital for solar heating is one means of anticipating future capital obstruction possibilities for photovoltaic consumers.

The debate over the wisdom of offering federal interest rate subsidies to consumers of solar heating devices provides a focal point for observing the experience of consumers in obtaining capital to purchase and install solar heating devices. A major forum for this debate is the series of hearings being conducted on Capital Hill for the purpose of evaluating the necessity of various bills which propose the subsidies.[18] The arguments brought to this forum will assist us in constructing a comparison with photovoltaics, and provide background to the arguments in this section.

It was argued above that socially-optimal investments will be made in a well-functioning and competitive marketplace. Implicit in the proposals for interest rate subsidies is, therefore, a criticism of the workings of the marketplace. The possible failures in the market

mechanism which may warrant federal intervention fall into three main categories. A brief examination of these possible market failures regarding consumers and lender acceptance of solar heating will help us to anticipate possible market failures for grid-connected photovoltaics. The categories are as follows:

(a) Energy price failure: A primary motivation for this legislation is the rising real price and growing uncertainty of oil supplies for OPEC states. Prospective lenders and consumers of solar technologies are as uncertain as anyone else of the future prices of conventional fuels. This makes life-cycle costing an exercise fraught with unusual uncertainty--uncertainty that is generated outside of the market mechanism in the realm of international politics. The lender cannot be sure whether the solar investments make the consumer better or less able to meet monthly finance charges. And the consumer remains uncertain of the present value (if life cycle costing is used at all reaching his investment decision) of his energy savings.

(b) Regulatory uncertainty: The unpredictable introduction or deletion of regulation which will affect the economics of solar heating ventures is confusing to consumers and financiers (as well as producers) of solar technologies. Effective long-term planning is impossible if major changes in the economics of solar investments are pending. This thwarts solar development.

(c) Obstruction of information flow to investors: The reluctance of many lenders to make loans to solar projects, and the hesitation of the general public to accept even the more simple solar technologies as being reliable and cost-effective, is in part an indication of poor public awareness of the state of the art in solar heating. While it is true

that solar trade magazines are now peppered with descriptions of solar loan programs available through private lending institutions, resistance to lending for solar projects is still widespread. In a 1977 study commissioned by the National Science Foundation[19] it was shown that nearly one-half of the lenders surveyed either thought that commercial applications of solar technologies in their own areas would take more than ten years (14% of those responding) or had no opinion at all (34%). In addition, 53% of all lenders thought that reluctance to lend to solar heated residences would be "great" or "substantial." Some of the reluctance is the product of rational evaluation of the economics of solar heating for a given region--an evaluation which leads to a reasoned reticence. But much of this hesitation is a product of anti-solar attitudes based on the traditionally slow-changing attitudes of the lending community. As was shown in the producer case of Solenergy, photovoltaic technologies are difficult to explain to bankers. As Alvin Alm, Assistant Secretary for Policy and Evaluation at DOE explains for the case of consumer financing:

> "Lenders consider mortgages on new homes with solar energy (or any relatively new energy technology) to be riskier than homes with "proven" energy systems. Furthermore, the market value of the property with the solar system is more difficult to determine and resale values in collateral liquidation circumstances are difficult to measure."

Thus, not only is the technology strange but a sort of "catch-22" exists as lenders remain very stubborn of solar heating until the systems are proven, but few systems are built because lenders are wary. Given the hesitation of lenders towards the "advanced plumbing" of solar heating, one can conclude that the capital supply to photovoltaics will be at least as hard to locate.

It is important to repeat that the existence of these legislative proposals implies that Congress believes the marketplace is failing to direct capital to projects which are socially optimal. Photovoltaics may experience easier access to capital if lenders and consumers perceive photovoltaics as a descendant of successful solar heating technologies. If photovoltaics is subjected to the kind of hesitation which characterizes the behavior of lenders towards solar heating, then we may expect the market's failure to distribute adequate information to investors, and the failure of investors to act to their advantage based on that information to occur as well for photovoltaics. These market failures will probably be repaired in good time for solar heating as they would for photovoltaics without government intervention. In the interim, however, housing and commercial structures would be built with conventional heating, thereby unnecessarily delaying the proper acceptance of solar technologies.

