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CONCEPTUAL DESIGN AND SYSTEMS ANALYSIS OF PHOTOVOLTAIC
POWER SYSTEMS. FINAL REPORT

Volume 4. Nontechnical Issues

By
P. F. Pittman

July 1977

Work Performed Under Contract No. EY-76-C-04-2744

MASTER

Westinghouse Electric Corporation
Research and Development Center
Pittsburgh, Pennsylvania

U.S. Department of Energy

Solar Energy

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FINAL REPORT
CONCEPTUAL DESIGN AND SYSTEMS ANALYSIS OF
PHOTOVOLTAIC POWER SYSTEMS

VOLUME IV - NONTECHNICAL ISSUES

by

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Prepared for
Energy Research and Development Administration

July 1977

ERDA-ALBUQUERQUE OPERATIONS OFFICE

Contract E(11-1)2744
Dr. Donald G. Schueler
Sandia Laboratories

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FOREWORD

The work described in this report was done by Westinghouse and its subcontractors under ERDA Contract E(11-1)2744. This program is part of the National Photovoltaic Program managed by ERDA through the Division of Solar Energy, Dr. Morton B. Prince, Acting Assistant Director, Photovoltaic, and The Silicon Technology Branch, Dr. Leonard M. Magid, Acting Chief.

Responsibility for the management of the Systems Definition Project of the National Photovoltaic Program, under which this contract fell, was delegated by ERDA to the Sandia Laboratories. The Program Manager at Sandia with responsibility for this contract was Dr. Donald Schueler, who was assisted by Dr. Billy W. Marshall who was the Task Leader for the Systems Definition and Analysis Task.

PREFACE

This volume contains a description of the investigation of nontechnical issues relating to solar photovoltaic energy systems performed on the contract entitled, "Conceptual Design and System Analysis of Solar Photovoltaic Power Systems", sponsored by the Energy Research and Development Administration.

This is Volume IV of the final report which contains five volumes in all. The other volumes are as follows:

- Volume I - Executive Summary
- Volume II - Systems
- Volume III - Technology
- Volume V - Additional Studies

ACKNOWLEDGEMENTS

The work described in this report was performed under ERDA Contract E(11-1)2744 by many contributors from Westinghouse and its subcontractors. A listing of contributors is contained in the following paragraphs.

The leader of the nontechnical issues task for all three types of systems studied was Mr. E. F. Federmann, who was assisted by Mr. R. W. Stoeltzing. Both are staff members of the Westinghouse Research and Development Center.

A number of subcontractors contributed to this task as well. A listing of the subcontracting firms and the principal contributors at each one is as follows:

<u>Firm</u>	<u>Contributor</u>
Burt, Hill, & Assoc.	P. Richard Rittelmann Steven Nearhoof
Charles River Assoc.	Dr. William Hughes William Gilbert
Impact Assessment Inst.	Dr. Martin V. Jones

In addition to the contributors listed, many other people within the Westinghouse Research and Development Center contributed to the completion of this task as well as report preparation. Included were typing, drafting and duplicating services. In particular, Denise Horvath spent many hours preparing the drafts and final copy of this report.

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ABSTRACT

Conceptual designs were made and analyses were performed on three types of solar photovoltaic power systems. Included were Residential (1 - 10 kW), Intermediate (0.1 - 10 MW), and Central (50 - 1000 MW) Power Systems to be installed in the 1985 to 2000 time period. In the residence, a total energy system where the waste heat from the array is used to heat the dwelling appears optimum. If a suitable government incentive is forthcoming, Residential Systems begin to become economically viable in selected areas in the 1985 to 1990 period, while Intermediate and Central Power Systems begin to become viable in the 1990 to 2000 period.

SUMMARY

A large number of nontechnical issues impact upon solar photovoltaic power systems, and in the long run, they may be more influential in determining the course of this technology than technical issues.

The rate of implementation of this technology will be determined by an interaction between government and the private sector. Solar photovoltaic system costs will depend upon production volume which, in the near term, will depend upon government incentive programs. A possible scenario studied calls for an annual solar cell installation rate of 500 MW in 1985 increasing to approximately 10,000 MW by 2000.

The utility/residence interface deals with the rate to be charged a residential customer purchasing only a small fraction of his total energy needs from a utility while obtaining the majority of his energy from a solar energy system. The rate charged to such a customer will have a significant effect on the overall economic viability of a residential solar photovoltaic power system. The problem is a complicated one with no clear cut solution, and therefore, it deserves additional thought and study. A possible alternative is an autonomous residence designed to operate without utility energy altogether.

A host of secondary impacts resulting from the use of solar photovoltaic energy systems must be considered. These range from the reduction of air pollution to the possibility of locating residences in remote areas without concern about the need for utility feeder lines nearby.

Institutional factors to be considered include land use issues, insurance, banking, taxes, etc. Regulatory considerations include

building codes, safety considerations, and zoning. National interest concerns include resources, environment, health, demographics, national security, and national policy.

As a result of the study of nontechnical issues performed, none was found that would constitute an impediment to the widespread use of solar photovoltaic energy. These issues are important, however, and must be addressed now.

INTRODUCTION

During the 1960's solar photovoltaic electric power systems were of interest primarily for use in space vehicles where the variability of weather need not be considered. Spacecraft systems started at power levels less than 100W in the early 1960's and increased in size to levels of several kilowatts in the early 1970's.

Until the advent of the oil embargo several years ago, terrestrial applications were limited to small, special purpose installations where the advantages of a totally isolated power supply made it possible to justify the high cost of the solar photovoltaic power system. Since the embargo, however, a great deal of thought and effort has been devoted to the use of solar power in general and solar photovoltaic power in particular as an alternative source of energy for terrestrial applications.

The National Photovoltaic Conversion Program, managed by ERDA, is oriented toward developing photovoltaic conversion of solar energy as an economically viable energy source. The effort of this contract is oriented toward the conceptual design and system analysis subtask of the Systems Definition Project which is one of the many facets of the National Photovoltaic Conversion Program. The principal objective of this contract is to provide conceptual designs and system analyses of three types of solar photovoltaic electric power systems. Included are:

- Residential Power System (1 - 10 kW).
- Intermediate Power System (0.1 - 10 MW).
- Central Station Power System (50 - 1000 MW).

The Residential Power System (RPS) considered provides a substantial fraction of the electrical and thermal needs of a residence. Two options were considered as means to obtain the supplemental energy needed. One assumed that the energy required would be supplied by a utility. For this case, the billing rate used by the utility for the small amount of energy used becomes a critical parameter. The other option assumes that the residence can be autonomous and require no utility connection at all. In this case, the supplemental electrical energy is furnished by a small engine/generator, and the thermal energy either from the same engine/generator or from a fossil fueled heater. For the systems utilizing utility energy to supplement the RPS output, the return of excess solar generated electrical energy to the utility grid was not considered.

In the Intermediate Power System (IPS), power may flow either from the solar array or from the battery into the utility system. The battery may be charged from the solar array or from the utility line, depending upon the strategy used, and would be used primarily for load leveling. The IPS would most likely be located at an industrial or commercial substation.

The Central Power System (CPS) is assumed to be tied into a large utility grid which would contain pumped hydro or other storage. Energy storage within the CPS itself was not included. Energy from the CPS would be dispatched directly into the utility grid whenever available. The operation of storage would be a separate utility system consideration.

The analysis of the performance of the RPS was accomplished with the aid of a mathematical model of the system analyzed by means of a computer program. Inputs to the computer model included weather and load data for the location selected. An additional input was operating strategy relating to power flow and timing within the system. The output was a description of system performance over a one year period to be used to verify the suitability of the parametric values chosen.

The performances of the Intermediate and Central Power Systems were determined using a computer program which contained an analytical model of the solar cell. The annual energy and peak power outputs of the cell were then determined on a per unit area basis for arrays operated in various tracking and non-tracking modes using hourly weather data.

After the performance of each system was determined, an appropriate economic analysis was made to determine the economic viability of each system installed during the 1985 to 2000 time period.

The final report on this program is divided into five volumes. This is Volume IV entitled, "Nontechnical Issues", which contains a detailed description of the investigation of all nontechnical issues impacting on solar photovoltaic energy systems. Volume II entitled, "Systems", contains a detailed description of the conceptual design and analyses of all three systems as well as a summary of the nontechnical issues task. The detailed technological investigations upon which the systems designs were based are reported in Volume III entitled, "Technology." The results of the follow-on efforts are not included in Volumes II, III or IV but are reported in Volume V entitled, "Additional Studies." Volume I is entitled, "Executive Summary."

During discussions regarding subsystem analysis, a continuing problem was encountered with varying definitions of the terms "array", "module", and "field" used in relation to the solar cell arrays. The following definitions are used throughout this report.

Module - A module consists of solar cells and backplates, as well as concentrators, cover plate, heat transfer means if used.

Array - An array consists of one or more modules mounted in a rigid supporting structure which may move as a unit if tracking is provided. The modules comprising the array are replaceable.

Field - A field comprises one or more arrays providing power for a solar photovoltaic power system.

Throughout this report, values of electrical power quoted are always peak and not average or rated. In addition, all economic analyses performed used constant dollars with the year 1975 as the base.

1. IMPLEMENTATION

1.1 Implementation Rate Assessment Assumptions

Before discussing the details of the basis for determining likely implementation rates, it is important to repeat the key initial assumptions listed in Volume II. If these assumptions made are not valid, the use of photovoltaic systems in the foreseeable future, even with the projected reduced cell cost, is likely to be quite small.

The assumptions made are as follows:

Residential Power System - There will be a pre-commercialization program of the type discussed in Volume II to enable the residential system to reach a high level of production volume. The program will also have as an objective the establishment of a mature marketing structure in all regions of the nation when completed.

Central Power System - While the RPS will require a short period of support after which it is expected to stand on its own, the CPS will probably have to be supported for the rest of this century. This is not to say that there is not justification and reason for such support. Two examples of a similar nature are the development of hydro-electric and nuclear energy systems. The important items are the ability to eventually become competitive as well as the introduction of possible ancillary benefits such as the recreational value of the dams for hydro, the tie-in with weapon development for the nuclear systems, or the development of depressed regions. Assuming that government support will be available, the ERDA estimate of 20,000 Megawatts of electric power by 2000 is used.

Intermediate Power System - The IPS is to a great extent in the same position as the CPS. Although there will probably be some commercially profitable proprietor-owned applications before 2000, their

number will not have a great affect on the implementation rate. This is not only a function of viability, but the way a commercial enterprise values money as compared to a homeowner. We have somewhat arbitrarily assumed that a substantial percentage of schools and government buildings will include IPSs by 2000 with a small percentage of commercial establishments. Utility owned installations appear more promising.

1.2 Time Period

Large scale implementation is assumed to begin in the year 1985. This is about the earliest time that system pricing will be in a practical range in the best regions. Installations prior to this time will be experimental and financially-assisted systems. After this a precommercialization program is envisaged until the systems become competitive in most regions. Projections are extended to the year 2000.

1.3 Regions

Six major regions have been selected to represent the different national situations. The selections were based on a combination of population concentration centers, data availability, housing type conformity, and load pattern. Distinctions between regions are often not sharp for each criterion, but differences in solar applicability are large enough that the breakdown is worthwhile. One or more cities were selected to represent each region based on the availability of rather complete solar and climatic data. The regions chosen are defined in Figure 1.1 together with the location representative of the site city.

<u>Site City</u>	<u>Region</u>	<u>Regional Population 1970 (millions)</u>
Madison, Wisconsin	Great Lakes	44.2
Cleveland, Ohio	Great Lakes	
Wilmington, Delaware	Northeast	42.3
Atlanta, Georgia	Southeast	28.4
Mobile, Alabama	Gulf Coast	18.4
Phoenix, Arizona	Southwest	6.0
Santa Maria, California	West	<u>16.2</u>
	TOTAL	155.5

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Fig. 1.1 — Region outlines and location of site cities

Site Cities - The site cities have conditions relating to solar use which are typical of their particular section of the country.

- Madison - Typical of colder East North Central States
- Cleveland - Typical of Ohio and the interior New England States
- Wilmington - Typical of Northeast coastal States
- Atlanta - Typical of a wide band extending across much of the center of the country
- Mobile - Typical of the hot Southern States
- Phoenix - Typical of the dry Southwestern States
- Santa Maria - Typical of the milder portions of California

Although all regions of the United States are not represented, the regions shown include slightly over 75% of the present population and are expected to maintain or exceed this percentage in the year 2000.

The remainder of the country would be expected to have an adaptability to solar systems consistent with the regions analyzed; however, area characteristics will have important influences that must be taken into account. The cloud cover patterns of the Northwest, the wide variation of solar radiation in the Rockies, and special effects of high latitude in Alaska are examples.

The use of solar energy outside the United States was not considered in this study.

1.4 Types of Structures

A structure of some type is always associated with a solar installation. For the RPS, this is usually the residence itself, and there are advantages to integration of the solar equipment into the structure. For the IPS, additional mounting structure is usually involved, although there will be numerous exceptions. The CPS will tend to exist independent of other structures.

1.4.1 Residential

There are a number of types of residential structures.

(1) Single Family Detached - the familiar and popular "house", accounting for about half of all new housing units (including mobile homes).

(2) Single Family Attached - includes duplexes and row houses or townhouses. Except for the common wall, these are the same as the detached housing units. About 10 to 15 percent of new housing units are of this type.

(3) Multifamily Low-rise - Low-rise apartment buildings account for 15 to 20 percent of the new housing units. The somewhat smaller roof area per family unit is compensated for by reduced thermal and electrical demand compared with single family units.

(4) Multifamily High-rise - High-rise apartment buildings make up about 3 to 10 percent of new housing units, and are the least favored among conventional units for solar application. The small roof and southern wall area compared to electrical demand make the design difficult, and the desire by the building owner for a rapid return on his investment causes the added initial expense to reflect unfavorably. Further, utility bills are easy to pass thru to tenants.

(5) Mobile Homes - These units, sometimes called trailers, comprise 15 to 20 percent of new housing units. Because of their small roof area, relatively short life, and the fact that their main advantage is low initial cost, these units have not been considered for solar installations.

Undoubtedly some structures in the last three categories will be equipped with solar energy systems, but they will simply augment an already large quantity in the other categories.

