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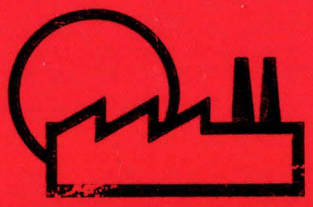
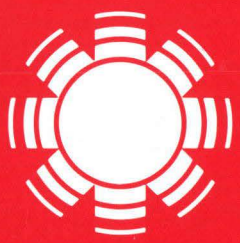


Solar Industrial Process Heat Program: FY79 Annual Report

Compiled by D.W. Kearney



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Solar Energy Research Institute
A Division of Midwest Research Institute

1617 Cole Boulevard
Golden, Colorado 80401

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SOLAR INDUSTRIAL PROCESS HEAT PROGRAM: FY79 ANNUAL REPORT

COMPILED BY D. W. KEARNEY

OCTOBER 1979

PREPARED UNDER TASK NO. 3470.20

Solar Energy Research Institute

1536 Cole Boulevard
Golden, Colorado 80401

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FOREWORD

This report was prepared by the task and subtask leaders of the SERI Industrial Process Heat Program. The authors acknowledge the support of the Agricultural and Industrial Process Heat Branch of the Office of Conservation and Solar Applications of DOE, under the direction of Jimmie F. Dollard, Branch Chief.

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ABSTRACT

This report summarizes the objectives and accomplishments of the SERI Solar Industrial Process Heat program during the 1979 fiscal year. Preliminary plans for the 1980 fiscal year are also described.

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SECTION 1.0

OBJECTIVES AND SUMMARY

Industrial process heat (IPH) is defined as thermal energy used in the preparation and treatment of goods produced by manufacturing processes. The industrial market sector is the nation's largest single consumer of nonrenewable fossil fuels and was responsible for about 37% (28 quads) of the national energy consumption in 1977. Within this sector, process heat constituted about 25% of national energy usage (about 19 quads). Process heat requirements cover a wide end-use temperature range. About 40% of the energy is needed up to 175°C (350°F), 9% between 175°C and 290°C (350°F to 550°F), 11% between 290°C and 590°C (550°F to 1100°F), and 40% above 590°C (1100°F).

Current low- to intermediate-temperature (up to 300°C) solar systems are capable of significant contributions to the process heat needs of many industries. Continued research and development should produce systems that operate efficiently at higher temperatures. Surveys have identified many potential applications for solar IPH, and studies aimed at optimum matching of process and technology will identify applications with greatest potential for success.

Present industrial solar system costs and performances are not economically competitive in today's market, partially because of the state of the technology and partially because of existing prices of conventional energy resources, the lack of sufficient tax incentives, and the high return on investment normally required by industry (e.g., simple payback periods of a few years). As energy supply shortages occur, fuel prices increase, and lower-cost solar IPH systems are introduced, larger markets for solar IPH systems will develop. Although cost goals are difficult to define, given the wide variations in IPH applications and differing industrial investment criteria, a primary objective of the SERI industrial process heat activity is to support the DOE program to bring about system cost reductions for IPH technology and to identify the best near-term candidate industries and applications.

In FY79 the SERI industrial process heat program was directed toward advancements in technology, systems analysis and testing, IPH field test performance analysis, IPH applications studies, market characterization, and market development. The emphasis of these efforts was on the development of components and systems technology, IPH field tests, and applications analysis. Market studies were less emphasized, but an important base is established for subsequent work. SERI industrial process heat activities were, for the most part, funded through the Agricultural and Industrial Process Heat Branch of the DOE Office of Conservation and Solar Applications. Studies of potential high-temperature IPH applications (>300°C) were carried out through the DOE Office of Energy Technology.

Component technology efforts included an analytical assessment of the near-term performance potential for line-focus parabolic trough concentrating collectors, initiation of a procurement to encourage mass production of parabolic troughs, and management of a characterization test program for line-focus collectors. Supporting activities by the SERI Materials Branch included development of reflectors and absorbers, reliability studies, and development of instrumentation for characterizing concentrating collector performance. An experimental IPH system (SERAPH) to be located at SERI has been designed, and contracts for the major subsystems (collector field and energy distribution system) have been awarded. Refinements were made to an efficient computer model

combination (PROSYS/ECONMAT) for the technical and economic evaluation of IPH applications, and this model was utilized to assess potential applications (from both technical and market viewpoints) in several industries. Supplementing this assessment were a number of individual plant case studies to validate the model and gain insight into specific industrial applications. DOE has in progress 18 IPH field tests in industrial settings, all monitored through the San Francisco Field Office. During FY79, SERI developed data acquisition guidelines for projects ready to be constructed and compared the performance and cost of the six hot-water and hot-air projects in operation. DOE assigned to SERI the management of four new large-scale IPH field tests for applications below 100°C (212°F), and in late FY79 SERI began the selection (via RFP) of these projects.

Market characterization and development activities included in-depth surveys of the economic decision criteria of several industries, extension and update of existing industrial process heat data, assembly of an industrial directory for use in IPH market development, and mapping of IPH suitability criteria.

SECTION 2.0

ORGANIZATION AND SCOPE

The SERI industrial process heat efforts were divided into five tasks: Management and Planning, SERAPH Facility, Applications Analysis, Market Characterization, and Technology R&D. The first task included both the management of the remaining four SERI research efforts and the management of the external activities (large-scale field tests, development of mass-producible collectors, and line-focus collector characterization). The manpower and expenditures for these efforts are given in Table 2-1.

The remainder of this report summarizes the specific FY79 objectives and accomplishments in each of these tasks and briefly describes FY80 plans.

