Department of Energy Resource Assessment Program 5-year Plan

FY 1991 - FY 1995

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Introduction

The U.S. Department of Energy's (DOE) Resource Assessment Program produces scientific descriptions and assessments of the nation's renewable energy resources, such as solar energy. Information about the resources—for example, how solar energy varies with location and climate—is required to develop energy conversion technologies, design and site systems, and forecast the systems' performance. With information about resource availability and renewable energy system performance, DOE can assess the potential for renewable energy to contribute to the nation's energy supply as part of the long-term national energy strategy.

The Resource Assessment Program is currently concentrating on solar radiation resource assessment, but an initiative is under consideration at DOE to expand the Program's activities to include other renewable energy resources, such as wind, biomass, hydropower, geothermal, and ocean thermal. DOE's lead center for solar radiation resource assessment is the Solar Radiation Research and Metrology Branch in the Solar Electric Research Division at the Solar Energy Research Institute (SERI). Work is performed at SERI under the Solar Radiation Resource Assessment Project.

This 5-year plan for fiscal years (FY) 1991 through 1995 gives the strategy to produce solar radiation resource characterizations and assessments under the DOE project at SERI. It is consistent with the mini-multiyear plan for resource assessment prepared by DOE in 1989 and incorporates the comments received at a project overview held in April 1990 at DOE Headquarters.

The solar resource

Purpose of the Solar Radiation Resource Assessment Project

Primary considerations in gaining national acceptance of solar conversion systems are reliability and predictability. Because solar conversion systems use an intermittent resource (i.e., solar energy), we must thoroughly understand the resource availability and variability to reliably predict the energy that will be produced by these systems. An understanding of the resource variability also allows us to design systems to take advantage of the resource characteristics, such as generating electricity with solar conversion systems during the sunniest part of the day to offset peak load demands caused by air conditioning requirements.

Thus, an understanding of the spatial (geographic) and temporal (hourly, daily, seasonal) variability of solar radiation at different locations is fundamental to the nation's efforts to develop and use incident solar radiation as a renewable energy resource. In addition to spatial and temporal characteristics, the spectral content of solar radiation is important to design and develop spectrally selective technologies, such as photovoltaics. For example, multiple layer photovoltaic (PV)

cells are being designed to capture energy over an extended region of the solar spectrum to increase their efficiencies; therefore, the sensitivity of PV cells to natural spectral variations should be evaluated.

A quantitative and scientific understanding of the spatial, temporal, and spectral characteristics of solar radiation is attained through measurements, computer models, and analyses of data to extract features relevant to energy production, such as daily and seasonal profiles of solar radiation availability. The purpose of DOE's Solar Radiation Resource Assessment Project at SERI is to help meet the needs of industry, utilities, researchers, and government for these solar radiation data, models, and assessments, as required to develop, design, deploy, and operate solar energy conversion systems.

The Need for Solar Radiation Resource Assessment Information

The need for solar radiation resource assessment information is evaluated by direct interaction with industry, utilities, and laboratory researchers. SERI also receives specific guidance from a Science and Technology Review Committee, with representatives from universities, government, and utilities. From the many needs identified, DOE and SERI determine common needs that can be addressed to reach a large number of users. This results in the most cost-effective use of program funds. The common needs are as follows.

- Continuous, reliable measurements of solar radiation from a large network of sites in the United States to develop resource assessments
- Maps and data of solar radiation availability and resource characteristics covering the United States for various types of solar collectors
- Long-term data bases that represent the natural spatial and temporal variability of solar radiation

- Spectral solar radiation models and data sets for the design and development of spectrally selective solar energy conversion systems
- Design or typical-year solar radiation data sets that can be used for design and economic comparisons of solar energy systems
- Site-specific (local) solar radiation estimation methods for site selection and performance predictions
- Research-quality data bases to develop resource characterization methods
- Models or algorithms to convert solar radiation data from one component to another. For example, from total (global) solar radiation on a horizontal surface—the most common measurement—to solar radiation directly from the sun's disk (direct) and scattered radiation (diffuse) available to a collector surface of any orientation and configuration
- Accurate solar radiation measurement instrumentation and methods to characterize the solar resource and evaluate system performance
- Worldwide solar radiation resource assessments to evaluate market potentials for U.S. industries and design systems for foreign markets.