1.4.2 Commercial and Light Industrial

Many types of commercial and light industrial buildings show promise of being suitable for solar energy utilization. These include

low-rise offices, schools, stores and shopping centers, certain government buildings, and military structures. It is important that there be sufficient roof area to accommodate a large enough solar array to meet a substantial fraction of the electrical needs of the building. Arrays mounted elsewhere than on the building proper tend to be more expensive and their increased cost must be justified.

1.5 New Construction Rates

The implementation of solar systems will depend in part upon the amount of new construction begun during the major implementation years starting about 1985. Predictions of future construction, rarely successfully done, are especially uncertain for a time period as far away as 1985-2000. A rather fundamental approach has been taken in the case of residential construction using household formation rates, type of housing preference by age of head of household, replacement rates reflecting the age distribution of existing housing, etc. This approach was chosen rather than the use of regression techniques based on past construction data. The results of the method chosen yield a trend line for the period of interest, but projections of cyclical swings about this trend line will not be attempted.

The method used is that developed by Marcin for the U. S. Department of the Agriculture, and improved and updated by Hirst et al., for ONRL. Selections of population trends and other inputs to the construction model were made at moderate to low levels. It is not known whether time will verify these selections, but this approach means that the conclusions are not dependent upon a particularly favorable situation in housing construction.

Household formation was taken as Series C from the Bureau of the Census Projections of 1975. This choice results in a rather flat pattern for the amount of new construction thru the end of the century. The projections do not include construction to satisfy vacancy requirements which is equivalent to assuming that the number of vacant housing units will remain constant throughout the period.

Data used in deriving the quantity of new residential construction starts are shown in Table 1.1.

It should be noted that the new housing projections, shown later in Table 1.2, are very sensitive to both the vacancy rate and the replacement rate (rate of destruction or demolition of housing units). Up to one-third of new construction can be for replacement, and the number of vacant housing units is often as much as several times the amount of new construction. Thus, a year's delay in scrapping, and households moving into most of the available vacant units during that year could theoretically bring new construction to a halt. Considerations of this type plus the all-important economic climate helps explain why there can be such a strong variability in new housing construction rates.

1.6 Relationship with Solar Heating and Cooling

Solar heating and cooling of buildings has already started to reach practicality and is becoming economically justifiable in a number of cases. This trend is expected to continue and to expand. In many ways the solar heating and cooling uses will pave the road for photovoltaics, whether it be rough or smooth.

- The reputation for reliability will be established.
- The appearance of solar collectors will become familiar.
- Performance information will be more accurate.
- Labor matters will have been resolved.
- Sun rights questions will be closer to resolution.

Another very important consideration is the possibility of retrofitting these solar buildings with a photovoltaic electric system. If properly designed in the first place for this compatability, the thermal-type heat exchanger could be removed from the collector assembly and replaced with a photovoltaic/thermal backplate heat exchanger. The addition of

TABLE 1.1

Parameters Affecting New Residential Construction By Region

	<u>U.S.</u>	<u>Study Area</u>	<u>Great Lakes</u>	<u>North-east</u>	<u>South-east</u>	<u>Gulf Coast</u>	<u>South-west</u>	<u>West</u>
Percent Replacement Rate - Annual	0.85	0.85	0.85	0.50	1.15	1.15	0.85	0.85
Percent Single Family Detached	52	52	52	52	54	54	49	49
Population In Year 2000 (millions)	249	194.5	49.2	48.0	37.9	24.9	9.1	25.2
Households In Year 2000 (millions)	100.3	79.2	20.0	18.1	15.8	10.5	4.1	10.8

battery storage, inverter, and electric controls would complete the conversion. The possibility of conversion would help sell the thermal systems, and more importantly would provide a large backlog market for the electric systems when they go into production. Manufacturers could more confidently set up for large scale production, and unit costs would drop earlier and more sharply. In addition, the nation will experience added energy savings which will accumulate through the years. Although these benefits are quite sizeable, it should also be noted that there will be an added cost to the solar thermal owner for this convertability.

In a building already much more expensive initially than a conventional one, such a further cost may not be acceptable. It is worthwhile examining in detail the value of providing for such a retrofit possibility.

1.7 Development of a Pre-commercialization Plan for RPS

The number of buildings constructed in the U.S. using solar equipment for heating and/or cooling is relatively small at present. Very little is known about these installations by the public. In general, they are viewed as experimental or suitable only under special circumstances. Use of solar energy for the generation of substantial amounts of electricity is in fact almost entirely experimental. However, the widely recognized energy shortage has brought the possible use of the sun to replace some of our customary energy sources into a new prominence. While searching for ways to conserve energy and reduce the drain on fossil fuels, the inexhaustable, widespread, clean, "free" energy from the sun has a strong appeal. The use of solar energy as a realistic alternative energy source for the heating/cooling of buildings is already within the scope of today's technology. This study has shown that a low priced solar cell could lead to practical use of solar energy for the generation of large amounts of electricity. As the scarcity of fossil fuel grows -- with attendant expected rises in cost -- solar energy will be moving into a progressively more competitive mode over the coming years.

It is a worthy objective of solar energy research to achieve early and widespread use of this source: early so that we begin to secure the benefits quickly and build up the amount of substitution without delay (the low cost solar cell must be achieved), and widespread so that the amount of savings can be large and available over a wide region. The accomplishment of this objective will require a "plan of action" or strategy. Without an action plan, the movement of solar energy into the energy scene will be an evolutionary and spasmodic process. This is contrary to the desired goal -- that is the early and widespread utilization of solar energy to alleviate pressures on fossil fuels in this country. Some of the specific reasons why a definitive plan of action will be required are discussed in the following sections.

1.7.1 Why a Plan of Action (Strategy) is Needed

Following are the primary reasons why a plan of action is an absolute necessity if early and widespread usage of solar energy is to be accomplished in the U.S.:

(1) If there is no action plan, the spread of solar energy usage will be dictated by economics...meaning that natural migration of activity will be toward those regions of the country where the solar concept will achieve competitive status most quickly. This means that early and widespread usage of solar will be obviated. Further, the impression will spread in the general populace that the use of solar energy is only feasible in especially favorable areas. Such an impression could strongly retard widespread acceptance and usage.

(2) In order to establish the scope of "market base" that will be necessary to attract investment by component manufacturers, service organizations, etc., an "assured" market will be necessary. If left to natural evolution, this market base will not become visible in any particular region of the country until solar energy reaches the "competitive mode". Thus, without carefully planned market creation...including well-conceived incentives...the physical part

of the industry will inevitably lag. This means that the logistics will not be in place when the competitive mode is reached in each region.

(3) The consuming public (individuals, families, commercial and industrial establishment owners) must be made aware of the concept during the period when solar is moving into the competitive mode. Most persons are only aware of solar energy in a shallow manner. If widespread usage is to be achieved in this country, a vast, positively-toned education program must be steered toward the consuming public...as soon as is possible.

(4) Parties that will be involved in the physical aspects of the solar situation must also be educated...both as to concept and also the manner and methods by which they might fit into the picture in a profitable way. These parties will include: architects, engineers, builders, financial institutions, service organizations, component manufacturers, etc.

(5) "Institutional barriers" are a recognized deterrent to rapid acceptance of new concepts in the construction market. These barriers must be overcome to the degree possible if solar energy is to attain the psychological positioning among interested party groups that will be necessary if early and widespread utilization is to be accomplished.

(6) In order to convince the American public that solar energy can be a realistic approach, it will be most advisable to develop a "success story" through substantial usage of solar in believable, normal market conditions. A "solar farm"...or the use of solar on governmental structures alone...would not be a believable enough exercise to sell the average citizen on the idea that solar energy can be a worthwhile and socially acceptable supplement to conventional energy forms.

(7) Failure to move the solar program ahead with an action plan will cost the country dearly in its efforts to conserve fossil fuels. Each instance where solar is competitive but is not used, means that irreplaceable conventional energy sources must be employed. It takes much time and many installations to make an important impact on energy use. Most persons are surprised to learn the small percentage of electrical energy supplied by nuclear, despite its having been introduced in practical form over 20 years ago.

1.7.2 Elements of the Strategy (Plan of Action)

The basic strategy involves two parts: education...and creation of a substantial usage market.

1.7.2.1 Education

(1) The educational program must be designed to encompass all interested party groups: consumers, architects, building contractors, service and installation tradesmen, code authorities, labor unions, financial institutions, etc. Further, different educational approaches and appeals will have to be directed toward the two basic market segments (commercial/industrial/institutional as opposed to single family residential).

(2) Experience to date indicates that while the concept of solar is appealing and simple...the actual physical applications are going to be rather sophisticated and subtle. The educational phase of the strategy will be structured to: (a) create a favorable image and/or positioning for solar energy in relation to alternate methods; (b) to provide the training and instructional tools that will be required by the various interested party groups to properly cope with solar energy as it comes on stream and (c) to work with interested party groups to minimize institutional barriers (codes, jurisdictional problems, etc.) so that solar can come into the picture more smoothly than would normally be expected.

It is entirely possible that a strong well-spring of good feeling toward solar energy exists in the sub-conscious of the American public. It has basic appeals..."something for nothing"; "space-age syndrome"; "helping the country become self-sufficient in energy", etc. That portion of the educational program directed toward the general public must be structured so that by the time solar becomes an economic reality, the general public will be eager to embrace the concept. On the other hand, the program must suppress the idea that seems to be growing that usage of solar on a widespread basis is going to be available to the public within a very short period of time. This could create a demand that, if not satisfied, could boomerang from an "image" standpoint.

1.7.2.2 Creation of a Substantial Usage Market

Education and creation of interest are not enough to ensure the early and widespread utilization of solar energy for total energy residential systems. In order for those firms that will play an important part in the ultimate success of the solar project (builders, service people, etc.) to be stimulated toward investment in the necessary facilities that will be required to accommodate the solar principle prior to the competitive mode, a substantial beginning market will have to be created or assured. Two physical actions are suggested to accomplish this:

(1) Action by federal, state, and local governments to encourage utilization of solar energy for their own building, both in new and retrofit situations. Care must be exercised in this part of the project strategy to restrict solar installations to situations where the application is sensible and logical...not "forced". Throughout this program, the "black-eye syndrome" must be avoided if at all possible.

(2) The second action recommended is the creation of a market that is sufficient in size, scope, and geographic dispersion to encourage the private sector to move into the solar situation. This

proposed action is designed to: (a) prove the realism of solar usage in "normal" situations to the public at large...and (b) to provide the market backbone that will encourage participation of interested party groups prior to the actual advent of the solar truly competitive mode.

While purposely steering clear of definitive numbers at this time, we would propose an action of approximately this scope: several communities would be selected from each geographic region. The communities will be selected from each of the geographic regions utilizing criteria such as those listed below:

- (a) a growth suburb close to a metropolitan area...including rural communities in some cases.
- (b) a community with an available mix of interested party groups "in-place"...or close by...including architects, engineers, builders, financial institutions, distributors/dealers/service people, etc.
- (c) should have a fairly normal mix of building types.
- (d) should be a community that is not as yet "built up" so that variations in land utilization will be possible, if necessary, to accept design heterogeneity.
- (e) the community attitude toward solar is "understanding" so that cooperation of community government and influential groups is most likely to be forthcoming.
- (f) a community where the local utilities are relatively cooperative, and tend to view solar as an adjunct to their energy domain, rather than a threat.
- (g) a community where pollution regulations are a factor...and where legal, zoning, and code factors are relatively favorable.
- (h) a community within the region that is reasonably close to reaching a stand-off between the economics of solar application and alternate fuel usage.

A mix of buildings will be constructed over the period of years between initial installation and the reaching of the competitive mode by solar energy. All interested party groups will be pre-solicited for cooperation; "incentives" will be made available to interested party groups as is necessary. As solar energy gains acceptance within the chosen communities...and as the lowering cost of solar compared to the cost of alternate energy sources so dictates, the incentives will be carefully withdrawn, leaving the communities on a self-sustaining basis. These will be the "success story" types of situations that can be used to properly and honestly sell the American public on the acceptance of solar on a widespread basis. Hopefully, the strategy can be so handled that utilization of solar energy will be something that the consumer (home owner, building owner, utility) wants to do... rather than feeling that he is under governmental subsidy, or that he is feeding at the government trough.

Again, the number of communities and the number of buildings and installations of various types that should be "targets" for the action plan are subject to variation as the program develops definitive information. However, we feel that the program should be large enough so that systems using about 3 million square meters of collector area are in place by the end of 1985. From then until 1990, between the pre-commercialization program and the gradual achievement of commercial success, there will be about 30 million square meters in place. This is equivalent to about 600,000 residences, and a 1990 rate of 200,000 residences/year. Construction will be laid out to include a range of single family residences, plus some special light commercial, light industrial, schools, or hospital building types. Actual construction will be progressive...roughly doubling each year during the program years...and if realistic economic competitiveness has been reached by solar, the incentives can be slowly withdrawn and the market will proceed under its own power from that time on. Obviously, the degree of incentive and the time span that incentives will be required will vary considerably from area to area. Again, proper sensitivity must

be applied in the selection of buildings so that the application of solar (new and/or retrofit) will be attractive and as functionally successful as is possible. If a well-known and well-regarded firm can be enlisted to construct a local building, it would be of great value in the over-all embracement of the principle by the local public. Further, embracement by the local utility could have far-reaching impact since it is inevitable that solar is going to be "combined" with other energy types in most situations.

1.7.2.3 Incentives

It is probable that each of the interested party groups will require some sort of incentive in order to move into the solar picture prior to the competitive mode. The degree of incentives required is still an unknown. Some feel that the depth of favorable reaction to the solar principle is such that very little may be required in the way of incentives in order to bring about "pre-competitive" utilization of solar on a wide-spread basis. Others feel that incentives will have to be substantial in order to achieve utilization on a broad basis. At any rate, incentives of some type appear to be an inevitable necessity.

1.7.2.4 Other Necessary Considerations

Three other important aspects of the solar strategy deal with (a) necessary code changes; (b) channels of distribution for components, subsystems, and systems; and (c) customer service requirements.

1.7.2.5 Summary

The strategy proposed appears to be simple at first glance. However, it is muscular...and designed to create the two primary essentials for widespread and early acceptance of solar energy usage by the American consumer: (a) the creation of a usage market of sufficient size and dispersion to encourage the entry of private sector interested party groups...(b) the creation of a "success story" that is realistic enough to be accepted by skeptical consumers., (c) the attainment of large quantity production so that costs become better

than competitive. Without these ingredients, realization of the primary objective of the entire solar project is improbable.