Table 2-1. FY79 SERI IPH PROGRAM[a]

Task	Task Leader	Total FY79 Expenditure ($K)	Subcontracts Awarded ($K)	Approximate Person-Years Effort	Total SERI Staff Involvement
Management and Planning	D. Kearney S. Sargent	77.5	150	1.0	8
SERAPH	J. Castle	264.1[c]	362.5	2.8	6
Applications Analysis	K. Brown	241.6	10	3.0	9
Market Characterization	P. Ketels	111.0	80.2	1.5	4
Technology R&D	R. Gee[b]	142.8	0	2.9	5

[a]Program leader: D. W. Kearney; external program management: S. L. Sargent.

[b]Acting.

[c]Operating funds: $210.1 K; capital funds: $54.0 K.

SECTION 3.0

SPECIFIC OBJECTIVES AND ACCOMPLISHMENTS

3.1 MANAGEMENT AND PLANNING

3.1.1 Internal Research

The management of the program evolved during FY79 as SERI internal organization changed. Initially, the program was under the cognizance of the IPH Oversight Council, chaired by Frank Kreith and including representatives of various SERI branches in addition to the IPH task leaders. By the final quarter of the fiscal year, the program structure and direction were sufficiently established for the program leader and task leaders to assume total planning responsibility. The major planning efforts were the development of the IPH portions of the Institutional Plan and the FY80 Annual Operating Plan (AOP). The IPH portions of the Institutional Plan were compiled chiefly by the Oversight Council members, but the AOP required detailed planning at task and subtask levels.

Routine reporting and budget tracking were conducted by the task leaders through the program leader. These activities included monthly and quarterly reports and periodic reviews.

The evolving nature of SERI and the IPH program in FY79 led to the assignment of significant activities that fell outside previously established task responsibilities but involved many members of the IPH program and required considerable time. A summary sketch of these accomplishments follows.

Technology Seminar for Public Constituents:

As part of a larger SERI seminar, five IPH staff gave a day-long presentation of the status of the U.S. IPH effort for representatives of consumer and energy activist groups.

National IPH Conferences

- October 1979; Denver, Colo.: Organized by SERI Conferences group under direction of James Mills, Idaho National Engineering Laboratory (INEL); and
- October 1980; Oakland, Calif.: Chaired and organized by SERI.

U.S./Italy Bilateral Solar Agreement

SERI participated in discussion of potential Italian IPH projects, including agreement concerning scope and tentative schedule.

Assessment of High-Temperature Industrial Process Heat Applications

A critical technical review was performed of the feasibility of utilizing solar industrial process heat at 290°C to 590°C (550°F to 1100°F) in significant energy-user industries, such as petroleum refining, wet corn milling, cane sugar refining, and Fullers Earth processing. The evaluation, documented in SERI/TR-333-468 [1], suggests that cogeneration and hot air systems offer the greatest solar potential.

Seminar for U.S. Congress

SERI presented a seminar on the scope, technology, and economics of solar industrial process heat to staff members of the U.S. Congress.

Regional Solar Centers

SERI hosted an informal meeting with IPH representatives of the regional solar centers in September 1979 to discuss future plans and potential cooperation. SERI also participated in proposal evaluation of IPH application studies at MASEC (Mid-American Solar Energy Complex).

IPH Strategy and Objectives Overview

SERI coordinated preparation of a major overview of solar industrial process heat by representatives from SERI, Sandia Laboratories, and PRC.

Addresses and Papers

Five invited addresses and six papers were presented at seminars, conferences, and other meetings during the year.

3.1.2 External Management Activities

IPH program management began in January 1979 in coordination with the ongoing internal IPH program. The objectives of the program management activity are: (1) to provide technical, contractual, and project management of SERI subcontracts for IPH R&D and demonstration projects; (2) to provide technical monitoring and project management support for DOE contracts and to assist DOE in long- and short-range program planning; and (3) to assist in selection, technical monitoring, and management of international joint projects and to provide general, technical, and management support for the national IPH program.

Low-Temperature IPH Demonstration Project

The objective of the low-temperature IPH project is to demonstrate the technical and economic viability of utilizing solar energy to displace fossil fuels in providing industrial process heat below 100°C (212°F), and to demonstrate the ability of solar systems to provide a significant amount of the energy requirements of an industrial process. Secondary goals are to reduce collector costs through mass production and economies of scale by funding large installations (approximately 50,000 ft^2), and to encourage participation of a user industry by cost sharing.

This project was initiated on March 1, 1979. SERI received authorization for the project from the Chicago Operations Office on June 1, and the RFP was released on June 29. The RFP was closed on September 13, and technical evaluation and cost evaluation will be completed by October 7. Discussions with the firms determined to be within the competitive range are expected to be completed by October 24. Final negotiations with the selected contractors will be complete November 21, and the scheduled award date is December 28, 1979. Contract starting dates are expected to be sometime in January with contract duration of eight months. Preliminary design reviews will take place three months after the starting date of the contracts, and the 80% design reviews will take place four months later. The first phase of this project is expected to end by September 1980.

Mass-Producible Collector PRDA

The objective of this undertaking is to promote the development by industry of mass producible designs for line-focusing concentrating collectors and collector components and subsystems with improved thermal performance, enhanced durability and reliability, and reduced manufacturing and installation costs. Specifically, it is desired to increase the thermal performance of the collectors from 40% to 60% at 316°C (600°F), to reduce the cost from $\$25/ft^2$ to $\$10/ft^2$, and to increase the lifetime of the collector from 3 - 5 years to 10 - 20 years. The PRDA has two categories: (1) development of complete collectors, and (2) development of collector components or subsystems.

Phase I for both categories is the engineering and manufacturing development of existing designs. Duration of this phase is 12 months. Phase II for both categories is the fabrication and testing of prototypes and the preliminary design of a production line. The duration of this phase is also 12 months. Phase III for category (1) only is the detailed production line design (with a duration of 6 months).