CONCLUSION

Based on the discussion above, the following conclusions are reached:

(1) It is difficult to project future participants in the industry because photovoltaic technology is immature. No one knows who the technological "winners" will be.

(2) However, it is probable that the mass-production photovoltaic industry will consist entirely of wholly-owned subsidiaries of (large) conglomerates. This agglomeration will be finalized when the watershed technology appears in the mid to late 1980's.

(3) Small independents will survive only as suppliers to specialty, or systems, markets; that is, to those markets requiring customized construction of the cells themselves and/or the systems which derive and allocate power from them.

(4) Consumers of mass-produced photovoltaics will experience reluctance to lend on the part of financial intermediaries. This reluctance will be of a similar magnitude to that observed towards solar thermal heating.

(5) The solar thermal heating precedent may "pave the way" for photovoltaics to some degree. However, energy pricing failures, regulatory uncertainty, and obstruction of information flow to potential customers and to financial intermediaries will slow the development of mass photovoltaic markets.

RECOMMENDATIONS

The introduction of federal programs to subsidize photovoltaic producers and/or consumers is ill-advised until grid-connected photovoltaic technology stabilizes. That is, until a "standard"

technology emerges, government subsidies to accelerate the timetable for marketing of grid-connected photovoltaics would distort the process of technical development by encouraging the purchase of mmature technologies. However, once the $2.80/Wp (the "watershed") technology emerges (most likely with considerable federal aid in the development stages), the willingness of the industry to produce it, financial insittutions to lend to its consumers, and consumers to buy this technology should be closely monitored. If market development is ponderous, some means of lubricating capital allocation will be advised. At this time, the involvement of the currently-proposed Solar Energy Development Bank may be necessary to promote and subsidize the technology's general acceptance.

Footnotes

1. Schiffel, Dennis, et al., Solar Energy Research Institute, Solar Incentives Planning and Development: A State-of-the-Art Review and Research Agenda, August 1978, p.2.

2. Text of Public Law 95-590.

3. The adjusted present value method requires the application of separate discount rates for each cash stream within the project based on the (systematic) risk estimated for each stream.

4. Strictly speaking, investors need only be compensated for that portion of risk which cannot be diversified away by holding a sufficient variety of securities. This "systematic" risk is a measure of the degree to which the return on investment in question is correlated with the return on the entire market portfolio of risky projects.

5. Telephone conversation with official from Exxon Enterprises, 6/25/79.

6. Schiffel (SERI), ibid., p. 20.

7. Fourteen firms are listed by the Jet Propulsion Laboratory's L. Dumas, in a memo to C.D. Frederickson dated 4/3/79. Twenty firms are cited by the Citizens' Energy Project, in "Solar Cells" (Report No. 27), dated 1978.

8. Wall Street Journal, March 1, 1979, p. 29. The firms are Holec of Holland, and Leroy Somer, S.A., of France. The purchase magnitude was obtained through a Solarex executive.

9. The photovoltaics branch of OCLI, called the Applied Solar Energy Corp. (ASEC), is so large relative to its parent firm that it is categorized here as an independent.

10. Solar Energy Intelligence Report, August 13, 1979, p. 336.

11. Note that the Denver-based investment banking firm of J. Daniel Bell suggested a public offering to Solarex. Dr. Joseph Lindmayer, President of Solarex, rejected the idea because he "doesn't need" the capital.

12. This information was obtained in a personal interview with Robert Willis in June of 1979.

13. Macha also provides arrays to JPL.

14. Information concerning capital allocations by oil companies was gathered in telephone interviews in June 1979.

15. Rosen, Benjamin M., Morgan Stanley Electronics Letter, 5/15/79, p. 2.

16. Jacoby, Henry, Larry Linden, et al., Government Support for the Commercialization of New Energy Technologies, MIT Energy Laboratory Report No. MIT-EL 76-009, November 1976.

17. The DOE grant should also have increased the value of TI's debt.

18. See H.R. 605, the Solar Energy Development Bank Act, and S. 1308, Senator Henry Hackson's Omnibus Energy Bill. In this paper we focus on the H.R. 605 debate.

19. Barrett, David, et al., Financing A Solar Home, (Lexington, Ma.) Lexington Books, 1977, pp. 39, 66.