1.7.3 Objectives of the Pre-commercialization Program

To recapitulate, the pre-commercialization program has three main objectives. They are:

(1) To reach high volume so that costs are reduced through application of the learning curve to both the modules and elements of the power conditioning and thermal systems.

(2) To cover all regions - not just those most favorable - so that the marketing structure is mature in all regions and to assure the required high volume production.

(3) To establish confidence in the user by designing a program that allows him to make commercial decisions before the actual system costs warrant it.

Although a detailed pre-commercialization plan requires considerable study and knowledge of the situation at the time it is to be put into effect, some general mechanisms can be considered here as representative of action that might be productive. The role of incentives will also be considered in a general way.

1.7.4 Likely Mechanism of Pre-commercialization

The preliminary analysis indicates that there is a broad spectrum of policy and incentive alternatives which would overcome the pre-commercialization barrier. These are various combinations or packages which could be assembled into a system of policies and incentives. To be most effective, any program will require coordinated policies and incentives by federal, state, and local governments. The most important ones will be those that will create and aggregate assured markets in ways that will stimulate private investment. It appears unlikely that aggressive private industry investment will be forthcoming in the near-term without evidence of a substantial set of government policies and incentives.

Combinations of the policies and incentives which might be employed in a pre-commercialization program must take into account a number of key issues regarding public policy. Also, the context within which policies and incentives will be evaluated and enacted must be considered. Some examples are as follows:

(1) Use of solar energy for residences will be significantly affected by policies and incentives enacted on closely related major fronts including: development of new energy sources in general; energy conservation; housing; and comprehensive tax reform. An extensive examination of trends in this larger context was beyond the scope of this project. However, it is important to recognize the significant impact that these other areas may have, and the need to monitor how the emerging policy and incentive actions there will impact solar energy use. At this stage it is not yet clear which of the solar energy policies and incentives might be included in other broader policies and legislation and which would require separate and specific treatment. However, the importance of these interactions can be clearly demonstrated by the potential impact which could be created if trends toward energy budgets or energy efficiency/utilization standards for buildings continue.

(2) The very nature of the fragmented, horizontally structured construction industry markets which contribute to the need for policies and incentives also contribute to the lack of a strong constituency for supporting solar energy systems. No one or few groups of key participants can see enough advantage to aggressively promote solar policies and incentives. Likewise no one or few groups sees a sufficiently significant payoff to make significant risk investments in developing solar total energy systems, compared to other risk investments. This status prevails in spite of a generally supportive attitude by most construction industry sources. Clearly, residential economic analyses indicate that break-even cost-competitiveness will not be achieved in most locations by 1985. Without other very strong, in fact compelling evidence that a market will exist and be of

sufficient size to justify investments, the private sector is unlikely to commit significant market and manufacturing development costs. On the other hand, if reasonable production quantity can be achieved, say by 1990, commercial markets will be available in most regions. The purpose of some of the possible specific incentives described in the next few paragraphs is to "bridge the gap".

1.7.4.1 Direct Government Action

(1) Develop a program for government aggregation of collector purchase requirements for public buildings. Such a program could include state and local requirements as appropriate and could be operated to provide a guaranteed cost to the user for various standardized collector designs. The program need not be limited to supplying public building requirements either. Various alternative means exist for implementing a program such as the following:

- (a) Government acts as the procurement agency and enters into long-term contracts for modules at guaranteed prices which decrease over time. The modules could be provided to users at a cost that would approach competitive costs.

The end objective of such a program would be to drive the cost of modules down through achieving volume production and process development while also making modules available to designers and builders at reasonable costs, but below initial actual costs. In any plan to accomplish this, intensive manufacturing process development should be funded.

There are strong arguments for a mechanism under which users are able to obtain the modules at costs as close as possible to that necessary to be competitive. The difference between the currently achievable costs and expected future competitive costs would require government support.

(b) Government develop and own the module manufacturing facilities which would be leased to industry.

Variations of this could include either industry performance of the manufacturing and process development under management services contracts or industry leases of the facilities to manufacture and deliver their products. The latter is not uncommon to DOD.

(2) Beyond aggregation of public markets, actions can be taken by federal, state, and local governments to encourage use by providing favorable credits or points to developers of Planned Unit Developments (PUDs) and/or large residential/commercial complexes, who include solar designed facilities in an appropriate mix. Such a system of credits similar to those achieved by including open spaces and other environmentally and socially desirable amenities could be an effective stimulant. The program could be combined with a federally funded program of grants or contracts which would encourage integration of buildings into land-use plans and could also be applied to individual buildings where appropriate. Here again, performance standards and criteria should be included.

(3) The development and adoption of energy utilization efficiency measures and standards for new buildings, giving recognition to solar contribution could be expanded. To be most effective, while least constraining upon design options, a flexible overall design goal or budget could be considered rather than specific component requirements. Credits and penalties for over and under achievement of guideline utilization could be incorporated into amortization schedules, tax credits, etc.

(4) Adoption of mandatory life-cycle cost use in evaluation of building costs for public building could help to insure the higher first-cost alternatives are not unjustly penalized.

(5) Development of joint industry-government programs with the utility industry through groups such as Electric Power Research Institute (EPRI) and the American Gas Association (AGA) could be a factor in attracting private investment from the utility industry.

1.7.4.2 Financial Incentives

(1) Working through FHA, VA and other federal mortgage insurance programs, a package for new construction financing could be provided. Such a package could include:

- (a) 100% financing of the additional solar system costs, with no additional down payment.
- (b) extended repayment period on the solar system loan or on both the basis loan and the solar system loan. Periods of 30 or more years could be considered.
- (c) low interest rates for the solar loan.
- (d) protection from costs of replacing systems which do not function within accepted standards.

To be effective, such a program would have to be available as an add-on to conventional financing as well as FHA and VA. This could be of significant value to the individual buyers and also in the case of investors where leverage is very important. However, to be of maximum value in opening up the options for moderate income buyers it would be necessary to get lending institutions to modify their eligibility evaluations to reflect the lower operating costs.

(2) A solar home improvement loan package could be considered also. Initial indications as to the feasibility of retrofitting residences suggests that this is less attractive than the new construction case.

(3) Low-cost government loan programs to finance the purchase of new or retrofit systems could be provided to small businesses and other similar categories of buyers wishing to install systems.

(4) Encouragement or assistance could be given to the development of businesses which would lease solar systems to users thereby relieving the end-user of the initial capital investment. A number of alternatives could be pursued here including the involvement of local utility firms in performing this function, development of a public corporation to do this, or government guarantees for private corporations. Incentives would probably have to be provided to the leasing firm to overcome the risks in leasing equipment until the business developed to a point where realistic risk appraisals could be made.

(5) To the extent that the above types of actions do not meet economic competitiveness, direct user grants or subsidies could be provided. As indicated under the market aggregation section, it appears preferable to start out with prices to users at the levels expected to prevail in the future rather than introducing user subsidies which would probably be more difficult to administer, and more subject to abuse.

(6) A program could be developed to orient leading institutions toward revising their financial analyses of a lender's ability to pay, or in the case of an investment project, the financial feasibility. This, of course, assumes that financial payoffs will be available as a result of incentives provided, but it gives recognition to the need for lending institutions to understand and internalize these user benefits in their financial analysis procedures. Financial incentives to lending institutions to internalize such changes could be considered if necessary.

(7) Low-cost or direct government insured loans could be provided to firms for investments in developing solar manufacturing, distribution and servicing capacities. A program specifically directed toward small business firms in the installation, service, and distribution area could be designed. In spite of very tight capital markets, once manufacturers can see an identifiable market that has both the willingness and ability to pay, the necessary capital to finance investments should become available. Therefore, the need for such programs may diminish as assured markets are identified, except for small businesses.

(8) The use of tax exempt and/or government guaranteed bonds to finance solar investments by manufacturing and/or distribution and servicing firms could be approved.

(9) Direct government investment in part or all of the facilities and equipment costs as described above could be a powerful incentive since the perceived risk in investing in long-term fixed and specialized assets may be the greatest. The need for such risk-reducing measures will be greatest for the case of solar collectors and modules since there are no existing plants nor organizations with the significant manufacturing experience.

(10) The marketing strategy proposed calls for early development of a high level of product and service availability throughout the distribution system. The level necessary will require training, inventory and other availability costs beyond those normally provided in new product introduction. These additional costs invested to insure user satisfaction and accelerate the diffusion of readiness may require direct underwriting by a government agency. The costs involved include both additional start-up or product introduction costs and operating costs required to sustain the added availability of product and service.

(11) While the potential need for government action is greatest for the module components, the significance of the product and manufacturing engineering necessary to produce other electrical system and conventional components tailored for solar installations should not be underestimated. Production of overall competitive systems will require significant modifications to existing product designs to get the best match of performance and cost. While there may be no radically new requirements, there will be a need for extensive product design and testing to insure that the redesigned versions achieve desired reliability and performance.

The size of the initial market probably cannot be itself justify the high level of engineering desirable to insure successful redesigns which will provide good field performance even in the early

units. The slowness of many other innovations to take hold has been due to poor field performance and reliability of early units. Further, experience has shown that the source of the problem is frequently mundane rather than due to the innovation aspect of the new product or system.

The financial problem may be most severe for the small component manufacturers but it will be common to all. Left to the normal forces at work in the competition for scarce corporate product development and manufacturing dollars, the amount each potential supplier will put in will depend on his other priorities and perception of the potential sales from these solar components. Government action to support the intensive efforts necessary to achieve early high field performance even in the less innovative components and sub-systems should be included in a program.

1.7.4.3 Tax Incentives

There are a variety of possible tax incentives to users at the federal level, including:

(1) Individual and corporate tax deductions and/or credits have been proposed in various pieces of legislation. These incentives could be applied to individuals only, corporations only, or both, and could cover both retrofit of existing buildings and new construction. One of the arguments against this form of incentive is that it would subsidize only those who could afford to buy the improvement in the first place. However, coupling with financing incentives could be an alternative. Clearly this type of incentive could be very effective with the investor-owner. Similar steps to provide credits or deductions for state income taxes could be provided.

(2) Accelerated amortization schedules for solar systems could be provided for corporate and investor-owned property. It could be applicable to new and retrofit installations and could be related to an energy efficiency coefficient which gave increased rates for better conservation/efficiency designs, as discussed above.

(3) Property tax reductions through deductions and credits or through reduced assessments could be enacted by local government or where necessary through state sponsored legislation.

(4) Solar equipment could be exempted from sales taxes by States.

1.7.4.4 Building and Manufacturer Incentives

(1) To the extent that any of the above incentives were enacted for users, the effects would influence builders perceptions of user acceptance and thereby would provide incentives to builders and manufacturers.

(2) Corporate tax deductions or credits could be provided for both operating costs and costs that would normally be capitalized by firms investing in the development of a capacity to produce, install, or service solar systems. While these are normally discussed in the context of the manufacturer, they could be employed to provide incentives to any firm making qualified expenditures. These could be particularly effective incentives for investing in the marketing, distribution and other costs which are not normally capitalized. Although these could be enacted at state levels as well, federal action would be necessary to provide effective incentives.

(3) Accelerated depreciation or amortization of qualified manufacturing or other solar-related capital expenditures could be provided. Such a program could be expanded to include distribution and service facilities.

(4) Property tax deductions or exclusions from assessed value for real property investments for solar system manufacture, distribution or servicing could be provided. These could be enacted by local or, where necessary, state governments.

1.7.4.5 Other Areas

(1) Regulatory action and/or legislation could be enacted to encourage utility company investment and participation in utilization

of total solar energy systems. A leadership role in this could be undertaken by the Federal Power Commission. However, the various state regulatory bodies would also have to take actions.

(2) Government provided or backed insurance may be necessary over the near-term to avoid unacceptable increases in insurance rates. As experience develops to enable the industry to make realistic risk appraisals, the need should diminish.

(3) Provide for a treatment of data rights and patents rights that would encourage both investment and participation in partially government funded development, while requiring commercial use of the exclusive rights within a given time.

(4) Develop a government sponsored program for the communication of information necessary for buyers, builders and manufacturers to be able to assess the design requirements, costs and benefits of the use of solar energy systems. While this action sounds somewhat similar to the various proposed "Solar Data Banks", the emphasis here is on a focused program of dissemination of design and application data for use in building programs rather than the broader issue of dissemination of research and application results.

1.7.4.6 Conclusions

The alternative available government policy and incentive actions are many and include Federal, State and local government actions. Needs exist for incentives to buyers, builders and equipment manufacturers. The significance of the institutional barriers and the extended period prior to economic competitiveness indicate that a concerted program of incentives will be required to achieve early and widespread use. Selection of an appropriate set of actions from among the many alternatives will require analysis of their costs, and feasibility, and related public policy issues.

A major consideration in carrying out additional analysis of incentives would be the feasibility of the various mechanisms for implementing incentives and the administrative complexities each might

introduce. While the intended end beneficiaries of a program of incentives would be homeowners, direct incentives to them may not be effective in aggregating a critical mass of private investment.

Past success with programs involving joint industry-government funded programs in the energy field suggest the possibility that policies and incentives which would encourage industry investment through organizations such as the Electric Power Research Institute (EPRI) and the American Gas Association (AGA) could be one effective alternative.

The actions of federal and state agencies to include solar utilization in public facilities, while significant, will not necessarily lead to diffusion into non-public facilities. Therefore, while creation and aggregation of the public sector market will be valuable, it is not a substitute for creation of private markets. While local governments also can provide for market creations in local public facilities, by far the most critical policies and incentives they can adopt would be the incorporation of land-use planning and zoning ordinances which remove potential barriers (sun rights, three-dimensional zoning, etc) and include favorable credits or bonuses for developers/builders who incorporate solar installations into plans.

1.8 Implementation Rate

RPS

Table 1.2 is a projection of housing unit starts to the year 2000 for the United States and the regions covered in this study. Based on the analysis which shows the solar RPS better than economically competitive virtually everywhere by the year 2000, we assume that, in that year, 70% of the new detached single family residences will be solar equipped. The remaining 30% will not utilize RPSs for site or other reasons. We also expect that there will be 100,000 single family attached units using RPSs and perhaps 20,000 annual retrofits by the year 2000.