Multiyear Goals and Key Activities

The multiyear goals of the Solar Radiation Resource Assessment Project mirror the common needs identified above but are scaled according to available funds. Each year, DOE and SERI agree on a set of key activities that address these goals within the limits of the fiscal year funding. In recent years, funding has supported three to four people including the project manager and part-time administrative support. The current multiyear goals are as follows.

Multiyear Goals and Key Activities

- To produce a 30-year (1961-1990) solar radiation data base for the United States to replace the 1953-1975 data base, followed by development of products (design/typical year data sets, maps, data summaries, etc.) and methods for site-specific solar radiation estimates
- To support the collection of high-quality solar radiation data for the United States through cooperation with the National Oceanic and Atmospheric Administration (NOAA), which operates the national solar radiation (SOLRAD) network, with DOE's solar radiation network sites at selected Historically Black Colleges and Universities (HBCUs), and with other regional networks as resources permit
- To produce a limited, research-quality spectral solar radiation data base and spectral simulation model for various climate conditions, as needed for the development of spectrally selective solar energy conversion technologies
- To disseminate products and research results and maintain laboratory expertise as the nation's lead center for solar radiation resource assessment information.

This 5-year plan reflects a multiyear commitment to achieving the DOE/Solar Radiation Resource Assessment Project's goals in logical steps. It first describes the *Core Research Project*, followed by *Project Enhancement Initiatives* that would require additional funding to accelerate progress in critical areas.

The first initiative would expand resource assessment activities to include other renewable energy resources, in addition to solar radiation, such as wind, biomass, hydropower, ocean thermal, and geothermal.

The second initiative proposes that DOE/SERI establish and maintain a national solar

radiation energy network to fill a critical need for high-quality data.

The 5-year strategy assumes base funding levels of about \$1 million (plus inflation increases) that support four to five people. Proposed project enhancements would increase the staff to nine or ten people and allow for subcontracts (e.g., to universities and solar radiation networks). The enhancements would increase the viability and efficiency of the project to perform national solar radiation resource assessments, as well as expand resource assessment to include other renewable energy resources and establish a solar radiation energy network.

The Core Research Project

Each of the key activities in the *Core Research Project* for FY 1991 through 1995 is described here, including the rationale, status, and future plans.

National Data Base Development and Data Base Products

Rationale

DOE and the Solar Radiation Resource Assessment Project have given top priority to developing a national solar radiation data base, covering the period from 1961-1990, to replace the 1953-1975 SOLMET/ERSATZ data base. The 1961-1990 time frame was selected to

coincide with the period to be used by the National Oceanic and Atmospheric Administration (NOAA) to establish new long-term means or norms of climate variables (e.g., temperature and precipitation). The 1953-1975 SOLMET/ ERSATZ data base was created by combining rehabilitated measured hourly global (total)-horizontal solar radiation data for 26 SOLMET (SOLar METeorological) sites, modeled (estimated) direct-normal values for the 26 sites, and modeled global-horizontal values for 222 ERSATZ (meaning synthetic) sites with meteorological data. A new, upgraded national data base is needed to account for any recent climate change and to

SERI researchers validating QC software

reduce known errors in the 1953-1975 data base.

The 1961-1990 data base, which will include measured data from at least 40 stations and estimated (modeled) values for an additional 200 locations, will improve the quality of solar radiation data for the United States because of the addition of good-quality data for 1977 to 1985, the addition of new NOAA SOLRAD data acquired between 1988 and 1990, and improved models. The

improved models will be used to estimate missing data and to estimate values at the ERSATZ stations using meteorological data. Attention is being given to the statistical characteristics of solar radiation, (e.g., variance, skewness, and kurtosis), as well as mean values, to properly represent the natural distribution of the data. The new data should be more representative of current climate conditions because any climate changes that have occurred since 1975 will be contained in the new data base.

Status

The 1961-1990 data base development is a multiyear effort that includes elements such as development of post-measurement quality assessment procedures, models to convert global-horizontal measurements to direct-normal and diffuse components, models to estimate solar radiation using meteorological data (e.g., cloud cover), and efforts to recover data acquired at the NOAA SOLRAD stations. Work on the data base elements is well under way. For example, SERI has developed a quality assessment software package (SERI QC), which is under review by Sandia National Laboratories-Albuquerque and others, and has developed large data sets of high-quality

Example of data products

measured data for model development. Procedures for producing the new data base will be in place by the end of 1990.