The final PRDA draft was prepared by SERI and the Chicago Operations Office after review of preliminary drafts by Sandia Laboratories (Albuquerque) and DOE Headquarters. The preliminary CBD announcement was made on May 1, and the final announcement was issued July 5, 1979. Due to a number of delays, the Chicago Operations Office was unable to issue the PRDA during FY79 in time to finalize contracts by the end of the fiscal year. DOE Headquarters therefore decided to program the FY79 funds and issue the PRDA in early FY80 with FY80 funding. Based on the current schedule, the PRDA is expected to be issued in November; a Bidders Conference is scheduled shortly thereafter. Proposals are due in early January 1980 and contracts are expected to be finalized in mid-March 1980.

Line-Focus Collector Testing and Analysis

This task seeks to make available data on instantaneous, daily, monthly, and annual thermal performance of commercially available line-focus collectors. This data will be useful to system designers in enhanced oil recovery, industrial process heat, and solar thermal power.

A subcontract was signed with Sandia Laboratories (Albuquerque) for testing, evaluation, and publication of results. Sandia will use the in-house module test facility and/or one or more commercial testing laboratories. During FY80, Sandia will evaluate DOE-approved independent testing facilities to determine which facilities will be able to meet the requirements for testing line-focus collectors. The collector testing is expected to be completed by March 1980, and the results of testing and predictions are expected to be published in July 1980.

Assistance in IPH Program Planning

This effort proceeded at a relatively low level during FY79. SERI personnel participated in the preparation of a draft IPH Multi-Year Plan for the DOE Office of Conservation and Solar Applications, and they provided input to DOE Headquarters on long-range IPH plans incorporating technology produced for the solar thermal power program. It is expected that this activity will continue in FY80.

In addition, a Commercialization Readiness statement was prepared for the IPH Resource Manager in connection with the National Plan for Accelerated Commercialization (NPAC). Task staff members also supported the SERI Technology Commercialization effort by reviewing NPAC planning. They presented a briefing to the NPAC steering committee in April 1979.

3.2 SERAPH

SERAPH (Solar Energy Research and Applications in Process Heat) is intended to be a versatile outdoor test facility in which a variety of technical issues can be addressed that presently inhibit the application of solar energy in industry. Significant progress was made toward the implementation of SERAPH during FY79. The notable accomplishments were in the areas of conceptual planning, analytic modeling, subcontract initiation, and equipment procurement. Personnel active in the SERAPH development process were drawn from the Thermal Conversion Branch and the Measurement, Design, and Support Branch within the SERI Research Division. Additional support was provided by the Experimental Systems Operations Division at Sandia Laboratories and by architects of the Planning and Design Group (an architectural and engineering firm). Approximately three persons-years of effort were expended during FY79 in the SERAPH subtask area.

The SERAPH conceptual plan provides for a modular facility capable of incorporating all the elements of a solar IPH system (see Fig. 3-1). SERAPH will be built on three acres of the SERI permanent field site in Golden, Colo., during FY80. Solar system elements include concentrating collector fields (1000 to 3000 ft^2 each), thermal energy storage, an auxiliary heat source (10^6Btu/h capacity), and a controllable load. All the energy passing through the facility ultimately will be dissipated by a cooling tower on the field site since there will be no fixed load. The equipment layout is such that the collector field and storage subsystem can be replaced or augmented. Provisions are included in the conceptual plan for testing other hardware (e.g., an absorption chiller of 10 to 25 tons) intended for commercial or industrial solar use. SERI report SERI/RR-34-152 [2] describes in detail the SERAPH features.

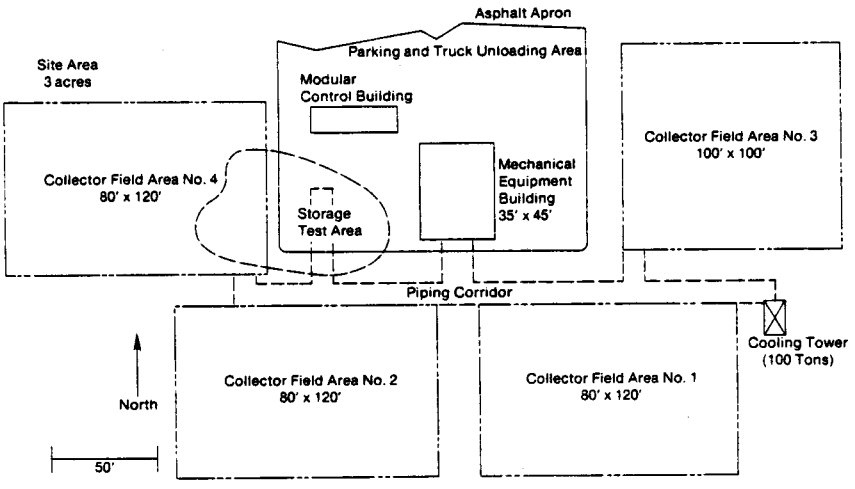

Figure 3-1. SERAPH Experimental Facilities

A concerted effort has been made to mesh SERAPH capabilities and uses with solar thermal programs at other institutions. Extensive discussions have been held with personnel of the Sandia Solar Test Facility so that their efforts are not duplicated. A document regarding the respective uses of solar thermal facilities at Sandia and SERI has been issued based on these discussions. In addition, SERAPH plans have been an input to the solar facilities review carried out by the PRC Energy Analysis Company for DOE.

Analytic models pertaining to SERAPH subsystems were prepared in FY79 in parallel with facility planning. A transient collector field model was created which will be useful in establishing proper flow and temperature control in the solar energy delivery system. The state of the art of solar controls was surveyed and the results are reported in SERI/TP-39-240 (presented at the ISA 1979 Annual Conference) [3]. SERAPH controls initially will be the conventional analog type used widely in industry. Later they will be replaced by supervisory and direct digital control. A second modeling effort has been initiated so that the long-term performance of SERAPH as a whole can be understood and the results extrapolated to other IPH projects. The basis for this more comprehensive modeling effort is the Sandia SOLTES code (Simulator of Large Thermal Energy Systems).