Table 1.2
New Housing Unit Construction Estimates
(Millions of Units)

	Year									
	1980	Σ	1985	Σ	1990	Σ	1995	Σ	2000	
U.S. Households	78.2		84.7		90.2		95.3		100.3	
U.S. New Housing Unit Const.		9.5		9.3		9.0		9.0		
U.S. New Single Family Det.		4.9		4.8		4.5		4.5		
*Study Households	60.1		65.4		70.2		74.7		79.2	
*Study New Construction (Housing Units)		8.1		7.7		7.6		7.9		
*Study New Single Family Detached		4.2		4.0		4.0		4.1		
Great Lakes Region - MAD, CLV										
New Construction (HU)		1.8		1.7		1.6		1.5		
New Single Family Det.		1.0		0.9		0.8		0.8		
Northeast Region - WIL										
New Construction (HU)		1.4		1.3		1.2		1.1		
New Single Family Det.		0.8		0.7		0.6		0.6		
Southeast Region - ATL										
New Construction (HU)		1.9		1.8		1.9		1.9		
New Single Family Det.		1.0		1.0		1.0		1.1		
Gulf Coast Region - MOB										
New Construction (HU)		1.2		1.2		1.3		1.3		
New Single Family Det.		0.7		0.7		0.7		0.7		
Southwest Region - PHX										
New Construction (HU)		0.5		0.5		0.5		0.5		
New Single Family Det.		0.2		0.2		0.2		0.3		
West Region - SAM										
New Construction (HU)		1.2		1.2		1.3		1.4		
New Single Family Det.		0.6		0.6		0.6		0.7		

*Regions covered in this study detailed in Section 1.3.

The total annual rate by the year 2000 is 750,000 units. The 1990 figure is established by the pre-commercialization plan and is estimated at 200,000. By the end of 1985 there should be about 60,000 constructed or in process. Taking an average solar array size of 50 m² per residence, the following RPS implementation is projected:

<u>Year</u>	<u>Annual Installed SC Area (m²)</u>
1985	3 x 10 ⁶
1990	10 x 10 ⁶
2000	37.5 x 10 ⁶

CPS

Assuming 20,000 MW peak electrical capacity by 2000 and a support program that builds to this in a linear manner, we have the following:

<u>Year</u>	<u>Annual Installed SC Area (m²)</u>
1985	1.5 x 10 ⁶
1990	3.0 x 10 ⁶
2000	15.0 x 10 ⁶

IPS

Table 1.3 is a projection of various types of new commercial construction in the United States. Using some very arbitrary assumptions, a linear buildup from one percent in 1985 to one-third of the schools and to five percent of the other structures by 2000 and allowing for an average three-story level for offices and stores, we obtain the following:

<u>Year</u>	<u>Annual Installed SC Area (m²)</u>
1985	0.5 x 10 ⁶
1990	2.0 x 10 ⁶
2000	7.0 x 10 ⁶

Although these are guesses, they appear optimistic and do not seem to greatly affect the implementation rate.

TABLE 1.3

Annual New Commercial Construction Floor Area
(Millions of Square Meters)

	<u>1985</u>	<u>1990</u>	<u>2000</u>
Offices	28	36	50
Schools	13.5	13.5	13.5
Stores	65	80	110

Summary

Table 1.4 presents the total implementation for all three systems. If the pre-commercialization and government support assumptions mentioned earlier are not valid, the implementation will be minimal.

TABLE 1.4

Total Annual Implementation Rate for Solar Cells
(Millions of Square Meters)

	<u>Through 1985</u>	<u>1990</u>	<u>2000</u>
RPS	3	10	38
CPS	1.5	3	15
IPS	<u>0.5</u>	<u>2</u>	<u>7</u>
Total	5.0	15	60

2. THE UTILITY/RESIDENCE INTERFACE

The Utility/Residence Interface relates to the different values that would be assigned to reduced individual residential energy use as assessed by the utility, the homeowner, and the public interest. The manner in which this issue might eventually be resolved is considered briefly in Volume II, and is explored in detail in Volume V. This section is concerned with general impacts on the interested parties.

For the remainder of this century, it is unlikely that even the most optimistic application of solar energy to residential use could have dramatic effects on utility systems, except in isolated or unusual cases. This is due to the slow rate of structure replacement, the limited solar application, and the continuing need for in-place electric utility systems in most areas. However, the question of reduced business in the long term is a valid one to ask, and therefore it must be discussed.

Virtually every industry over the very long term changes and expands with the times. In the distant future it seems highly logical that the utility industry would expand its activities to non-regulated, and possibly more profitable activities such as selling or renting power conditioning and storage equipment to residences. It could also produce and sell photovoltaic modules, even install them. Especially if incentives are provided for this type of activity, new opportunities would be available to the utility industry and its suppliers.

Further, the optimum use of a solar-utility combination could enhance the use of electrical energy in place of other base energy forms. From the resident's point of view, he need not feel restricted in using these combined forms of energy to obtain maximum benefits at

minimum costs. A positive long-term point of view such as this could result in a three pronged effort (utility-consumer-government) to promote solar energy use for mutual benefit.

3. AUTONOMOUS RESIDENCE

3.1 Autonomous Home Concept

The basic concept of the autonomous home was outlined in Volume II both in the section describing the RPS and in the one discussing Non-Technical Issues. While further study is needed to determine how extensive its economic application might be, a preliminary estimate indicates that about 60% of the new construction in the 1990 to 2000 era that opted for solar could go autonomous.* This is not to say they would, but they could, thereby adding an option. The purpose of this section is to consider some conceivable, although not always likely, impacts of this prospect.

3.2 Conceivable Secondary Impacts of the Autonomous Home

Most solar energy planning assumes that solar energy users would need to, want to, and be able to make arrangements to draw upon a community's or region's conventional central power plants for a percentage of their annual electric power needs. However, it is conceivable that residents in locations having reasonable insolation might opt for economic or other reasons to dispense completely with the utility as an auxiliary energy source. For this reason it is worthwhile to discuss what some of the requirements for, and impacts of, such independence might be, even though in many cases it may not be used.

The severity of the impacts would depend upon how rapidly in any given community or region that solar energy users would be able to attain complete independence from the utility. In most cases, even

* See Volume V for the results of an in-depth study of the autonomous residence which are not included here.

over long periods of time, this would be a small percentage of the total in-place. Also, the nature of the impacts might vary, depending upon whether the class of users who attained complete independence were mainly single family homes, multi-family complexes, or commercial-industrial-government structures.

If complete independence were to occur, it would probably occur gradually, not suddenly, and would mainly affect a portion of the new building market. Because of this, the most likely consequence would be that electric utility growth in the affected region would be slightly slowed, rather than drastically reduced.

3.2.1 How Public Utilities Might React

It is likely that the reaction of public utility management to even a slightly slowed growth condition would vary from place to place and from time period to time period. Under conditions like those that have prevailed in recent years, it is possible that the utility might view the loss of some portion of the new buyer market as a temporary "blessing in disguise". This loss would reduce the pressure that has been placed upon them in recent years to expand their physical plant capacity under adverse conditions, i.e., a tight market for the fuel they buy, a need to pay interest rates high by historical standards for capital expenditures, site location difficulties for new power plants, the pushing of the operating rate of existing power plants beyond optimum capacity, the difficulty of obtaining approval for higher rates from public utility commissions, etc.

Tax incentives, coupled with rate-making agreements, could minimize any possible contention between the solar-energy user and the public utilities. For instance, utilities could be allowed to bill solar energy users a substantial penalty charge for their low energy consumption. In return, because the development of solar energy is considered in the national interest, solar energy users would be permitted a write-off of a substantial percentage of this penalty charge on their federal income tax. There are numerous precedents

for such favored tax treatment when the public interest is at stake; e.g., homeowner mortgage interest deductions. Many Congressmen have already proposed that income-tax deductions covering investment costs associated with installing solar energy units be allowed.

Another means of minimizing contentions would be to allow public utilities to absorb some of the additional costs of supplying auxiliary power to solar energy users through general rate increases. Under these arrangements, if electric power companies could show that their energy costs when supplying minimal usage to solar energy users are actually higher, they would be permitted to absorb this cost in the general rate structure. In effect, this would mean that non-solar energy users would be subsidizing those using solar energy. Again, there are precedents for this type of procedure. First, utilities frequently have preferential rates for special classes of customers e.g., municipalities, government agency buildings, and educational institutions. In the solar case, the compensating benefit to the general public appears as a reduction in air pollution where fossil-fired plants are used, as well as the preservation of energy resources. Second, there are countless precedents in our economy for charging some customers less than their full "fair" share of a producer's average costs of production. For instance, airline service to many small cities, and mid-day, mid-week flights, involving far less than capacity loads, are both subsidized by capacity-load flights.

The willingness of the public utilities to cooperate with homeowners using RPSs which replace energy they would otherwise supply is likely to be influenced by several considerations. One would be the nature of general public opinion as well as that of particularly important segments of a community's infrastructure. If the growth of the solar sector made only a very minor impact on the vitality and profit position of the conventional utilities, no one would likely be greatly concerned. However, if serious inroads occurred, it is likely that new local alliances would probably be formed because a thriving

utility industry has traditionally contributed to a "healthy" community infrastructure in many ways. (A depressed utility industry would probably result in deterioration in the quality of service to all users and perhaps to rate increases - a condition not unlike the railroads).

If a completely independent solar energy industry appeared to have a significant impact on the conventional utility industry, one reaction might be that the industry would fund large increases in research programs in an attempt to make its current technologies (nuclear, coal, oil, etc.) technically superior, more reliable, less costly, and aesthetically more attractive than the new solar technology. A more likely alternative would be for the utilities to use solar energy as a source for intermediate and central power plants. Another option would be for conventional utilities to make financial investments in the production, marketing, and maintenance of equipment used for residential solar power systems. The latter option would probably require public commission approval.

3.2.2 How Solar Energy Users Could React

It is possible to anticipate a number of ways in which solar energy users, as well as potential users, would react if one of the ground rules for the use of solar energy was the need to be completely independent of central utilities. First of all, potential purchasers of solar energy units would be more cautious about buying such units. They would have to be more thoroughly convinced relative to the reliability and maintainability of such units than they would if they felt sure that they could buy energy from the central power plant in the event of a solar outage.

Second, those who did buy would take much more comprehensive safeguards to cover their own energy needs in the event of a solar outage, resulting either from unfavorable weather or equipment malfunction. Among the many precautions that they would probably take are the following:

(1) The individual residence oil-fired generators and oil-storage tanks would have to be very reliable and of sufficient capacity.

(2) In addition to the individual residence backup units, entire neighborhoods might construct larger backup units.

(3) Individual residences would probably provide other backup heating and cooling devices such as wood-burning fireplaces, other fossil fuel heaters, etc.

(4) Some multi-family units might seek to utilize sophisticated systems that would generate energy by recycling the buildings' waste products.*

(5) In instances in which communities or neighborhoods provided centralized backup services, like a large oil-fired unit, tight administrative regulations would probably be established to prevent non-essential consumption during the emergency. These regulations would resemble those that many communities adopted in the past in time of drought to conserve water, such as banning the washing of automobiles, the sprinkling of lawns, etc.

3.2.3 Other Possible Impacts

To the extent that an entire community might rely exclusively, rather than partially, on solar energy, it would maximize all of the benefits available from not using fossil fuels. Among these would be cleaner air and better health resulting from a lower incidence of respiratory diseases.

Inventors and entrepreneurs would be stimulated to provide many new support-type products if some communities set out to

* Several federal departments, including HUD and the U.S. Bureau of Standards, have been experimenting for the last 5 years with a Modular Integrated Utility System (MIUS). The MIUS system seeks to combine in a single engineering package, suitable for multi-family dwellings, a variety of public utilities - electricity, heating and cooling, water treatment, trash disposal, and sewage treatment.

become completely independent of central power plants. One such category of products would be the rechargeable appliance. Consumers today can purchase rechargeable flash-lights, table lamps, electric shavers, hand drills, lawnmowers, and similar appliances. In a solar energy society, there would be market pressure to extend the rechargeable concept to vacuum cleaners, washing machines, and many other consumer appliances that could perhaps operate several days on a direct solar charge.

Someone would probably seek to manufacture and market a low-cost, simple-to-use device using the family automobile engine to generate household electricity for short-term emergency periods if all else fails.

A community that aimed to be completely independent of conventional central power plants would probably stress, initially at least, higher-cost homes for affluent families because of the additional costs involved in providing energy backup systems to cover possible solar outages.

If a community's major electric power resources were provided mainly by an independent solar sector, the community's ability to attract new industries, as well as to retain some existing ones, would be lessened, especially energy-intensive industries. Industrial and demographic relocations would result.

Under these conditions, the mix of a region's industry would alter. Older type industries linked to the central public utility would not be present, but a new industry to sell and service the solar energy units would flourish.

In a larger sense the solar energy user's independence would represent one of the first major departures in many years from the tendency to centralize modern industrial economies. Most other new technologies - such as the telephone, television, computers, modern highway networks, the credit card system, etc. - have reinforced the interdependence among a community's households, industries, and

and community's services. Solar energy, if it can offer complete independence from central power sources, would have a decentralizing influence.

The success of solar energy users in achieving "independence" - if such independence seemed to be highly prized by solar energy users - would lead to efforts, research and institutional, to decentralize (i.e., make independent from central operators) other utility-like services such as solid and liquid waste disposal.

The independence created by solar energy might lead to more decentralized housing. Land, now remote and uninhabited, would become attractive to people who prefer isolated living but who do not seek it now because of the difficulty in obtaining utility connections.

If this movement toward decentralized housing progressed substantially, existing boundary lines among some cities and counties might require revision.

The complexity of rendering community services generally - education, public health, fire and police protection, etc. - would increase if housing units were more widely scattered, heterogenous, and quasi-independent.

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4. GENERAL SECONDARY IMPACTS

4.1 Potential Impacts of Solar Energy Utilization

The impacts resulting from producing electrical energy by solar means will depend both upon the degree of market penetration that solar energy achieves and how rapidly that penetration occurs. In turn, the degree of market penetration will depend upon the strength of the national commitment to overcome the barriers to solar energy utilization. Figures 4.1 and 4.2 visually depict these relationships.

Figure 4.1 relates the time required, the degree of market penetration, and four different levels of national commitment. Under the conditions postulated, a lesser national commitment would take longer to achieve a lower level of market penetration than would result from a greater level of commitment.

Figure 4.2 classifies the major barriers to solar energy utilization into various categories and illustrates a small sample of linkages between these barriers. Linkages are mutual relationships between barriers which tend to intensify or lessen the severity of their impact. (The list of possible linkages has been kept small to simplify the presentation).