Future Plans

The 5-year strategy reflects a transition from completion of the new data base in 1992 to development of data base products such as design or typical-year data sets, maps, data summaries, and methods to estimate site-specific solar radiation values. In 1991, the data base development procedures will be validated and production of the data base will begin. The data base is expected to be completed in 1992. Following data base completion in 1992, user-friendly data products for the solar community will be developed and disseminated. Examples include design or typical-year data sets, maps, and statistical summaries. These data products will be developed in cooperation with interested users, such as the Sandia National Laboratories-Albuquerque Design Assistance Center, for development of design data sets.

In 1991, the Solar Radiation Resource Assessment Project staff will participate in the International Energy Agency (IEA) Solar Heating and Cooling Program's Task 9-D that

is addressing methods to supplement measurement network data, but only limited participation is possible because of the focus on the 1961-1990 data base production. Enhanced funding would allow greater participation in this task as well as another IEA task that is addressing criteria for producing design or typical year data sets.

In 1993 through 1995, more emphasis will be placed on site-specific solar radiation resource assessment. This activity is important because measurement stations are very sparsely located in the United States, and data are needed to evaluate and choose the best locations to deploy solar conversion systems. A mesoscale data grid will be developed for solar radiation estimates across the United States, with associated geographical information and map products.

The locations of existing solar radiation networks (national, state, and private) will be compared with the grid locations to identify measurement reference points and gaps in the

data. Methods such as satellite estimation of solar radiation will be developed and applied to obtain more detailed regional assessments where solar radiation measurements are lacking. The mesoscale solar radiation estimates can be compared with averages of daily satellite-derived solar radiation estimates from NOAA at $1^\circ \times 1^\circ$ latitude-longitude resolution.

During this period, the project will renew its activities on solar radiation modeling, quality assessment methods, and data processing/analyses upgrades to apply to site-specific resource assessments. The first 5-year update of the national solar radiation data base will also be initiated in 1995.

Solar Radiation Networks

Rationale

The collection of long-term, high-quality solar radiation data is critical to characterize annual variability and climate trends, develop design or typical-year data sets for solar conversion

system performance analyses, and update the national data base at 5-year intervals. The map on page 6 shows the location of NOAA's SOLRAD network stations along with the location of 6 stations funded by DOE through SERI at Historically Black Colleges and Universities (HBCUs). Other regional networks are operated by entities such as the Pacific Gas and Electric Company, the University of Oregon, and the Illinois State Water Survey. Because DOE does not operate a national network of its own for energy resource assessment, DOE supports data collection by these various groups so that SERI can request data for use in energy-related resource assessments and refer users to the regional networks.

Status

NOAA's operation of the 38 stations in the SOLRAD network, with support from DOE, was good from 1977 to 1980. Due to major decreases in funding, about 50% of the data from this network were lost between January 1981 until the network shut down in October 1985. No data were collected from October 1985 to January 1988 when limited network operations resumed. From 1975 to 1990, NOAA's operation of the SOLRAD network has been intermittent, limited, and uncertain because of funding constraints. In addition, National Weather Service operational upgrades and automation in the 1990s may result in closing some SOLRAD stations and changing the way cloud cover data are obtained (an important consideration for modeling efforts that use meteorological data to estimate solar radiation). SERI and NOAA have a good cooperative relationship and they interact in such areas as quality assessment procedures and radiometer calibrations.

DOE's and SERI's HBCU network located in the southeastern U.S. has collected more than 95% of all possible data from the time the stations were first put into operation in 1985 to the present. This excellent record is the direct result of constant interaction with a concerned SERI staff and the personal dedication of HBCU faculty and students. However, funding to HBCUs must be corrected in 1991 to sustain this performance. These stations provide

HBCU solar radiation network operators and roof-top equipment at South Carolina State College (top) and at Elizabeth City State University (bottom)

valuable data in the Southeast where SOLRAD stations are sparse.