In FY79, subcontractors were competitively selected to provide two major pieces of the SERAPH facility. American Hydrotherm of New York City will design and fabricate the three mechanical equipment packages constituting the Energy Distribution System (EDS). EDS will be responsible for transferring energy between the collector field(s), storage device(s), and load. Barber Nichols Engineering of Denver, Colo., will provide the initial parabolic trough collector field (Solar Energy Delivery System, or SEDS). SEDS consists of 1980 ft^2 of Suntec troughs, an advanced tracking system, controls, and a heat exchanger interface with EDS. Direct equipment purchases include a graphic annunciator panel; a microprocessor-based, programmable logic controller; and the necessary analog controllers.

In summary, the direction for SERAPH implementation is established with respect to capabilities and schedule. Subcontracts have been awarded for the major elements and site planning is underway so that the facility can be installed in FY80. SERAPH will provide an opportunity to monitor, reconfigure, and evaluate a solar IPH system much more thoroughly than is possible in field tests or demonstration projects.

3.3 TECHNOLOGY R&D

The objective of the technology research and development task has been to develop analytical tools to define concentrating collector performance and to determine steps necessary for the continued development of concentrating collectors. Three principal efforts directed towards this goal are described in this section.

A simple procedure has been developed for prediction of yearly average collector energy delivery of systems operating at constant or nearly constant temperature. The year-round average energy output of a collector can be read off directly from a set of graphs, using only the slope and intercept of the instantaneous collector efficiency curve, and the all-day average incidence angle modifier. Details of this procedure are in SERI/TR-34-304 [4].

Optical analysis and optimization of line-focus concentrating collectors was performed. Computer ray tracing has been traditionally utilized for concentrating collector optical

analysis. In this analysis, a macroscopic analytical approach was developed that yields all the parameters needed for the optical design of line-focus parabolic troughs with minimal computational effort. Parabolic trough intercept factors, optimum rim angles, and optimum geometric concentration ratios are shown graphically. This analysis is presented in SERI/TR-34-092 [5].

Finally, an analysis was completed that assessed several technology advancements that will significantly improve parabolic trough performance. Better design, improved fabrication techniques, and the development of improved materials are ways in which concentrating collectors can be improved. Eight specific improvements were evaluated with respect to the annual energy delivery. Figure 3-2 indicates the performance increase, relative to commercially available trough technology, resulting from three of the most significant technology advancements. Complete results will be available in SERI/TR-332-440 [6].

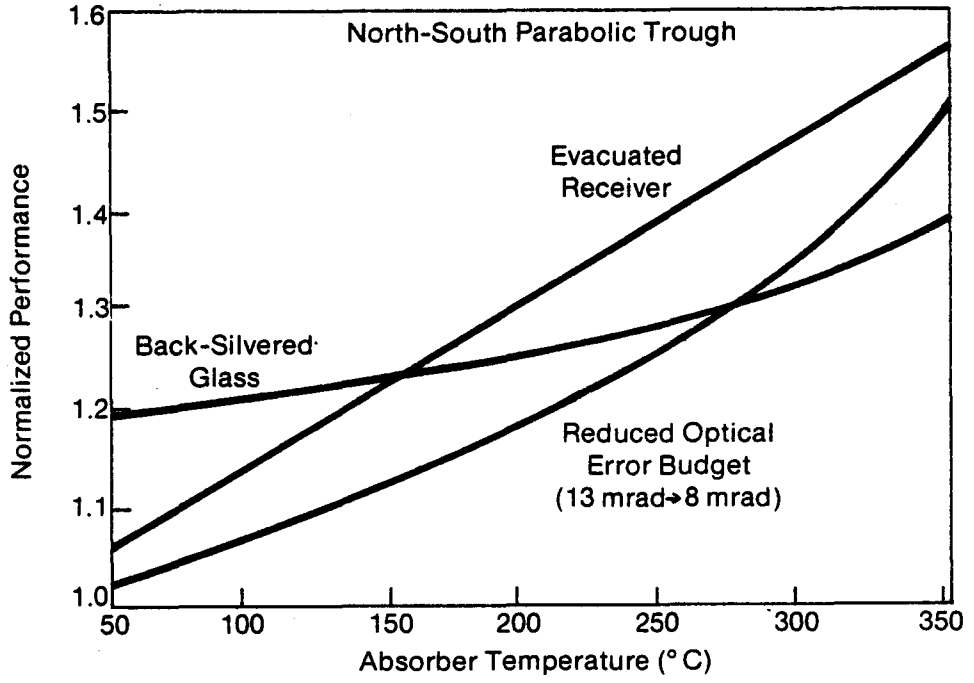

Figure 3-2. Trough Performance Benefits vs. Temperature

3.4 APPLICATIONS ANALYSIS AND SYSTEMS STUDIES

Development of solar energy for industrial process heat depends upon a program oriented to user needs for developing technology. Industrial process heat, as an application, requires an application-motivated program. Certain aspects of FY78 work were continued and several completely new directions were taken. The task included the five efforts described in this section.

3.4.1 Applications Analysis

During FY79, work begun in FY78 was completed on a major effort termed "industrial process end-use matching." The methodology and codes, developed at SERI, allow feasibility analyses of process/solar system combinations in various locations to determine advantageous near-term solar IPH applications. The codes and data bases (diagramed in Fig. 3-3) are valuable tools for not only such a large-scale feasibility analysis, but also for a variety of sensitivity and case studies of particular locations and industrial processes.