One of the key considerations in determining the degree of future national commitment to develop and utilize solar energy would be what happens in the case of other energy technologies in the period from now through the year 2000. These other energy technologies include oil, gas, coal, nuclear, geothermal, etc. Not only will changing price relationships among these various forms of energy be important in determining which forms of energy consumers will favor 10 to 25 years from now, but the relative success of each of these

Figure 4.1

THE PROGRESS OF SOLAR ENERGY DEVELOPMENT AND UTILIZATION *
Market Penetration vs. Time Required vs. National Commitment

Dotted Line Coding

- A. An urgent, all-out effort to develop and utilize solar energy as rapidly as possible with almost unlimited funding, top priority for scarce resources (such as scientific and management talent), and all required enabling legislation.
- B. An expanded program for the future development and application of solar energy, but with some limitation on funding and other resources required for this effort.
- C. A steady, but modest, program to further develop and utilize solar energy. Temporary set-backs occasionally occur relative to the degree of national commitment to this program, but none of them in the long-run is disabling.
- D. A program lacking in sufficient effort to achieve solar cells of the required low cost, or insufficient pre-commercialization support to reduce unit production cost for more conventional components. Failure of either will prevent significant use.

* National commitment is defined as the amount of money, the quantity of scientific and management know-how, and the general intensity of the national effort assigned to achieve a stated goal - in this case, rapid solar energy development and utilization.

Figure 4.2. The Market Demand for Solar Energy in the Year 2000: Relevant Parameters

energy technologies in its total marketing strategy and in its abilities to cope with its own peculiar types of institutional constraints will be critical. Figure 4.3 which had been developed previously, is used to illustrate this point. This exhibit lists some of the factors that will determine the future price of coal, one of the major alternative sources of energy.

Among the societal considerations that will be impacted upon by the degree of solar energy utilization, as well as by the manner in which this utilization occurs, are the following:

- National inventory of resources

- Air quality environment

- Water quality

- Land use

- Landscape aesthetics

- Capital investment

- Employment

- Health

- Safety

- Demographic movements

- Institutional realignments

- Local building codes

- Legal rights

- National security

- International relations

Each of these general impact categories can, of course, be broken down into many lower-category impacts. For instance, among the many organizations that would be affected by institutional impacts

Figure 4.3

FACTORS THAT WILL INFLUENCE THE PRICE OF COAL

are: labor unions, financial institutions, construction and manufacturing industries, electrical utilities, and government at all levels (federal, state, and local).

Some of the most significant secondary impacts of a widespread utilization of solar energy would involve a reduced national exposure to the deleterious impacts that occur from using many of the other forms of energy. Figures 4.4, 4.5, and 4.6 list in a three-step sequence how the environment would be improved by the use of solar energy.

Since so many considerations could affect the manner of solar energy utilization, and because the time period in question is a relatively distant uncertain future, it is best to discuss illustratively the impacts that could occur. To portray these illustrations, we have used two scenarios (Figures 4.7 and 4.8). As defined here, optimistic means "favorable to the development of solar energy". Pessimistic means "unfavorable to the development of solar energy".

All parameters affecting the future cost/effectiveness of solar energy are subject to uncertainty. A range of values, rather than a single value, exists whether one is talking about future performance levels, the date by which specified improvements in performance will occur, the expected reliability of future systems, the ease of maintenance of such systems, costs of all types (installation, operation, maintenance), etc. Historical experience with prior technologies, including such energy technologies as nuclear energy, also indicate that the most serious institutional obstacles do not surface until the technology becomes operational. In the light of this experience and considering the uncertainties involved, solar energy planners would do well to routinely utilize the least optimistic estimate whether the issue is one of future technical performance, cost, or the possibilities of institutional reform. Emphasis should be placed on protecting, at least financially, the "pioneers" who are willing to be the first to use solar energy units. Government guarantees in one form or another should remove financial risks from the shoulders of early buyers.

Figure 4.4

HOW SOLAR ENERGY WILL LEAD TO A BETTER ENVIRONMENT

STEP 1: BASIC ASSUMPTIONS

Geographic Distribution:

Solar energy systems installed in most new houses.

System Design:

Standardized solar energy system, produced on automated production lines, available for new houses.

System Cost:

Initial system installation costs remain relatively high; life cycle cost for system competitive with electric utility costs.

Public Attitude:

Favorable results during previous demonstrations have convinced the home-buying public of the merits of solar energy for new homes.

Competitive Fuels:

The cost of all types of energy continues to increase, with a reduced consumer demand for electricity.

International Relations:

Large dependence on foreign oil supply continues, with some leveling-off of the price due to decreased demand and international agreements between oil producers and consumers.

Etc.

Figure 4.5

HOW SOLAR ENERGY WILL LEAD TO A BETTER ENVIRONMENT

STEP 2: ILLUSTRATIVE IMPACTS

Economic:

Higher initial cost of new homes forces marginal home buyers to consider lower-priced housing or houses constructed prior to the development of solar energy.

Energy:

Impact of new housing developments on existing energy systems greatly lessened, enabling scarce fossil fuels to be allocated in greater amounts to other consumers or conserved.

International:

Demand for foreign energy supplies stabilizes and somewhat lessens, causing a slight decrease in the price of foreign oil.

Environment:

New communities with solar energy systems record lower air pollution levels.

Construction Industry:

Increased demand for solar energy systems by consumers leads to active competition among contractors, resulting in more suppliers and installers, easier servicing of units, and a decline in high installation and service charges.

Etc.

Figure 4.6

HOW SOLAR ENERGY WILL LEAD TO A BETTER ENVIRONMENT

STEP 3: ONE POSSIBLE SEQUENCE OF EVENTS

Figure 4.7

A PESSIMISTIC SCENARIO

The Sequence

Demands for federal money to support costly, high priority "current needs" programs greatly increase. Examples: increased military expenditures to counter aggressive foreign actions, increased aid to distressed cities, a national health insurance program, etc.

Concurrently, citizens resist further tax increases while continuing to label inflation as the main national problem.

Intense competition for federal financial support develops among programs catering primarily to long-term national needs.

This competition is particularly strong in the energy field where five or six major forms of energy seek scientific and commercial breakthroughs.

Proponents of newer, relatively unproven energy technologies, like solar energy, become ensnared in very aggressive, highly optimistic promotion campaigns.

Preoccupation with rapid market penetration leads to premature commercialization involving inflated performance and financial advantage claims.

Early purchasers of solar energy units become quickly disenchanted because:

- purchase and installation costs prove to be higher than expected,

- savings in energy operating costs are smaller than expected,

- frequent malfunctions necessitate almost monthly service,

- maintainability becomes a major problem as serious delays occur in obtaining replacements parts and in obtaining qualified service personnel.

Many early buyers of solar energy units scramble to sell them, but can do so only at a substantial financial loss.

After much tribulation, a lower-key, more tightly regulated solar energy program becomes implemented.

Figure 4.8

AN OPTIMISTIC SCENARIO

The Sequence

Alternative forms of energy become competitively less attractive than solar energy as a result of:

mounting tension in the mideast occurs as militant groups take charge of OPEC and drastically raise oil prices,

domestic oil is plagued by a long series of cost-increasing mishaps, e.g., construction costs of the Alaskan pipeline skyrocket,

new research reveals far greater health risk from air pollution, and environmentalists win major court and legislative battles to reduce coal strip-mining,

several well-regarded authorities challenge some safety features of existing nuclear plants. A number of nuclear plants close down for comprehensive, prolonged inspection,

research on geo-thermal energy has disappointing results,

energy conservation measures fail; per capita energy consumption greatly increases.

Aided by expanded federal R&D funding, important cost-reducing solar engineering breakthroughs occur.

Congress enacts numerous financial incentives to encourage solar energy manufacture and purchase.

Manufacturing advances reduce solar energy equipment costs below current expectations.

Enlightened industry marketing creates many satisfied solar energy buyers.

Lending institutions adopt innovative financing arrangements to facilitate solar energy purchases.

Service industry develops responsive, reliable, modest-cost maintenance service for solar energy units.

Labor unions cooperate to avoid jurisdictional disputes relative to installing and servicing solar energy units.

Local building codes modified to remove barriers to construction of solar energy equipped structures.

Courts satisfactorily resolve the "solar rights" issue.

4.2 Possible Adverse Impacts of Solar Energy

Overview

The objective of this discussion is to explore in a single section what conceivably might be some adverse impacts from the nation's efforts to develop solar energy. No attempt has been made to assign a likelihood to any of these impacts, and many of them, if foreseen, could be avoided by judicious advance planning. In any event, whether or not solar energy achieves its market penetration goals, policy makers should not ignore the possibility that solar energy development could bring with it, like all other past technologies, adverse, perhaps currently unanticipated, impacts.

The lack of an extensive literature dealing with the potential adverse impacts of solar energy is not adequate reason to ignore the possibility that there may be some genuine, adverse consequences of securing a substantial portion of mankind's energy from the sun. The lack of an extensive literature on the subject is due mainly to the fact that solar energy has not yet reached the commercialization stage. Historically speaking, few technologies have generated concerns relative to adverse impacts until they once become operational. The automobile, television, and nuclear energy are just a few that might be mentioned. In each of these cases, there was little professional or public discussion about adverse impacts until the commercialization stage was reached.

It is probably a fair generalization that the major adverse impact of solar energy, like that of most other technologies, would be to complicate man's life both as an individual citizen and collectively in communities and as a nation. This complication would be in numerous ways.

4.2.1 Building a New Home

For many years to come, anyone who decides to equip a new house with a solar energy unit is likely to find that it will not only cost more to acquire this type of home, but it could take much

longer. In some cases, he will have to secure time-consuming deviations from local building codes. In other cases he may have to spend considerable effort in satisfying himself that he has selected a reputable contractor and the best brand of solar energy unit.

4.2.2 Energy System Maintenance

In current day society, the average consumer has to give almost no time or thought to the maintenance of his energy system because the conventional central power plant is so completely reliable. When houses generate their energy on-site, consumers will take on a responsibility resembling that they now have for their television set and automobile. If a householder neglects periodic maintenance of his solar energy unit, as in the case of his automobile, he may pay dearly for the neglect, not only in money, but in inconvenience and the use of his personal time.

4.2.3 Insurance

Conventional, central power plant energy systems impose no insurance problems for the householder. By contrast, the lack of actuarial data, the susceptibility of some areas to vandalism or hail storms, or other presently unknown factors, may pose a major challenge for the householder in obtaining appropriate insurance coverage on his solar energy unit.

4.2.4 New Appliance Purchase

At the present time, when a new appliance appears on the market, the householder has only two decisions to make: does he want it, and can he afford it, i.e., is it worth the price to him? Solar energy users will face a third question: "can my solar energy system provide the additional energy that I will need to operate this new appliance?".

4.2.5 Technological Obsolescence

Like most new technologies, solar energy will in the long run create many new jobs. However, in the process of achieving the

long run state, many temporary economic dislocations will occur, and, as with other technologies in the past, sometimes these dislocations will last for many years. People employed in installing supply lines for conventional electrical energy systems will find their employment opportunities reduced. Industrial firms supplying conventional utility systems might experience reduced sales unless they replace lost production with solar components. Investors in conventional utilities could see reduced opportunity.

4.2.6 Urban Sprawl

Citizens, as individual householders, will achieve a new freedom in selecting the site for a new home because the availability of solar energy could in many instances free them from dependence on the power lines of central electrical utilities. When many citizens take advantage of this option, communities will disperse more. Although there will be some advantages to this, there will also be problems. Commuting distances to places of employment will increase, and, among other things, this will consume more energy. The costs of providing many community services - education, fire and police protection, etc. - will increase.

4.2.7 Citizen Dissensions

It seems quite likely that soon after the solar energy reaches the commercialization stage that it will become the focal point for environmental/political controversy. The history of weather modification projects provides an analogue. For instance, there is no substantial evidence that the artificial suppression of hail either increases or decreases the level of rainfall. Yet, in times of drought and flooding, weather modifiers have been charged with and sued, either for reducing the amount of rainfall or for increasing it. The courts have never decided favorably for any of the plaintiffs in these cases. Yet, the mere suspicion or allegation that weather modification activities contributed to the damage has been enough to cause legislatures to cut off state funds for weather modification

programs. In a similar way, it is quite possible to anticipate that if a region having a substantial number of solar energy collectors, were to experience several seasons of unusually cool weather perhaps with unseasonal frosts that killed agricultural crops, that solar energy installation would be blamed by some people for it. With the diversity of viewpoints among scientists on all subjects, it is extremely likely that some scientist(s) would provide professional testimony to support the damage charge. As a result, depending upon the frequency and the severity of the unusual weather, solar energy might become susceptible to some of the same emotionally-laden controversies that nuclear energy is today.

4.2.8 National Vulnerability

The subject of weather modification raises another specter. If all goes well, in another 25 to 50 years, presumably the nation will be obtaining a substantial percentage of its total energy needs from solar sources. In this same time period, if current trends continue, science may also learn to control the weather; all major nations of the world are now engaged in research. Because the possibilities for dislocation and disruption from weather modification are so devastating, the United States and USSR have already signed an agreement outlawing the use of weather modification as an instrument of warfare, just as most nations have outlawed biological warfare. However, it is not unthinkable that at some future date a hostile foreign power or a militant domestic group would seek to bring major economic dislocation to the United States or any other nation by disturbing their solar energy systems through weather modification activities.

The discussion to this point of potential adverse impacts has assumed that the current ambitious, optimistic goals of solar energy planners will be achieved. What are some of the likely adverse impacts if these goals are not achieved? In the past, many other major innovations, such as the picturephone and the rotary engine automobile, have been introduced, and it appeared for a while that they would

revolutionize the industry. Yet, they failed to do so. If this happens in the case of solar energy, it is highly likely that the credibility of the federal government and the R&D community will receive a serious blow because of the wide publicity that is now being given to solar energy. Everyone and every organization that has helped to pioneer the industry may suffer financially, i.e., those who purchased solar energy units; those who manufactured them, and those who went into business to install and service them. From a national point of view, an expensive "opportunity cost" will have been incurred. The millions of dollars that were spent in solar energy research would then have been more usefully employed in other energy research. Finally, the nation's total energy position could be jeopardized. Investing in a solar energy program that failed would be similar to buying a bad insurance policy. If solar energy fails to achieve the planned market penetration, many serious national level adverse impacts may occur. The nation might become more vulnerable to blackmail from foreign energy suppliers, our international balance of payments position would deteriorate, our standard of living might decline, and serious unemployment might occur.