A number of state and private networks are operating at various locations across the United States. For example, the University of Oregon operates a network in the Pacific Northwest; however, the number of stations has been reduced from 11 to 6 due to funding reductions. The Pacific Gas and Electric Company operates a 14-station network in its service territory in California, and data can be purchased by interested users. The Illinois State Water Survey operates a 14-station weather network, that includes solar radiation, to determine the effects of weather on agriculture and assess alternative energy generation from the sun and wind. Various other networks exist across the nation that

collect local data for specific purposes. There is no central coordinating group to acquire these data, obtain instrument calibration histories to estimate measurement uncertainty, assess the quality of data, and combine them into a common format for distribution. SERI has the expertise to provide leadership and coordination for a central data archive, if funds were made available.

Future Plans

With the 1991-1995 *Core Research Project* budget, SERI will continue to interact with NOAA to monitor the status of the SOLRAD network, to acquire and process data as they become available, and continue development of a national data base for energy purposes. A larger portion of the *Project* budget must be devoted to the 6-station HBCU network in 1991 to continue operation and ensure a high percentage of data recovery; funding levels should be reassessed in later years. During 1991-1995, SERI will interact with other

networks to the extent possible without impacting work on major tasks such as production of the national solar radiation data base.

Spectral Solar Radiation Data Bases and Models

Rationale

Simple spectral solar radiation models and research-quality spectral data are needed for the design (e.g., optimization), performance analysis, and deployment of spectrally selective solar conversion technologies. For example, ultraviolet (<400 nm) data are needed for studies on materials degradation and research on the detoxification of hazardous wastes using catalysts operating at high-energy wavelengths. Natural spectral solar radiation variations are examined with respect to the response function of solar conversion devices to quantify the sensitivity of devices to these variations.

Status

The wavelength distribution (spectral content) of solar radiation is characterized in the same way as broadband radiation—using measurements and models. Models are necessary because it is not practical to routinely operate sophisticated spectroradiometers at many locations to capture different climate conditions. Models are developed to simulate spectral solar radiation using more commonly available meteorological data. SERI maintains both a spectral data base and a simple spectral solar radiation model that are used by various solar conversion technologies.

In the late 1980s, SERI was fortunate to obtain the cooperation of the Pacific Gas and Electric Company and the Florida Solar Energy Center to build a spectral solar radiation data base that includes about 3000 spectra and associated meteorological and broadband data. The documentation has been written and the data base is ready for dissemination. Now it is important to develop spectral data sets that will help users apply the data to their specific needs. There is also a need to extend the data beyond the current wavelength limits of 300 to 1100 nm (limits of the spectroradiometer used to acquire the data) to include more of the

Natural spectral solar radiation variations documented in the data base

ultraviolet and near-infrared wavelengths of interest to all of the solar technologies.

SERI has developed a widely distributed, simple model to simulate clear-sky, spectral solar radiation. What is needed is further validation of the model with high-accuracy measurements and upgrade of the model if necessary. There is also a need for a cloud-cover modifier that will allow simulations for application to solar conversion systems operating in cloudy climates. SERI interacts with scientists dedicated to spectral solar radiation modeling, such as those at the Air Force Geophysics Laboratory (AFGL), to incorporate model improvements that can be validated.

The limits of model improvements and validation are set by measurement uncertainties. For this reason, SERI is interested in developing spectroradiometers with accuracies approaching $\pm 2\%$ covering the wavelength range from 280 to 3000 nm, with less than 1-minute response time (to avoid irradiance fluctuations). SERI has been a leader in modifying spectroradiometers to apply to solar energy applications and will continue to modify, calibrate, and operate these instruments to obtain solar spectral measurements and establish measurement uncertainty.

Future Plans

A relatively small part of the Solar Radiation Resource Assessment Project is devoted to spectral solar radiation models and measurements because of the emphasis on development of the national solar radiation data base. Plans for 1991 and 1992 are to improve spectroradiometry to obtain high-accuracy measurements. The measurements can be used to extend the wavelength range of the spectral data base and validate model improvements. Funding increases could provide subcontracts to universities and other laboratories to improve the simple spectral model based on progress reported in the literature. Plans for 1993 through 1995 are to develop spectral solar radiation profiles for different climates in the United States using the spectral data base and models, and to develop user-responsive data products from these data.