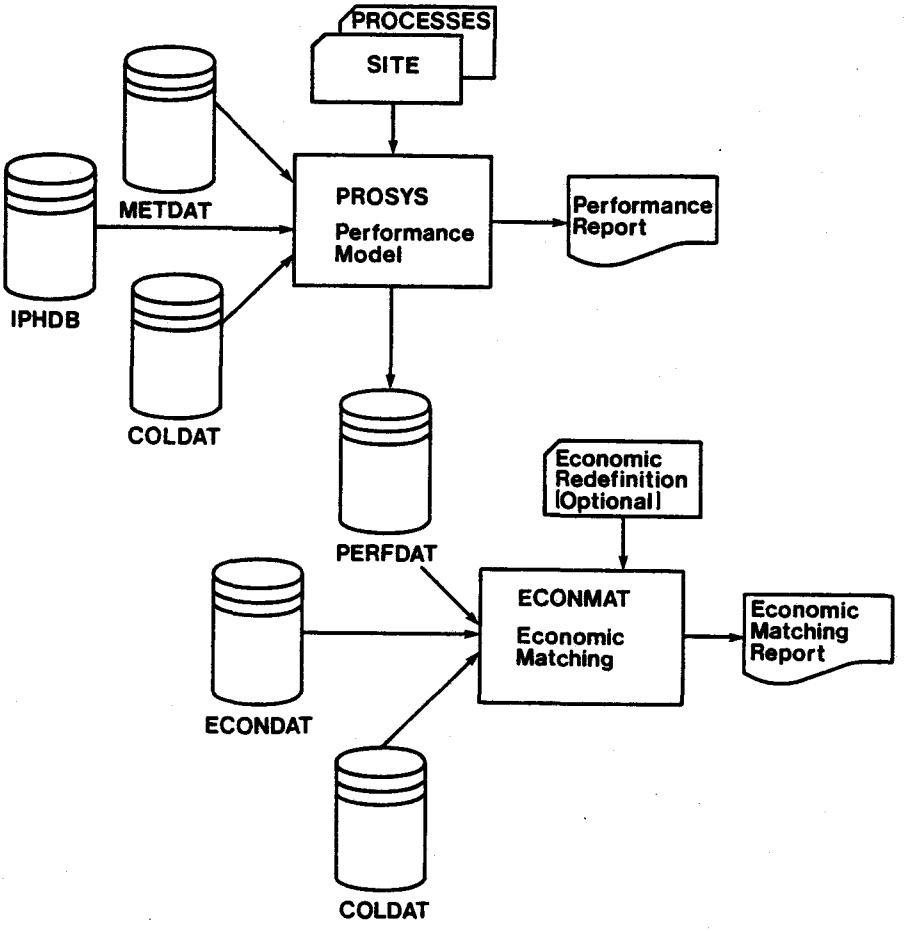

Figure 3-3. End-Use Matching Systems Flow Diagram

It was recognized in FY78 work that the lack of specific and extensive data on industrial process heat demand in many cities of the United States hinders effective end-use matching on a national scale. However, the tools PROSYS/ECONMAT are very useful when ample data is available. To obtain such data, in-depth analysis of several industries was undertaken in FY79 to supplement published energy use data. Industries for this analysis were chosen on the basis of near-term potential for solar IPH and in order to avoid duplicating efforts at other laboratories and institutions. Site visits were made to

fluid milk dairies, bakeries, paint manufacturers, nonferrous foundries (die-casting), and wet-corn milling plants. In addition, detailed process information on the petroleum refining industry was collected; this information was used for more detailed estimates of typical industrial heating loads for the analysis codes. Feasibility of selected solar systems in all 26 SOLMET sites was then tested and mapped to give an indication of the most suitable applications for immediate and future installations. The applications analysis is documented in SERI/TR-34-091 [7] and SERI/TR-333-468 [1].

During this analysis, a number of areas for improvement in PROSYS/ECONMAT were noted, and, in most cases, acted upon. For example, shading loss and heat extraction efficiency algorithms were added to improve the accuracy of the performance code PROSYS. The economic routines in ECONMAT were revised to allow calculation just of unit capital capacity cost [$/(MBtu/yr)] or full analysis of net present value. Later, several options for calculation of payback or break-even fuel price were added. These options and extensive graphic capabilities add to the effectiveness of the codes for sensitivity analyses and case studies.

3.4.2 Case Studies

The need for specific data on industrial energy use spurred the development of the highly successful case study program of FY79. Following two industrial case studies of luggage manufacturing and commercial laundering in FY78, six additional detailed studies were concluded in FY79 and two others were initiated. The purpose of case studies is to encounter design issues typical of actual IPH installations, including the issues of limited land availability, operating schedules, conservation opportunities, and process reconfigurations. At the same time, SERI provides the plant with an initial assessment of potential solar applications and improves communication with potential industrial users.

The case studies include a plant visit and energy audit, often involving numerous iterations on energy use data and occasional new measurements. After a plant energy balance is determined, suitable solar applications are identified. Solar collector systems are sized and costed using PROSYS/ECONMAT. The viability of an investment in any size of solar system is determined using the financial criteria supplied by the plant engineer. Investment opportunity is evaluated on the basis of net present value. A very important element of the case studies is the analysis of conservation opportunities. In many of the studies completed in FY79, several conservation measures promised to be more effective than the installation of a solar system.

The industries covered in recent case studies include paint resin manufacturing, meatpacking, bakeries, dairies, metal container manufacturing, oil recovery, and corn milling (SERI/TR-333-385) [8].

3.4.3 Field Test Data Analysis

DOE is concerned about ensuring uniform collection of operating and cost data from the IPH engineering field tests. Accordingly, SERI was asked to collect performance and cost data from the six operating IPH field tests (three hot water projects and three hot air projects) and to report on the comparative performance, cost, and operating experiences of the six projects in their first year of operation. In addition, SERI was asked to provide guidelines for data acquisition, including specification of a uniform data acquisition system.

Data acquisiton systems (DAS) for the six operating field tests and proposed for the three low-temperature steam projects were categorized and compared to a set of data requirement specifications generated in conjunction with resource, materials, and engineering specialists at SERI. Discussions with IPH contractors and DAS equipment suppliers specified reasonable guidelines for DAS hardware and data categories. These guidelines were introduced to contractors in the SPIPS program (Solar Projects for Industrial Process Steam) at the 80% Phase I Design Review.