5. INSTITUTIONAL, REGULATORY, AND NATIONAL CONSIDERATIONS

5.1 Institutional Factors

5.1.1 Land Use Issues (RPS)

Perhaps the most difficult institutional issues relating to solar generation at the residential level are the issues generally under the heading of Land Use. The right to light of an individual dwelling is not generally protected under the common or statutory law of the United States, although English common law protects such a right under the antiquated doctrine of ancient lights. To make a long story short, the simple creation of a right to light which benefits anyone placing a solar collector in place, does not appear to be sound public policy. Though beguiling in its simplicity, the same law which would serve as a shield to protect the homeowner making such an investment, could be used as a sword by an individual wishing to place an array affecting the use of neighboring land, in a manner which may not long be consistent with public policy. Rather than have the judgment, or perhaps guile, of individuals placing solar panels determine land use patterns on neighboring parcels, a planning or zoning approach would seem to be appropriate.

At the present time, however, American zoning processes may not have perfected the administrative expertise or even legal theory to adequately deal with issues relating to the right to light. For example, zoning has dealt with the issues relating to building height restrictions. But, although there is generally fighting when a height restriction is broken or some variance is approved, the implications of the change are not overwhelmingly severe to an area in the same sense that such a change would demolish any value in a solar array made subject thereby to a shadow behind a highrise built as a result of a change in zoning.

Zoning would have to change such that usual variance procedures, where they interfere with previously zoned areas designed to be suitable for solar, would have to take place over a long period of time during which the capital investment associated with the solar array could be amortized.

Obviously, zoning ordinances must be allowed by state law to clearly delineate areas in which solar investments will be protected, where private property contractual rights and easements cannot be relied upon. In such areas, the key issue will be how to change those uses over time. A model might be found in the manner in which industrial zones are changed. It would not seem appropriate to create a situation where the solar home is given a property right which cannot be "taken" under the law without due process. Due process would require compensation. Rather a form of amortization and process for change which takes into account the need to amortize a capital investment, would be more appropriate. Thus, in the event change were determined to be appropriate, perhaps years of advance notice would be needed so that a homeowner could consider replacing his solar system, move to another energy source or move to some central array approach. Less timely notice could require payment.

Some study should be given to the social issues which compete with the need for independent and replenishable energy supplies. Problems relating to population, desegregation and income redistribution, or mixing through zoning and planning cannot be ignored and in many instances could clash with the legitimate interest of protecting an individual's right of access of his array to the sun.

5.1.2 Insurance (RPS)

The capital investment associated with a single family dwelling, will be increased by the presence of a solar energy system at such dwellings. While the life cycle cost approach will indicate that this is a sound investment, the insurance for traumatic (i.e., almost anything but normal depreciation) insurable loss to this additional capital investment will thus be shifted from self-insurance for existing generation

on large central station electric generating plants as well as the existing insurance mechanisms on various other energy delivery systems (oil trucks, refineries, etc.), to the individual home. Whether the existing capital investment is insured or self-insured, the capital investment on individual homes will, of necessity, be insured by individual homeowners if not for their own interests, for the interest of various lenders. Consequently, the insurance industry's willingness to undertake the risks may impose an institutional barrier to wide-scale adoption of solar generation at the residential level. For example, current insurance mechanisms are widely dependent on certain standard policies, e.g., the New York form. Such forms are understood by the industry and its very diverse state by state regulatory structure. Co-insurance features of standard homeowner policies provide adequate protection for mortgage lenders when they are joined as a named insured in the homeowners standard policy under current circumstances. However, with the addition of the capital investment associated with solar generation, the risk of loss may require wholly new underwriting approaches.

A residential dwelling may have gained value after loss on a dollar for dollar basis for partial repairs made. On the other hand, where a home must also supply its own energy, the home as a whole may be of little value until 100 percent of the solar generation is restored. Where the burden of this restoration is on the homeowner and thereby in the event of loss placed upon the insurer, and derivatively on the mortgagee, more fully insured solar arrays might well come to be the requirement.

Similar problems of insurance may relate to other aspects of homeowners insurance and the insurance industry in general. After wide-scale geographic trauma, a flood, hurricane, etc., in the event of extensive destruction of solar generation, homes in an entire area might become unlivable until piece by piece the arrays are put back on the roofs. The consequences to those living in the homes and their insurers, in the form of alternate living arrangements, motels, travel,

etc., might well be more severe than under current situations where, even immediately following a flood, energy is generally the first major system after transportation to be restored. Insuring a damaged home with energy available is a less difficult underwriting risk than is a damaged home where energy must be restored by means of reconstruction of the array.

5.1.3 Banking (RPS)

Banking issues raised by the solar energy system relate to the entire capital costs purchase price of a home. Bankers lending upon a home are subject to a variety of self-imposed and officially-imposed standards relating to the lending limit as a percentage of appraised value. Appraisal standards, FHA, VHA, FmHA as well as a myriad of local bank policies, some with public overtones, (e.g., current issues over redline areas) raise serious issues regarding banking acceptability of solar-photovoltaic generation at the homeowner's level. The obvious key is the appraisal value of the extra capital costs associated with its solar-photovoltaic system. The additional capital costs must be reflected on a dollar for dollar basis (perhaps more for market entry) in the appraisal given by the bank. Review of various appraisal manuals, as well as federal and state loan program standards, would be necessary. In addition, to a certain extent, the life of use of the various components of the solar system will affect this judgment.

For example, it may be that in suburban areas where values for residential dwellings are expected by the appraiser to remain the same or increase over the life of the investment, there would be little additional risk in loaning on a solar home. Where, however, an area is declining or in the midst of change or uncertainty, it would seem that there is a premium on the low first cost dwelling or system due to the fact that the cost or loss associated with its becoming without value or being scrapped along with the neighborhood would be less, and its amortization can be accomplished more quickly. To a certain extent, the resolution of these problems may lie in the resolution

of the issues relating to right-to-light, discussed previously under Land Use Issues, as to the extent that state or local regulatory (zoning) processes render solar a sound investment, the banks might find that such solar areas were inherently more stable for a longer period of time than areas in which right-to-light protection were unavailable.

5.1.3.1 Impact on Capital Markets

If photovoltaic technology is introduced on a substantial scale, there will be some effect on capital markets. However, the dollar volume of investment that would probably be involved is so small in relation to the gross private domestic investment of the economy as a whole that it would pose no problem. A billion dollars a year is an amount that is normally readily handled. The overall cost of capital would be little affected by a new investment at this level. Moreover, what is relevant to the investment impact of solar technology is not the absolute number of dollars that it takes to invest in solar facilities and solar manufacturing industries but rather the difference between this investment and the investment that would otherwise have to be made to supply the energy from other sources. The energy from the photovoltaic systems is essentially replacement energy. There is investment involved in all of these. The only reason that there is any increase at all associated with the solar electric system is that photovoltaic cell technology is extremely capital intensive. Its cost structure closely resembles that of hydroelectric generation. The fact that photovoltaic power systems and the related manufacturing facilities do not involve huge projects of massive scale is important to the investment impact. This means that there can be no abrupt shocks imposed upon the capital markets and that the normal process of competition among the alternative uses of funds will proceed smoothly as scale of adoption of photovoltaic systems grows.

Finance problems for the IPS are not particularly difficult. Many major shopping centers have financial structures that are more complex than utility finance arrangements. The shopping center land

may be owned and have its own mortgage or be leased, the buildings may be leased or lease purchased with buyout provision in options which themselves may be traded. Leases within the building may be sold and resold. The individuals and financial markets that absorb this type of paper will not have difficulty in dealing with the financing of solar equipment.

5.1.3.2 Financial Effects of Mobility

Another aspect of great financial significance is the useful life and mobility of solar panels as used for the IPS. One reason for utility ownership of generation is the substantial sunk cost involved at each traditional generating station. Few industrial or other intermediate sized demands are able to accept the risks of a self-owned generator due not only to the engineering complexity but also to the uncertainty of the application life service reliability, and lack of significant anticipated salvage value. Solar may have extraordinary salvage value where the components are as interchangeable and mobile as the support structures and panels. There simply may not be significant depreciation of the panel or structure.

Simplicity of construction and simplicity of operation is then followed by simplicity of salvage and recycle or reuse. If this is the fact, the risks of self-generation at intermediate sites are much smaller and more easily handled than even the buildings or facilities served by the system. One function of the existing transmission system is to absorb and spread the risk of obsolescence by finding within a service territory or pool another demand to serve. The utility plant cannot follow the load so transmission takes its energy from place to place over time. With solar it may be found less expensive to move and reset-up the panels at the site of the new demand than to maintain an extensive transmission grid in the same areas of the country. The transmission grid could then become the constraint upon traditional generator schemes in all but the most dense areas of power demand and, of course, the superplant and associated grid.

5.1.4 Taxes

The tax structure of real property taxes based on assessed valuation will have an impact in the opposite direction to the banking issues. Thus, the higher valuation associated with additional capital investment solar generation on a home, the higher the taxes and the greater disincentive for the purchase of such homes. To a limited extent, state legislatures are now exempting capital investment in real property associated with solar or alternate energy sources. Such statutes should be analyzed. If this approach is not adequate or does not gain wide acceptance, then a portion of the operating cost gains associated with solar homes will be lost by increased tax assessments. It is an understatement to say that to the extent that wide-scale implementation will require state and local property tax reform as a condition, a major institutional barrier is encountered.

5.1.5 Electric Utilities

One of the salient features of solar photovoltaic generation of electricity at the intermediate and central station level is its relative simplicity. The basic major components, their combination, and their operation in a system all appear to be quite straightforward. Many implications flow from that fact.

The technology simply may not require the expertise associated with existing utility delivery systems. Generation at the intermediate level by solar is not anticipated to require the highly trained generator engineering function for construction and operation that is characteristic of current fossil plants. Even the central station solar plant may not require all of the traditional utility expertise insofar as generation is concerned.

One of the advantages of solar central station plants as power sources is that capacity additions are not lumpy and need not involve long lead times. A utility could conceivably purchase land for a CPS, obtain environmental impact and transmission line easement approvals, and then add solar arrays as needed over a period of time.

Mass produced solar components could then be produced for inventory and installed and located in a matter of months. Especially in view of the difficulty of precise load forecasting, the solar technology should receive a credit in economic comparisons with other power supply alternatives; it reduces the need for the entire power system to maintain long term reserve capacity for errors in load forecasting.

Generation planning, construction and operation, the dispatch and mix of generation over time, transmission and distribution engineering, and financial expertise are the key functions of the existing electric utilities.

As a model for the progress of implementation of solar generation, one might look to the growth of hydro generation as an example. The larger intermediate use of hydro was developed by a wide variety of institutions including municipalities, industry, and utilities both public and private up to sizes far in excess of the defined size for intermediate solar (1 MW) and approaching central station (100 MW) size. Only at the very largest hydro sites, public and private, did basically utility delivery systems once again dominate.

Utility system functions may evolve toward transmission/distribution and their integration with a more diverse generation function (dispatching) over time. An increasing role of storage, the rather widespread use of solar electric at the residential level, and the advent of intermediate solar generation may well cause a decline of utility owned generation at the intermediate level and an increase in the dispatch/distribution function. This is a common carrier function to which generation and storage loads as well as other utility and non-utility generation will relate.

Planning and dispatch of generation coupled with load dispatch creates in the utility network a carrier and market for energy. The utility (or power pool) may well act as a market: buying, selling and managing supplies and load both owned and unowned, perhaps upon a base of utility owned "superplants" of baseload breeder, coal and very large

solar. The analogy to the hydro generation is relevant here. The view of the power pool utility system as an emerging energy market system is also buttressed by the recent full participation by small municipal utilities in those power pools. Their right to full membership in pools as well as their right to join in ownership of very large central station generation facilities is a significant step in this direction. There are industrial organizations with existing generation facilities and planned power demands greater than many of these municipal pool members. One can easily foresee their extensive pool participation particularly if the intermediate station presents primarily the problem of fit with other generation sources and exhibits relatively simple problems of construction, engineering and maintenance.

This market view is a result of and dependent upon the use characteristics of intermediate solar generation. For example, the intermediate level solar needs large numbers of square feet near a suitable demand. A warehouse or shopping center operation requires similar size and proximity and are compatible uses. The opportunity to combine such uses and thereby reduce the total cost of both warehouse and generation will cause some combination of the two organizational functions to exist (e.g., the utility will buy rights on the warehouse or the warehouse will sell energy into a grid). As urban area thermal-electric generation declines or ceases entirely due to zoning and pollution constraints, it will tend to force large central stations to locate far from the electric load centers (land area constraint for solar; safety constraint for nuclear; pollution for fossil). This is already a fact of life in some areas, e.g., although most utilities dispatch their energy on an economy basis (highest cost plant goes on line last), Southern California Edison serving the Los Angeles basin uses a NOX dispatch (highest pollution emission plant on last). This in turn could easily cause a feedback supporting solar implementation at the intermediate level. High transmission costs also constrain large scale remote generation of any sort and will cause the central station to have to be of even greater size to obtain the lower per unit costs.

5.1.6 IPS Ownership

The intermediate system raises all the questions of ownership and utility/customer interface that have been raised with respect to the residential system. The approach of having the owners of the building also own the portions of the system integrated into the building, while the utility owns the balance is one of several possible alternatives.

The short payout periods that are customarily applied to commercial developments or shopping centers do not necessarily imply that the required rate of return on investment in a solar system need be extremely high. Commercial buildings and property are customarily financed at a variety of levels: the land is generally financed on a very long term basis, and frequently the buildings and improvements on the buildings are separately financed and owned. The principal reason for short payout periods is the risk to the developer that the immediate contemplated use of the property will not be profitable beyond a limited period. If the structures are well located and are usable for a variety of commercial or light industrial users, the property will have a good resale value and it would be profitable to invest in the solar system.

However, the positive incentive for the builders or developers of shopping centers or office parks to invest in intermediate photovoltaic systems appears to be small. Energy is a very small element in the total cost of a commercial development and the benefits from having a solar energy source might not justify the problems of dealing with an unconventional energy source where adequate energy could be supplied by the local utility, even if the latter is more expensive.