In 1992, IEA is tentatively planning to initiate a spectral solar radiation task to improve the

quantity and quality of available data. Part of the task may involve cooperation with the International Daylight Measurement Program, which is establishing a daylight measurement network. SERI will improve its spectral models and data base through interaction with IEA and others, such as AFGL, from 1992 through 1995.

Increased funding in the *Core Research Project* would accelerate progress in spectroradiometry, model development and validation, and production of special data products for the user community. It would also allow a more active role in IEA activities rather than participation mainly for information purposes.

Technology Transfer and Support Activities

Rationale

As the nation's primary solar energy resource assessment laboratory, SERI is called on to provide information and data to government, industry, utilities, and researchers. It is very important to disseminate information as extensively as possible without detracting from the key activities, such as the solar radiation data base development. SERI must maintain basic laboratory capabilities to continue to be DOE's source of expertise for solar radiation resource assessments.

Status

A primary means of disseminating information is through publications and presentations at national conferences. In addition, SERI responds, to the extent funding permits, to requests for data, assistance, and advice. Historically, more than 20 requests per month are received for information about instruments, calibration techniques, data sources, maps and data summaries, and models. This number is increasing with the increased interest in renewable energy technologies.

Future Plans

During FY 1991 through 1995, SERI will continue to disseminate information through publications and presentations and to respond to technical requests as budgets permit and to the extent that long-term research goals are not compromised. Facilities that will be maintained to support research and maintain expertise

The outdoor Solar Radiation Research Laboratory is where baseline solar radiation measurements are acquired and radiometer calibrations and special experiments are conducted

include the Solar Radiation Research Laboratory, an outdoor facility where baseline solar radiation measurements are acquired and radiometer calibrations and special experiments are conducted. The facility also includes data processing (computer) laboratories where large quantities of solar radiation data are processed to develop data bases and models.

Increased funding in the *Core Research Project* would allow SERI to increase interactions with users, including conducting solar radiation measurement and assessment workshops and developing specific data products requested by users. Currently, the Solar Radiation Resource Assessment Project is not funded to be a service or assistance center.

Project Management

Project management is required to meet the milestones on schedule and within budget, and to guide the project to produce high-quality solar radiation assessments as required to continue design, development, and deployment of solar conversion technologies. This 5-year

plan recognizes the need for at least one staff person to manage the project; provide monthly, quarterly, semi-annual, and annual progress reports and budget analysis; prepare annual and multiyear plans; and promote and represent the project nationally and internationally.

Core Solar Radiation Resource Assessment Project Key Activities, FY 1991 through 1995					
Key Activity	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995
Develop the new 1961-1990 Solar Radiation Data Base for the U.S.					
Develop data base products (maps, statistical summaries, design or typical year data sets, etc.)					
Initiate the first 5-year update of the national solar radiation data base					
Participate in the International Energy Agency Task addressing methods to supplement measurement network data					
Develop site-specific resource assessment methods, including satellite techniques, and mesoscale data grid for U.S.					
Interact with NOAA to monitor the SOLRAD network and process and acquire data for the National Solar Radiation Energy Data Base					
Operate the DOE solar radiation network at HBCUs and process data for distribution					
Improve spectral solar radiation measurement capability, especially UV and near-infrared					
Extend the spectral solar radiation data base into UV and near-infrared and validate and improve spectral models					
Develop spectral solar radiation profiles for climate regions in the U.S. using data base and models					
Participate in the International Energy Agency Task addressing spectral solar radiation and the International Daylight Measurement Year					
Disseminate technical reports, data, models, measurement/instrument information, etc. (technology transfer)					
Develop new, leveraged resource assessment opportunities with other laboratories, universities, and industry					

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Core Research Project summary of key activities

Project Enhancement Initiatives

Comprehensive Renewable Energy Resource Assessment Project

A Comprehensive Renewable Energy Resource Assessment Project has been proposed to DOE (1990) to encompass other renewable energy resources (wind, biomass, hydropower, ocean thermal, and geothermal) in addition to solar radiation.

The objective of the new comprehensive resource assessment project is to provide one-stop shopping and assistance for information on all renewable resources. Currently, the various resource assessment activities are scattered among agencies and laboratories throughout the United States and it is difficult for a prospective user of renewable energy technologies to obtain consistent information from one source to evaluate options. The comprehensive resource assessment project would coordinate efforts among the current experts around the country to acquire information in a common data base and a common format and to distribute information from a central source.