Cost and economic standards were established in a separate effort coordinated with this subtask. A program to provide a standard means of cost reporting and economic analysis of IPH for both contractors and government officials was initiated at the 1978 Solar IPH Conference. SERI, in cooperation with Lawrence Livermore Laboratory, developed this standard procedure (documented in LLL report UCRL-52814) [9].

The six operating IPH field tests were visited in FY79.* The data gathered is summarized in SERI/TR-333-323 [10]. In general, it was apparent that although solar system availability was good, utilization of the solar system in most cases was significantly lower than expected, thus reducing the effective annual energy delivery of the systems. In addition, thermal leakage losses and parasitic power requirements tended to reduce net system efficiency significantly. As a result, net annual system efficiencies in many of the IPH projects were less than half of the predicted efficiencies. Important areas of system design improvement are suggested in the report.

3.4.4 Communications

One of the goals of the FY79 program was to support the activities of the Technology Commercialization Division at SERI in an information dissemination and communications program. The Communications Branch analyzed the most immediate needs for communication to private industry on IPH. This analysis resulted in the publication of the brochure Putting the Sun to Work in Industry [11], first introduced at the Sixth Energy Technology Conference in Washington, D.C., in February 1979. The brochure has proven very successful; well over 9000 copies have been distributed since the first printing. The success and effectiveness of this brochure, as well as the tremendous response to IPH-related features in SERI's monthly In Review, encourage continued support of a communications program in FY80.

Communications and media activities were coordinated also with the SERI Public Information Office. In particular, the Public Information Office assisted in the preparation of a 15-minute color slide program and script on solar IPH for use by case-study and site-visit teams. The slide program was well received by industry audiences and has been requested by several Regional Solar Centers for use in their programs.

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*These projects include: Campbell Soup, Sacramento, Calif.; L&P Foods, Fresno, Calif.; La Cour Kiln Service, Canton, Miss.; SunKist Foods, Decatur, Ala.; Riegel Textiles, LaFrance, N.C.; York Building Products, Harrisburg, Pa.

3.5 MARKET CHARACTERIZATION AND DEVELOPMENT

Among the objectives of this task was the identification of the criteria, trade-offs, and methodology employed by industrial decision makers in the selection of energy supply alternatives for their respective processes. A second objective was to develop a marketing directory composed of manufacturers, designers, and potential users of solar IPH systems.

3.5.1 Market Characterization

Previous studies, such as those undertaken by InterTechnology Corporation, Mathtech, and Battelle, were reviewed by the SERI Economic Analysis Branch and used as principal references in the initial phase of the program. The information in these reports was updated, expanded, and disaggregated from the national level according to three- and four-digit SIC codes to determine the geographic location and number of plants within each of the industries initially considered in the program. This data is documented in SERI/PR-353-212 [12] and SERI/MR-353-414 [13].

The primary focus of the study was an in-depth analysis of four target industries: two in the process temperature range up to 290° C (550° F), and two in the temperature range of 290° C to 590° C (550° F to 1100° F). The industries were initially selected on the basis of annual energy consumption and process temperature requirements. The industries surveyed were fluid milk dairies and large bakeries in the low temperature range, and nonferrous foundries and cane sugar refineries in the high temperature range. Contacts with trade associations and plant site visits provided information on plant layout and physical constraints, process flows, operating schedules, and criteria applied in investment decisions.

Data obtained during a site visit was used in a system analysis, which determined the appropriate solar thermal technology and system cost for use in determining cost and benefit of the system to the prospective user. The economic analysis employed criteria obtained from the user during the site visit.

Preliminary conclusions of the program indicate that the supply of conventional energy is not as critical as initially expected. Most gas utilities are actively promoting industrial uses of natural gas and assuring present users of adequate supply in the short term. Although efforts are made to conserve energy and absorb some cost increases, the costs of conventional fuels are not a primary concern of the industrial user because eventually they are passed on to the final consumer. Efforts to retrofit existing plants, if economically viable, may be severely limited by the physical constraints of plant layout and siting.

To extend the detailed process data over a broader industrial base, the consulting firm Insights West (Los Angeles) was contracted ($55,500) to perform a series of 60 field interviews related to use of solar energy in industry. Work on the program will start by the end of October and the work period will be six to nine months. The contractor is to work closely with SERI program planning and directed efforts.

At the suggestion of McDonnell-Douglas Astronautics Co., SERI volunteered to chair a meeting of representatives of DOE laboratories and contractors with interests in industrial energy use data for solar applications. The result of this meeting, held in Los Angeles, Calif., in November 1978, was an informal agreement among 20 laboratories

and contractors to share data gathered on plant visits and interviews and to assemble this data in a standard format at SERI for use by cooperating organizations. This constitutes the Industrial Energy Data Collection activity (IEDC). At the present time, a contacts list of 152 industrial interviews is available.

3.5.2 Market Development

Two related activities were begun in late FY79 by the SERI Market Development Branch to provide a basis for designing and orienting a market development of solar industrial process heat systems. The two activities are: (1) preparation of a market development directory, and (2) development of overview market suitability determination and mapping. Both efforts will be significantly supported by students from the Colorado School of Mines.

The market development directory will be used primarily as an in-house SERI document for facilitating the selection of appropriate parties and the most effective channels for market development activities. The main subject categories in the directory will be potential solar IPH end users, architectural/engineering and consulting firms, and solar manufacturers. The information in the directory will include trade associations and publications for approximately 80 four-digit SIC industries and for architectural/engineering firms, consulting firms, and solar manufacturers. Also included will be: key energy statistics and a location list of the largest plants in each state for 15 low-temperature industries; a location list of engineering firms that emphasize services to industry or have solar IPH expertise; and a list of manufacturers of solar IPH collectors and systems. A draft of this directory has been completed and the final directory is expected in mid-October 1979.