The fact that the photovoltaic technology is modular so that central stations or intermediate systems can be constructed at any scale suggests that there may be a market for photovoltaic systems at scales considerably above the intermediate system prototype and well below the 100 megawatt prototype used for the central station. For

instance, the developers of a retirement community or other planned communities might decide to provide the bulk of their energy requirements through photovoltaic systems that could be built into roofs or canopies over some of the community facilities, including such things as tennis courts, malls, swimming areas, and the roofs of community buildings. Where these communities are not quite self-sufficient or where they could develop a surplus of solar generated electricity, there arise problems of interface. They may seek the right to exchange energy with the nearby utility or to supply the auxiliary energy locally.

Individual site owners (warehouse/shopping center roofs) of energy systems or even entrepreneur ventures (buying up roof rights) may be the organizations to initiate this market.

5.1.7 Stakeholder Groups' Attitudes Toward Solar Energy

Market acceptance is vital to the widespread utilization of any new technology. Stakeholder-group attitudes are indicative of the presence of barriers and incentives that influence the degree of market acceptance. To ascertain current attitudes toward solar energy, Westinghouse in the process of the Phase 0 exploratory study for the National Science Foundation conducted a nationwide solar energy survey in 1974. This was directed toward solar heating and cooling; however, the results apply equally well to the present study in many cases. Over 1700 persons were contacted by written questionnaire and by telephone interview. In addition to 1000 citizen-consumers, approximately 700 representatives from building trades labor unions, energy suppliers, builders, equipment manufacturers, architects, and construction financiers were contacted. Some of the similarities and differences in the attitudes expressed by those queried will be summarized here. As might be expected from such a large and diverse sample of respondents, there was a broad spectrum of reaction, ranging from interest and acceptance to skepticism.

5.1.7.1 Major Group Attitudes

Architects were favorable to emphasizing all types of buildings in introducing solar heating and cooling. Schools, commercial buildings, and office or professional buildings were singled out, however, as requiring special emphasis. They clearly preferred fitting systems to newly designed buildings as opposed to retrofitting of existing buildings. The same attitudes would probably apply to photovoltaic total energy systems.

Reactions of builders to the proposed solar energy system ranged from skepticism to qualified acceptance. None appeared anxious to pioneer with an untried and unproven system, and there was general concern that, without extensive merchandizing on their part backed up by documented success of the solar unit, buyers would tend to stay with traditional systems. Costs, aesthetics of the solar collector, and location of the storage tanks were major concerns.

Labor groups were in general agreement with other populations. They found increased weather stripping, caulking, and cooling to be less of a problem than other groups. Increased construction time was marginally acceptable, and they perceived the need for a modest amount of special training.

The manufacturers interviewed reacted generally quite favorably. Several said that the firms were already engaged peripherally in assessments of the feasibility of solar energy usage.

Of the seven groups canvassed, energy suppliers were the least enthusiastic about the proposed solar model and the benefits of currently feasible solar energy systems in general. Their objections centered on high cost, technological complexity, constantly fluctuating demand on their services, and general skepticism with respect to consumer acceptance.

Financiers believed generally that a solar supplement would have no direct adverse effect on financing and could possibly improve it. It was felt that solar systems will enhance the saleability of a

building, and that solar unit sales should experience a strong growth rate once these systems are in use (between 10 percent and 50 percent per annum). Saleability with solar units would be affected by cost considerations, just as conventional systems are, but the novelty of the concept is not considered likely to impair the market and, in fact, would probably enhance it.

Consumers generally shared most of the same attitudes as expressed by the other groups. The probable costs of solar energy were one of their major concerns. They also reacted adversely to the possibility of some of the inconveniences that solar energy might entail such as perhaps a need for smaller rooms or a higher operating noise level for the system.

In a number of key respects, representatives of the different stakeholder groups shared similar views relative to solar energy barriers and requirements.

5.1.7.2 The Importance of Costs

More so than any other consideration, all stakeholder groups were concerned about the costs of solar energy. This concern was evidenced in answers to different questions put to different groups.

(1) For instance, consumers, builders, and energy suppliers all agreed that market acceptability would be seriously impaired if it cost more than \$5,000 to equip a new house with a solar heating and cooling unit. (Not a photovoltaic energy system). These results are presented in Table 5.1.

(2) Architects and mortgage bankers agreed that if the heating/cooling solar energy unit (including installation) cost more than 15 percent of the total construction costs of the structure that market acceptance would be seriously impaired. These results are presented in Table 5.2.

TABLE 5.1

Acceptance of Solar Energy H/C System Costing Over \$5000
(Assuming 50% fuel saving)

<u>Group Surveyed</u>	<u>Acceptance Level</u>
Consumers	1.79
Builders	1.87
Energy Supplies	1.75

Code:

1: very unacceptable

5: very acceptable

TABLE 5.2

Acceptance of Solar Energy H/C Systems
(Assuming 50% fuel saving)

<u>Group Surveyed</u>	<u>Solar Energy System Cost (% of Structure)</u>			
	<u>0-5%</u>	<u>6-10%</u>	<u>11-15%</u>	<u>Over 15%</u>
Architects*	27%	48%	27%	0%
Bankers (over \$50K house)	36%	55%	9%	0%
Bankers (under \$50K house)	72%	27%	0%	0%

*These figures are based on a tabulation of responses by the Architect's Housing Committee and apply to new single family dwellings.

(3) There is other evidence attesting to the importance that bankers would place on costs in making loans involving solar energy structures. For instance, 85 percent of all responding bankers indicated that the potentiality that solar energy has for reducing fuel costs would be a highly favorable factor influencing their financing decisions. Also, 83 percent indicated that high maintenance costs for solar energy units would be regarded as a highly unfavorable factor. Other decision criteria such as reliability, maintainability, appearance, etc. were rated as less important.

5.1.7.3 Siting of Solar Equipment

There was no dominant preference among all groups as to the preferred siting for single-family residential solar units. Labor

union and building contractor representatives preferred a roof installation whereas consumers preferred an off-site central location. Architects also preferred an off-site central location using an aesthetic-acceptability criterion, but an attachment to a garage or carport using a technical feasibility criterion. Placement at the side of the house was the least preferred site. The results are presented in Table 5.3.

TABLE 5.3

Site Preferences for Location of Solar Energy Unit

<u>Site</u>	<u>Labor Unions</u>	<u>Group Surveyed¹</u>		<u>Consumers</u>
		<u>Builders</u>	<u>Architects²</u>	
Off-Site Central Location	2.42	3.30	3.70	3.45
In Yard	2.29	2.54	3.30	3.36
Attached to Garage or Carport	2.60	3.42	3.96	3.32
Roof	3.82	3.98	3.88	3.28
Side of House	2.74	--	2.82	2.71

¹Code: 1: very unacceptable
5: very acceptable

²Architects were asked to rate on two criteria: aesthetic acceptability and technical feasibility. The scores for architects shown above represent an average of the scores for the two criteria. These averages mask some differences in the ratings on the two bases of the architect group.

5.1.7.4 Maintenance Frequency

The anticipated need for maintenance is clearly one of the most important considerations in determining the market acceptance of a new life-support technology like solar energy. The survey findings, presented in Table 5.4, revealed both important similarities in opinions of some groups and important differences among others. Averaged over all groups, roughly a 6-month maintenance schedule was

considered as the maximum acceptable frequency. However, three important groups - energy suppliers, builders, and consumers - had more votes for an annual maintenance schedule as the maximum acceptable. Architects as a group, felt that a monthly maintenance schedule would be tolerable. Labor unions selected a 6-month maintenance schedule more frequently than any other time period.

TABLE 5.4

Maximum Acceptable Maintenance Schedule Frequency

<u>Group Surveyed</u>	<u>Schedule Frequency</u>				
	<u>Weekly</u>	<u>Monthly</u>	<u>Semi-Annual</u>	<u>Annual</u>	<u>Every 18 mo.</u>
Labor Unions	0	27%	42%	27%	4%
Energy Suppliers	0	4%	36%	50%	10%
Builders	0	3%	9%	63%	25%
Consumers	3%	8%	25%	47%	19%
Architects:					
Education	23%	47%	16%	16%	0
Housing	5%	50%	40%	5%	0
Design	21%	16%	53%	6%	6%
Commerce & Industry	20%	30%	30%	10%	10%

A further comment on the opinions expressed by architects is in order. Clearly, architects felt much more so than any other group that frequent maintenance checks could be tolerated. Roughly 85 percent of all architects felt that maintenance at 6-month intervals or less would be acceptable, and a sizeable percentage felt that weekly maintenance checks would be tolerated. In contrast, very few groups - energy suppliers, builders, and consumers - felt that weekly, or even monthly, maintenance checks would be acceptable.

5.1.7.5 Necessary Conditions

The need to make solar energy technically feasible and economically cost/effective imposes certain new requirements on all stakeholder groups. Considering the fact that these new requirements impinge more heavily upon some groups than others, it is somewhat surprising that there was not greater diversity of opinion among the different groups relative to the acceptability of these new conditions as shown in Table 5.5.

Everyone accepts the need for increased insulation, even those such as consumers who must pay the cost for such insulation.

The possible need for smaller rooms and higher operating noise is uniformly unpopular with every group.

Somewhat surprisingly, most groups do not feel strongly, one way or the other, about the need for fewer trees, smaller windows, and unconventional roof designs.

5.1.7.6 Summary of Survey Results

In introducing solar energy systems into buildings, emphasis should be placed on incorporating the systems into newly constructed buildings, as opposed to retrofitting systems to existing buildings. Emphasis should also be placed on middle- to higher-priced residences, and larger commercial or public buildings to start.

High costs for solar energy systems were found to be more acceptable in new buildings. This fact is another factor weighing against extensive retrofit.

Financers recommend that heavy emphasis be placed upon high-priced residences and large-scale developments in introducing solar heating and cooling.

TABLE 5.5

Acceptability of Possible Necessary Conditions

	<u>Labor Unions</u>	<u>Energy Suppliers</u>	<u>Builders</u>	<u>Consumers</u>	<u>a</u>	<u>Architects</u>		
						<u>b</u>	<u>c</u>	<u>d</u>
Increased insulation required	4.2	3.7	4.5	3.9	4.0	4.5	4.3	4.5
More space heating equipment	-	2.5	2.8	3.1	2.8	3.0	2.6	2.7
Fewer trees	-	-	3.0	2.6	3.1	2.4	2.5	2.8
Smaller windows	-	-	2.9	2.5	4.0	2.8	3.3	4.3
Unconventional roof	-	-	2.6	3.3	3.7	3.4	4.0	3.6
Smaller rooms	-	-	2.0	2.0	1.8	2.3	2.5	2.2
Higher operating noise	-	-	2.0	1.8	2.0	2.9	1.8	2.1
Increased skill required	4.2	2.7	3.1	-	2.5	2.8	3.2	2.7

Code for Architects:

- a: Education Committee
- b: Housing Committee
- c: Design Committee
- d: Commerce & Industry Committee

Code: 1: very unacceptable
5: very acceptable

5.2 Regulatory Requirements

5.2.1 Building Codes

A detailed analysis of the major applicable building codes in five site cities was performed for the Phase 0 study. The analysis included identification of areas, referenced to specific code sections with degree of priority, which must be addressed during detailed system and component design if potential problems are to be avoided. The general conclusion of the analysis was that, while careful attention would be required during detailed design, there do not appear to be any required changes. Although the analysis could not cover all the local variations from the model codes in the various code jurisdictions of the United States, the evidence from the analysis indicates that required changes will be minimal, provided care is taken during detailed design. There may be a need for code changes relating to system voltage and battery energy storage for the electrical systems however.

The findings are reinforced by comparisons to the likely system designs for large, complex buildings now using more advanced conventional systems. For example, while not yet widespread in use, heat-of-light recovery, thermal storage, and other complex subsystems, which could be part of a photovoltaic/conventional system, are already in use. In fact, part of the attractiveness of photovoltaics for this type of construction is the potential shared-use of some of these subsystems. Consequently, the significant new potential problems would likely be associated with the collector and storage subsystems and their interfaces with the building and other subsystems.

While many of the subsystems are used in highly engineered buildings, they would be new to the residential construction field and hence to the code authorities and personnel familiar with residential construction and with residential builders. The distinctions between the residential and nonresidential construction markets are very important and fundamental regarding the impacts of codes on the adoption of new products.

The code areas analyzed in depth are listed in Table 5.6 and include those generally associated with building construction and operation, i.e., building, electrical, mechanical, plumbing codes.

The absence of a significant number of required changes represents a positive finding; however, evidence from this project and numerous other studies analyzing the impact of codes upon the introduction of new products and innovations in the construction industry strongly indicates that the absence of a clear determination of "required changes", while important, is not sufficient to ensure successful avoidance of "code problems" in the introduction of new building technology. Therefore, any utilization plan must address the code problems or barriers as they are operative in the industry.

The process by which a builder obtains approvals involves picking his way through a complex of frequently overlapping code jurisdictions. Typically, this is done by establishing a network of contacts and information which tells them what practices are accepted by building inspectors in particular code jurisdictions. In evaluating whether to employ an innovation, a very important consideration is whether it will require new or different treatment by various code approval bodies. The possible requirement to clear a new product or system through a complex of jurisdictions, even though it does not violate written codes, is an inhibiting factor in itself. When this is coupled with the time lags, costs of negotiative approvals, and the uncertainty as to interpretations, a good picture is obtained of why a builder may well be reluctant to be innovative. This informal approval approach, whereby the written word of specific codes and regulations is interpreted by officials and onsite inspectors, is most important.

The significance of code problems as perceived by residential builders has been identified in a study conducted by the NAHB Research Foundation, Inc., for HUD on "Constraints to Builder's Use of Cost-Saving Innovations and New Products." In that study, two of the most

TABLE 5.6
Current Codes Used in
Five Site Cities

<u>City</u>	<u>Building</u>	<u>Plumbing</u>	<u>Mechanical</u>	<u>Electrical</u>
Mobile	Southern Standard Building Code (1973)	Southern Standard Plumbing Code (1971)	Southern Standard Gas Code (1973)	National Electrical (1970)
Santa Maria	Uniform Building Code (1973)	Uniform Plumbing (1970)	Uniform Mechanical (1970)	National Electrical (1970)
Atlanta	BOCA Basic Building Code (1970)	BOCA Plumbing Code (1970)	BOCA Mechanical Code (1971)	BOCA Mechanical Code (1971)
Wilmington	BOCA & Basic Building Code (1970) & Amendments*	BOCA, Plumbing (1970) & Amendments*	BOCA Mechanical Code (1971)	BOCA Mechanical Code (1971)
Madison	Special Code Building Code of Madison & Wisconsin Administrative Code for Building	Plumbing Code of Madison & Wisconsin Administrative Plumbing Code	Heating, Ventilating & Air-conditioning Code of Madison & Wisconsin Administrative Heating, Ventilating and Air-Conditioning Code	National Electrical & Special Electrical Code of Madison

*Special Wilmington Amendments

significant constraints identified related to the builders' perceptions of codes.