In addition to assessing the total resource (e.g., the *Core Research Project* described in this 5-year plan for solar radiation resource assessment), the Comprehensive

A Comprehensive Renewable Energy Resource Assessment Project would encompass other renewable resources such as wind, biomass, and hydro

Currently, the DOE Resource Assessment Program is addressing only solar radiation resource assessment, which is represented by the first box in the diagram (upper left corner)

Resource Assessment Project would examine the potential to develop the resource by incorporating constraints such as land use and topography and the economic value of the resource when combined with current technologies and their environmental benefits. All of these data would be combined into a geographically based information system covering the United States.

Solar Radiation Energy Network Project

It is in the area of measurement networks where funding enhancements are most critical to ensure collection of good-quality U.S. solar radiation data. There is a need for a solar radiation energy network in the United States to support the design, development, and deployment of renewable energy technologies. Energy is not the first priority for the NOAA National Weather Service stations. Their highest priorities include issuing forecasts and warnings of weather, flood, and ocean conditions to help ensure the safety and welfare of the general public. These priorities are reasonable and are not likely to change. If this initiative is funded in the next several years, the new monies would be applied to development of a national solar radiation energy network. Some important features of a national solar radiation energy network are as follows.

- Stations located according to initial assessments of solar climates and solar gradients to capture the total variability
- Stations located at or near NOAA National Weather Service stations whenever possible to maximize the operational efficiency
- Stations located near end-use energy applications
- Redundancy in measurements at all stations to reduce data uncertainty
- Collection, processing, quality assessment, and instrument maintenance on a daily

schedule to immediately identify and correct problems

- Careful instrument selection and regular instrument calibrations to allow good measurement uncertainty analysis;
- Incorporation of measurements needed to develop extrapolation or interpolation methods to produce solar radiation estimates at nearby locations that have no measured data.

The first step in establishing a national solar radiation network is to inventory existing solar radiation networks (e.g., state and private); establish cooperative data collection, quality assessment procedures, and data dissemination methods; and identify regions where measurements are lacking.

The priorities for developing the energy network are first to work with NOAA, HBCUs, and qualified state and private networks to define the required features; and then to design, locate, and equip new stations at key locations, possibly using universities, colleges, and other educational facilities. Data would be collected and processed at SERI while providing routine feedback and data assessments to each station.

Project Enhancement Initiatives Key Activities, FY 1992 through 1995 (proposed)				
Key Activity	FY 1992	FY 1993	FY 1994	FY 1995
Develop and execute a comprehensive renewable energy resource assessment project to encompass all renewable resources (solar radiation, wind, biomass, hydro, ocean thermal, and geothermal)				
Develop and maintain a national solar radiation energy network in the U.S.				

Project Enhancement Initiative Summary

Conclusion

The purpose of DOE's Solar Radiation Resource Assessment Project is to develop scientific and quantitative assessments of solar radiation resources as required to design, develop, and deploy solar conversion technologies and to assess the potential of solar energy conversion technologies as part of the national energy strategy. The 5-year (FY 1991 through FY 1995) strategy for the *Core Research Project* provides for development and dissemination of data bases, models, and data products that are needed to quantify the availability of solar radiation resources and describe the natural characteristics.

Two *Project Enhancement Initiatives* for FY 1992 through FY 1995 and beyond are proposed. The first initiative would expand resource assessment activities to include other renewable resources in addition to solar radiation, such as wind, biomass, hydropower, ocean thermal, and geothermal so that all renewable resources can be evaluated using a common data base. The second initiative proposes that DOE/SERI establish and maintain

a national solar radiation energy network in the United States to fill a critical need for high-quality data for developing and siting solar energy conversion systems.

The importance of solar radiation energy resource assessments is that they describe the natural variability of an intermittent resource that must be quantified and understood to successfully design and deploy solar energy conversion systems. A comprehensive understanding of the resource also allows us to recognize useful features that affect the economic viability of solar conversion systems, such as daily solar radiation profiles that suggest possibilities for peak electricity load shaving.

With this 5-year plan, the DOE Solar Radiation Resource Assessment Project seeks to anticipate and address the long-term solar radiation resource assessment needs to prepare for extensive deployment of solar energy conversion systems in the 1990s.

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