The overview market feasibility determination for solar IPH will identify industries and regions most suitable for near-term commercial implementation. In general, the economic feasibility of solar IPH is difficult to substantiate in comparison to low-cost fuels such as coal and natural gas. However, there are industries and geographical areas where solar energy more closely meets the decision-making criteria. The suitability analysis will be an initial effort to determine the particular industrial markets where development efforts will be most successful in stimulating solar installations. Examples of criteria to be used in this analysis are: U.S. solar radiation data, thermal output of various solar system types in different U.S. locations, fuel use locations and prices in the United States, fuel curtailment areas by type of fuel and by state, areas of stringent pollution regulations, states with available tax incentives by magnitude, and industries with temperature requirements less than 100°C (212°F) and 175°C (350°F) by number and sales in different U.S. locations. An interim mapping of these criteria will be completed in mid-October of 1979 to test the validity of the method and to determine the scope of the effort for the following seven months. A final report will be available in June 1980.

3.6 FY80 PLANS

The SERI industrial process heat effort for the coming fiscal year is structured similar to the FY79 program. A brief description of the task scope and expected accomplishments is presented in this section.

3.6.1 Program Management, Administration, and Planning

This task covers several efforts related to external project management and to planning and administration of the internal and external parts of the IPH program. Specific subtasks deal with: program management; program plans, reports, and conferences; administration and planning; technical monitoring of mass-producible line-focus concentrator development contracts; low-temperature demonstration project management; IPH planning assistance; and testing of commercial line-focus concentrators.

The first two subtasks - internal program management and program plans, reports, and conferences - cover the management and support of the internal program. Included are: definition of program objectives; tracking of project status; preparation and submission of progress reports; presentation of program reviews; coordination of in-house and external portions of the program; coordination of SERI research activities with IPH programs at other institutions; preparation of required documents, such as the AOP, Institutional Plan update, and Annual Review of Solar Energy; and preparation and conduct of meetings and conferences, such as contractor review meetings, national IPH workshops, and information dissemination meetings for the public and industry.

The third and fourth subtasks - external program administration and planning and technical monitoring of mass-producible line-focus concentrator development contracts - include administration of the externally contracted portion of the program and technical and contractual management of externally contracted development projects. Specific efforts are: coordination and oversight of project management; budget and report preparation; interface with DOE personnel; technical monitoring of an expected 8 to 12 DOE Chicago contracts for development of improved mass-producible concentrating collectors and components; conduct of program review meetings and site visits; and preparation of technical progress reports for the DOE Chicago contract managers.

The fifth subtask - low temperature demonstration project management - covers the continuation of contractual management of three or four low-temperature, large-area (50,000 ft^2), cost-shared IPH demonstration projects during the design Phase I, and one or more projects in the construction Phase II. Activities will include: letting three to four subcontracts for Phase I; 60% design and final design reviews; selection of one or more subcontractors to continue into Phase II; and award of Phase II subcontracts. The subtask for IPH planning assistance provides for continued assistance to DOE in the development of one or more national IPH development plans. The subtask for testing commercial line-focus concentrators continues an effort begun in FY79 to test commercially available line-focus concentrating collectors and to utilize the test results in a computer algorithm to predict daily and yearly performance for a number of locations. Sandia Laboratories (Albuquerque) will be responsible for the testing and analysis under SERI subcontract.

Expected accomplishments include:

- Presentation of program status reports at quarterly review meetings;
- Organization and presentation of a national IPH conference;
- Preparation and submission of the Institutional Plan update and the Annual Review of Solar Energy for IPH;
- Awarding of contracts for Phase I of mass-producible collector and component development;

- Awarding of three or four subcontracts for low-temperature demonstration projects, completion of design Phase I, selection of one or more projects for construction Phase II, and awarding of subcontract award(s) for Phase II; and
- Completion of testing and analysis of commercially available line-focus concentrators through Sandia Labs., and publication of results.

3.6.2 IPH Technology R&D

This task encompasses R&D on technology within the IPH program. The chief objective will be the creation of IPH system test facilities, as well as the development of components and materials. The majority of this work will take place within SERI. Exceptions to this will be subcontracts for facility equipment procurement and pond materials development by industry.

IPH technology R&D emphasis will be on line-focus concentrator characteristics, low-cost collectors, and IPH system performance. Specific subtasks include the SERAPH facility, advanced component development, and materials R&D. System behavior will be studied in SERAPH, which will become operational in FY80 and allow testing of solar components and systems as they reach the evaluation stage. Development of plastic materials suitable for low-cost collectors will be a primary component effort.

Line-focus concentrators are presently the most economical midtemperature [100°C to 300°C (212°F to 572°F)] thermal energy delivery device. Improvement of their performance will be actively continued. Optical instruments will be created to assess specularity and shape of reflector surfaces and the absorptance of receiver surfaces. Research on new reflector and absorber materials and the assessment of their durability will be pursued. Polymeric materials will be emphasized. The line-focus concentrator receiver also will be investigated. Loss mechanisms will be determined, and the sun tracker, a troublesome device in existing installations, will have its tracking capabilities quantified under a variety of sky conditions. Results will be available to industrial contractors developing improved mass-producible line-focus concentrators.

Expected accomplishments include:

- Construction and operation of SERAPH facility (delayed from FY79);
- Continued validation of long-term collector performance models as data becomes available from SERAPH, the Mid-Temperature Research Facility (formerly STAM), IPH field tests, Sandia Labs., and other sources, and publication of guidelines for system design;
- Evaluation of commercially available sun trackers and of thermal losses from commercially available receivers;
- Design and fabrication of a laser ray-trace system, as well as of instruments to measure flux distribution, specularity of mirrors, and absorptance and emittance of selective absorbers; and
- Materials research emphasing durability and polymeric development.

3.6.3 IPH Projects Analysis and Monitoring

The objectives of this task are: to ensure that instrumentation and data acquisition systems for IPH demonstration projects reliably evaluate system performance to within 6% accuracy; to ensure that cost and performance data are collected, analyses performed, and results reported in a consistent manner; to compare the cost and performance of the different IPH sites; and to study problems encountered at the various sites.