To quote from the study:

"Constraint 'It is prohibited by the building code. This constraint ranked fourth even though it is really only applicable in the majority of cases to five of the 12 innovations. Without getting into complex details, let me say that this constraint is the only one that is additive to any other one; namely, 'Although not prohibited specifically by the code, local building officials frown on it and we comply with the desires.' (That constraint ranked sixth). These two are additive in part, and we have estimated that had the question been a combined one, their aggregate weighted value would have been highest, namely about 0.55. The key here is that the new product must not only be accepted by the code, but all the building officials and inspectors need to be convinced that it is an acceptable alternative. A part of this problem of convincing all the many lesser officials is very evidently merely one of seeing to it that they get information about the new product. From the study it is quite evident that even the top building officials do not get all the information they need or they get inadequate and unbelievable information about new products from manufacturers.

Our experience and this research shows that lack of adequate technical information is an important constraint to use of cost-saving innovations, new products, and old products. For successful marketing of a new product, it is absolutely essential that the specific detailed information in installation, performance, cost, and availability reach the builder, his technical and marketing assistants, code officials, and their inspectors."

While the study cited above covered residential builders, a similar but perhaps less severe problem exists for the architect and engineer when dealing with engineered buildings. Although the architect or engineer may have a stronger technical knowledge of the issues involved with cost interpretations relative to a new or unusual design or subsystem, he still must make a business judgment as to whether the potential lost time and costs of the effort to obtain approvals will unfavorably impact accomplishing the job on time and within budget. If incorporation of a particular innovation would introduce risks of delay or nonapproval for his client, his responsibility to the client might require that he avoid use of that innovation.

Examination of the situation from the perspective of the cost approval authorities shows that their problems in dealing with new designs are formidable. Unless they have a body of reliable technical information from a qualified source as to the acceptability of an innovation, they are in a difficult position to approve its use. For this and other reasons, codes necessarily incorporate a significant body of technical standards developed by recognized groups such as:

- Fire and safety insurance groups.
- Professional and engineering groups.
- Industry-sponsored laboratories, institutes, or trade organizations.

Since some of the components of a photovoltaic system are unfamiliar and the solar collector is unknown, it will be necessary to develop standardized testing procedures, and performance and safety standards, and product identification and labeling.

Although codes are not related to equipment performance apart from its relationship to hazards, a need for performance certifications will exist to provide the designer and buyer assurance that the equipment performance has been established. The equipments requiring the development of new performance testing programs will be collector arrays, inverters, and possibly electrical and thermal storage.

Work is currently underway within the National Bureau of Standards on these areas.

In recent years, much work has been done to begin to overcome both the problems of actually restrictive codes and the perceived problems of builders and code officials growing out of inadequate and/or inappropriate information upon which to base their decisions about the use of innovations. Drawing from the experiences developed through the codes work in Operation Breakthrough, the work of the National Conference of States on Building Codes and Standards, and studies such as that of the NAHB Research Foundation previously cited, a number of strategies emerge as key to any successful plan to overcome potential code barriers.

Perhaps the single most important strategy is involvement of the standards and code setting organizations early in the process of designing a new product or system. A concerted effort would be required to involve the appropriate organizations as early as possible and to stimulate their active and timely response to the needs for new standards, certifications, and codes, as well as interpretations of existing ones.

While the strategy is essential, it is also apparent that the process of gaining product approval is both costly and time consuming for the manufacturers of new products. Provision should be made to minimize the time and cost burdens for equipment manufacturers.

5.2.2 Safety Considerations

The introduction of a photovoltaic energy system does not appear to present any unusually difficult problems; that is, problems which are new, or problems which have not been satisfactorily solved in other applications. There are, however, several distinctions from conventional systems which have safety aspects, for example:

1. Use on the roof of large areas of protective glass covers for the cells and its possible breakage.

2. Moderately high voltage direct-current wiring having a high current capacity and distributed over a relatively large roof area.
3. Large battery storage and protection against liberation of flammable hydrogen gas.
4. Inability to "turn off the sun" for installation, maintenance and repair of solar arrays, with consequent electrical shock hazard.

The organizations which must be involved with developing the applicable safety standards and certifying particular designs include in particular Underwriters' Laboratories. For aspects which are not explicitly covered by codes, reference is frequently made to authoritative sources such as professional and industry groups. A closely related requirement area which could be crucial to obtaining acceptable fire and hazard insurance ratings will be adherence to standards of the National Fire Protection Association (NFPA). Of particular concern would be areas such as use of flame resistant and noncombustible materials, use of fluids with good overall safety and nonflammability, ease of access for repair and maintenance, potential for damage to the rest of the structure due to malfunction, and susceptibility to vandalism or damage due to natural causes. The insurance and underwriting decisions also have an influence on the lending community which can affect interest rates on loans. Therefore, the importance of providing adequate and reliable assurance of system operation and safety information cannot be overemphasized.

5.2.3 Zoning

Many of the considerations affecting zoning have been discussed under a previous section on legal matters. Zoning merits separate discussion because it applies at the local level and deals in specifics.

Zoning regulations are generally set by the smallest of the governmental bodies having jurisdiction over a particular site. Each of these will need to reconsider its zoning regulations with regard to solar matters and to make the changes it deems appropriate. To avoid a confusing disparity of regulations, it would be very helpful if a set of zoning guidelines were established at the state or federal level. Enforcement also would usually be at the local level. Clear and easily used criteria need to be developed to resolve for local officials the three-dimensional problems which will arise. For example, a new second-floor dormer planned for a house shows a possibility of shading a small corner of a neighbor's array during the early morning hours in the summer. Considerable measurements and calculations would be necessary to find out if this would occur, and to what degree at various times. To write the zoning regulations so that there may be no shading at any time could severely limit or prohibit building practical structures on certain properties in hilly country. If a small amount of shading is permitted, the time period and degree of shading must be specified and accurate determination made of these in each instance. The problem is compounded in the case of trees because their geometry and light transmission change with age, wind, and season.

The "sun rights" issue has received considerable attention whenever solar installations on a widespread scale are discussed. This is due in part to the fact that the problem is easily recognizable, but its eventual solution is not. In this study it is not appropriate to try to resolve this problem, but it is proper to judge whether lack of reasonable zoning protection will importantly inhibit the introduction of solar photovoltaic technology. It is fairly clear that there now exists sufficient zoning for new single family residences. Most residential areas now develop and remain for many years without the incursion of large buildings to cut off the sunlight. Moderate zoning combined with a layout of streets, lots, and homes oriented to solar use will permit solar energy to be used for the life of the installation in the vast majority of cases. Trees may well be the most frequent

cause of solar shading; many persons building on wooded lots may forego solar to keep the trees.

A number of these issues are expected to be at least partially resolved during the process of introducing solar heating and cooling systems, which will tend to appear earlier than photovoltaic systems.

In the case of the IPS, a great many of the likely users have control of the adjacent ground area: schools have play areas and grassy plots, shopping centers have parking lots, military installations have perimeter security strips. Such areas will both help prevent neighboring structures from creating solar obstruction, and will also tend to keep these groups from obstructing their neighbors.

Installations of the CPS will probably include at least a strip of land owned by the utility surrounding the installation for security and access purposes, which will aid in preventing shading.

5.3 National Interests

5.3.1 Resources

The principal resources required for bringing solar photovoltaics to fruition are: adequate funding over a period of years, technical effort sufficient to produce the low cost, reliable, and efficient solar cells needed, and the quantities of raw materials to fabricate the equipment for the complete system.

The funding will be required in reasonable amounts on a continuing basis thru 1985 to support the solar cell development, system design, and resolution of the important non-technical issues. For the RPS, an adequate pre-commercialization program will have to be established. The CPS, and to an extent the IPS, will have to be federally funded well beyond 1985. Technical manpower and manufacturing resources for producing large quantities of practical solar cells and arrays will need to be committed on a continuing basis; special manufacturing

facilities for the cells will be required at an early stage. Fairly large, but manageable, quantities of raw materials will be needed, particularly lead for the batteries and possibly copper for the heat exchangers. Most of the materials required in large quantity are not used consumptively, but are in relatively easily recoverable form.

The resource saving is in the form of depletable fuel not used and energy not spent in constructing and utilizing alternate means. These savings continue throughout the life of the equipment, and increase on an annual basis as new installations are gradually added.

5.3.2 Environment and Health

Solar photovoltaic systems should have a net positive effect on the environment. To the extent it is applied to reduce the use of fossil fuels, photovoltaics will reduce the pollution resulting from the burning of these fuels. At the same time, it will reduce the associated reject heat from central stations being discharged into rivers and streams, now becoming a serious problem. Alternatively, it will reduce the need for cooling towers with their vapor plume problems, if this method is chosen to dissipate the reject heat. In the RPS, if a solar-thermal design is included, there is also a reduced energy demand for home heating.

Large installations may also serve as canopies or roofs that provide shade for other economic activities. The solar canopy might be used to catch rain water, particularly in dryer locations, and there is the possibility of locating light manufacturing underneath the solar canopy. It may also be that where land use is a problem in more densely populated areas, the solar central station can be located on the roofs of large industrial plants, over rail classification yards, or over vehicle parking spaces.

There is a general consensus that photovoltaic central stations have the fewest environmental or safety problems of most any major electricity generation technology. The aesthetic problem does

not appear to be very serious. The immediate visual impact could be neutralized by surrounding the central station with a mound of earth covered by vegetation. Reflection in the early morning or the late evening could in some locations add to the problem of glare from direct sunlight. Siting the central stations so as to avoid direct reflection into the path of traffic on major highways or airways would mitigate this problem.

Improvement in health will accrue to the extent that harmful effluents are reduced. This effect is highly localized in the case of CPS. It is dispersed in the case of IPS and RPS, but only to the extent that fossil heating/cooling is replaced: the credit for electric generation appears at the central station.

5.3.3 Demographics

Demographics, in the sense of where people live, would be strongly influenced by the widespread use of solar electric in many cases.

Where energy prices are rising rapidly and there are fuel availability limitations, such as presently is the case in the areas of the Northeast, there is a tendency for people to move away. A reasonably priced solar alternative could slow down or halt this migration.

People would tend to be attracted to other areas having a good fit with solar in terms of insolation and load pattern. Users at all power levels may prefer the known financial commitment of solar, once established, to the unknown future costs of conventional energy sources.

Certain regions not served by electrical utilities could experience new construction of various types earlier than would otherwise be the case. Second homes at remote locations, roadside rest and emergency stations, commercially operated hunting, fishing and ski lodges, and fire observation stations are examples.

On a small area basis, locations having poor solar accessibility may tend to be avoided. Places on the north side of steep hills and mountains, sites in the shadow of existing buildings, bridges, or other structures, or locations with unfavorable atmospheric conditions such as heavy fog or dense cloud cover will be much less likely to take advantage of solar electric energy.

5.3.4 National Security

There are a number of effects that the widespread use of photovoltaic power generation would have upon the security of the nation.

First, there would be reduced dependence upon imported oil, as well as a reduced demand upon domestic supplies, freeing them for use to meet any emergency.

Second, the use in IPS and RPS applications will reduce the effects of sabotage against central station plants. This could make the difference between a community continuing to function rather than virtually collapsing in many areas. This advantage might also apply in the case of natural disasters, such as severe storms or earthquakes.

Third, the modular nature of the collectors would make repairs relatively simple in case of damage that is not too severe. The same modularity would enable replacement power systems to be moved into an area with relative ease.

Fourth, many military applications can use the logistical advantage of not requiring a fuel supply.

5.3.5 National Policy

In considering the national policy implications of solar photovoltaics, it is necessary to include some factors that are more indirect than simply the production of kilowatt hours on the benefit side and the directly incurred commercial cost of production on the other.

First, photovoltaic systems avoid depletion of fossil fuel resources. This benefit may be only partially measured by the dollar cost of the alternative energy sources, because the market tends to be relatively shortsighted in discounting the future.

Second, the photovoltaic systems reduce dependence on foreign oil moving the country toward "Energy Independence." This benefit also accrues to any domestic energy source.

Third, the photovoltaic systems do not cause air pollution. Nuclear systems also have this benefit, but pose other environmental and safety questions that photovoltaic systems do not have.

All photovoltaic systems, including the intermediate and residential systems, have the above cited benefits, as do all other solar energy systems.

Photovoltaic central power stations can in some instances can serve to encourage economic development of depressed areas. However, the same can be said of other industries. Before one can conclude that photovoltaic systems should be subsidized to obtain this benefit, there should be good reasons for preferring the solar development over other industries that could be subsidized in the same area. One case identified in the study is the economic development of Indian tribes in Arizona and New Mexico, particularly the Navajo. Much reservation land is distant from conventional power sites and very well suited to solar station sites. The combination of favorable solar sites, potential local use for water pumping, and location of some solar manufacturing industries to fabricate components of the central station may be favorable to Indian economic development.

A conclusion of this study is that solar photovoltaics for the applications discussed in this report will not come into existence if left to natural market forces. The level of investment is too high, the time to payback is too long, and the uncertainties are too large to allow for high quantity system production and nationwide marketing capability. However, on a national basis the investment is modest,

the payback is sizeable and continuous, the technical uncertainties beyond the low cost cell are few and the other uncertainties can be overcome by an effective government implementation policy.

Although applications outside the designated region in the U.S. are not part of this study, it is more than likely that successful implementation here would mean that solar photovoltaics could be applied elsewhere. Use on islands without fossil fuel and remote from mainland sources is an obvious candidate. IPS units employed in developing countries for schools, hospitals, water pumping, and light manufacturing facilities may pre-date by decades the introduction of transmitted power from a central station type utility. The possibility is good that a solar photovoltaic IPS could operate for long periods without any trained operating personnel on site.

Foreign aid in the form of solar photovoltaic power plants could meet real needs, and is not easily diverted in other channels.