To accomplish these objectives, SERI will continue to make site visits to determine how demonstration projects are performing and to collect information concerning instrumentation and data acquisition. In FY79, SERI provided guidelines to contractors describing economic and performance analysis, instrumentation, data acquisition, and reporting requirements. These guidelines will be updated and further detailed, and a particular data acquisition system will be chosen.

Performance of each project will be studied and compared to predicted performance, and reasons for any shortcomings will be determined. The various projects will be compared in terms of cost and performance, and conclusions will be drawn regarding the suitability of solar energy usage and different system approaches for various industries and applications. Cost information will be provided to the SERI Systems Analysis Branch for detailed analysis and for support of the DOE Technology Characterization effort. Recommendations will be made regarding applications and design/installation considerations for future demonstration projects.

Expected accomplishments include:

- Site visits and technical assessment of operational IPH demonstrations;
- Completion of a cost/performance analysis report on the hot-water and hot-air projects;
- Initiation of cost/performance analysis of low-temperature steam projects; and
- Selection of data acquisition systems for future demonstration projects.

3.6.4 Applications Analysis and Systems Study

During FY78 and FY79, the methodology and tools for a detailed applications analysis (end-use matching) of IPH were developed at SERI. It became apparent that the value of the tools in projecting near-term applications of solar IPH and of assessing the sensitivity of these applications to various technical and economic influences is substantial. A number of actual applications were identified in FY79, but the task of gathering adequate data on industrial energy use limited the extent of actual applications identification. The usefulness of the tools is undiminished, however, and warrants particular emphasis in FY80. Various applications analysis projects of a more general nature can be accomplished and useful information on system applications can probably be provided by these tools without the time-consuming collection of extensive IPH data. For example, generic systems for particular classes of processing, such as hot wash water or drying air, can be analyzed for a wide range of locations and industries.

Work in FY80 will focus on five fronts: performance models, generic systems evaluation in industrial case studies, cost analysis, and an industrial park study. First, the codes PROSYS and ECONMAT will be further developed and a users' manual will be produced

and distributed. Assistance will be provided to interested researchers (such as the Regional Solar Energy Centers) in setting up and using the codes in various studies. As part of the DOE/OSA System Analysis and Test Program, a validation plan for IPH simulation codes will be prepared. Work will also begin in code development for more detailed IPH system simulation.

The second subtask will investigate the concept of generic or standardized system designs for classes of IPH applications. The feasibility of such a concept will be tested using PROSYS/ECONMAT for low-temperature water and air systems, with support from a subcontractor.

The third major effort will be the continuation of the highly successful industrial case study program. Several more case studies will be completed in FY80. Case studies have provided valuable insight into the needs and constraints of actual industrial plants; they provide an opportunity to advertise IPH to potential users; and they allow a useful comparison of solar and conservation alternatives for industry.

A fourth effort is closely related to the IPH projects analysis and monitoring task and to the technology characterization task of the Planning, Analysis, and Social Science program area. This subtask will undertake a complete evaluation of costs from current IPH projects and project designs, provide comparative analysis, and begin the development of reliable cost models for IPH system studies. As part of the FY79 effort, standard cost reporting formats have been supplied to IPH contractors.

The fifth subtask will focus on analysis of the general characteristics of large-scale IPH systems for industrial parks and new plant construction. This feasibility study should provide insight into key emerging markets and may be instrumental in directing new efforts in IPH pilot projects.

Expected accomplishments include:

- Publication of users' manual for the PROSYS/ECONMAT codes and investigation of new, more flexible, and more detailed codes;
- Support to the preparation of a system code validation plan in the Systems Analysis and Testing (SAT) Program and initiation of the comparative validation of IPH system codes;
- Evaluation of the feasibility of low-temperature hot-water and hot-air generic IPH systems;
- Completion of several case studies as well as a summary report of conclusions significant to the future design of systems and components; and
- Investigation of the future impact and viability of large-scale industrial park IPH systems.

3.6.5 Market Analysis and Development

The task of market analysis and development continues work started in FY79 and provides the opportunity to expand data collection efforts to three industries previously not included in the program. It is divided into two subtasks: market characterization and market development. The industries chosen for in-depth study will fall into the 30°C to 300°C (86°F to 572°F) and 300°C to 600°C (572°F to 1112°F) temperature ranges and

will be selected from the industrial selection matrix assembled during the FY79 program. To compile data on actual process operations and on decision-making criteria related to solar systems, appropriate trade associations and plant operators will be contacted. Additional field data will be obtained through the voluntary, interlaboratory IEDC effort that has been organized by several laboratories and contractors doing IPH research. In FY80, SERI will continue to be the central point for compiling and disseminating data.

Engineering and cost information obtained from field interviews will be used in determining the value of solar energy process heat systems. Assessment of this information will indicate the the minimum criteria that must be met by a solar system for it to be competitive with conventional and other alternative energy sources on the basis of performance and cost requirements. This assessment will aid in the establishment of specific cost goals for a solar system.

Based on market analysis findings of FY79, commercialization activities in FY80 will be targeted toward appropriate industries and geographical regions. The primary activity will be planning of industry-oriented workshops on IPH solar systems. Workshop topics will include system costs and performance, generic system designs, methods of financing, and available government incentives. SERI will seek to involve trade associations and industry representatives, state energy offices, and Regional Solar Energy Centers in the organization of the workshops. This commercialization effort will provide appropriate information to key people in the industry and also will evaluate the effects of this information in stimulating industry investments in solar systems. A second key effort will be the completion of the suitability mapping begun in FY79.

Expected accomplishments include:

- In-depth market analysis of three industries in coordination with Applications Analysis and Systems case studies;
- Establishment of cost goals for IPH solar systems;
- Planning workshops for industry and trade association representatives; and
- Completion of IPH suitability mappings.

SECTION 4.0

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