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DOE Solar Process Heat Program: FY1991 Solar Process Heat Prefeasibility Studies Activity

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DOE SOLAR PROCESS HEAT PROGRAM: FY1991 SOLAR PROCESS HEAT PREFEASIBILITY STUDIES ACTIVITY

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ABSTRACT

During fiscal year (FY) 1991, the U.S. Department of Energy (DOE) Solar Process Heat Program implemented a Solar Process Heat Prefeasibility Studies activity. For Program purposes, a prefeasibility study is an engineering assessment that investigates the technical and economic feasibility of a solar system for a specific application for a specific end-user. The study includes an assessment of institutional issues (e.g., financing, availability of insurance, etc.) that impact the feasibility of the proposed solar project. Solar process heat technology covers solar thermal energy systems (utilizing flat plate or concentrating solar collectors) for water heating, water preheating, cooling/refrigeration, steam generation, ventilation air heating/preheating, etc. for applications in industry, commerce, and government.

The studies are selected for funding through a competitive solicitation. For FY 1991, six projects were selected for funding. As of August 31, 1992, three teams had completed their studies. This paper describes the prefeasibility studies activity, presents the results from the study performed by United Solar Technologies, and summarizes the conclusions from the studies that have been completed to date and their implications for the Solar Process Heat Program.

1.0 INTRODUCTION

This paper describes the solar process heat prefeasibility studies activity implemented by the U.S. Department of Energy's (DOE) Solar Process Heat Program in fiscal year (FY) 1991 and documents the results from one representative study from the six selected for funding.

The National Renewable Energy Laboratory (NREL), the manager of the Solar Process Heat Program for the DOE, implements an annual Solar Process Heat Prefeasibility Studies activity. For Program purposes, a prefeasibility study is an engineering study of the technical and economic feasibility of using a solar process heat system for a specific application at the specific site of the potential end user. The study also includes an assessment of institutional issues (e.g., availability of insurance, permitting) that impact the feasibility and practicality of the system.

The prefeasibility studies activity focuses on potential solar process heat system projects that utilize commercially available solar equipment. Proposed solar projects involving prototype or solar equipment still in the research stage are not considered.

If the study shows that the solar system is significantly attractive with respect to cost, technical and economic performances and institutional issues, the potential user is expected to consider acquiring the system. NREL makes no commitment to participate in funding the design, acquisition, and installation of projects that prospective owners may wish to pursue after the pre-feasibility studies are completed. However, Program technical support— through NREL and/or Sandia National Laboratories— can be made available to those interested in acquiring solar systems.

2.0 STUDIES SELECTED FOR FUNDING IN FY 1991

The solar prefeasibility studies projects are selected for funding by means of a competitive solicitation. For FY 1991, six projects were selected for funding from 19 proposals submitted by offerors. These six projects are shown in Table 1.

A major goal of the Solar Process Heat Program is to help the solar industry place economically viable systems in the field in various applications, markets, and geographical regions. Consequently, the Program wanted to fund six projects that, collectively included:

- Different types of solar equipment (flat plate and parabolic trough)
- Different markets (e.g., industry, commerce and government)
- Various applications (e.g., water heating)
- Different geographical regions of the United States.

Table 1. Six Prefeasibility Study Projects

Study Subcontractor	Application	Solar Collection Technology	Location
EA Mueller (Baltimore, MD)	• Solar water heating for buildings owned by the state of Maryland	Hydronic Flat Plate	Maryland
Conserval Systems (Buffalo, NY)	• Solar Venti-lation air pre-heating for large industrial buildings	Air Flat Plate	Non-Sunbelt States
Energy Concepts Company (Annapolis, MD)	• Solar ice-making system for Non-Grid Connected fishing village in Mexico	Parabolic Trough	Mexico
United Solar Technologies (Olympia, WA)	• Solar absorption air conditioning for a 30-bed hospital	Parabolic Trough	Hawaii
Industrial Solar Technology (Denver, CO)	• Solar Asphalt bulk storage heating system	Parabolic Trough	California
Bechtel Corporation (San Francisco, CA)	• Solar absorption air conditioning for an 8,000 sq. ft. office building	Parabolic Trough	Hawaii

Each study requires approximately 6 months and involves the following:

(1) Assembly of the team, including the specific potential user whose application is to be investigated.

(2) Selection and optimization of the solar system; performing the technical and economic feasibility assessments; and addressing institutional issues.

(3) Specification of an action plan to be taken by the prospective owner and/or user, based on the results of the assessments.

(4) Documentation of study results and development of recommendations for the Solar Process Heat Program.

As of August 31, 1992, four subcontractors had completed their studies: Conserval Systems, Energy Concepts, United Solar Technologies, and Industrial Solar Technologies.

Section 3.0 describes the study performed by United Solar Technologies and the results and follow-up efforts in progress as of the preparation of this paper.

3.0 UNITED SOLAR TECHNOLOGIES PREFEASIBILITY STUDIES PROJECT

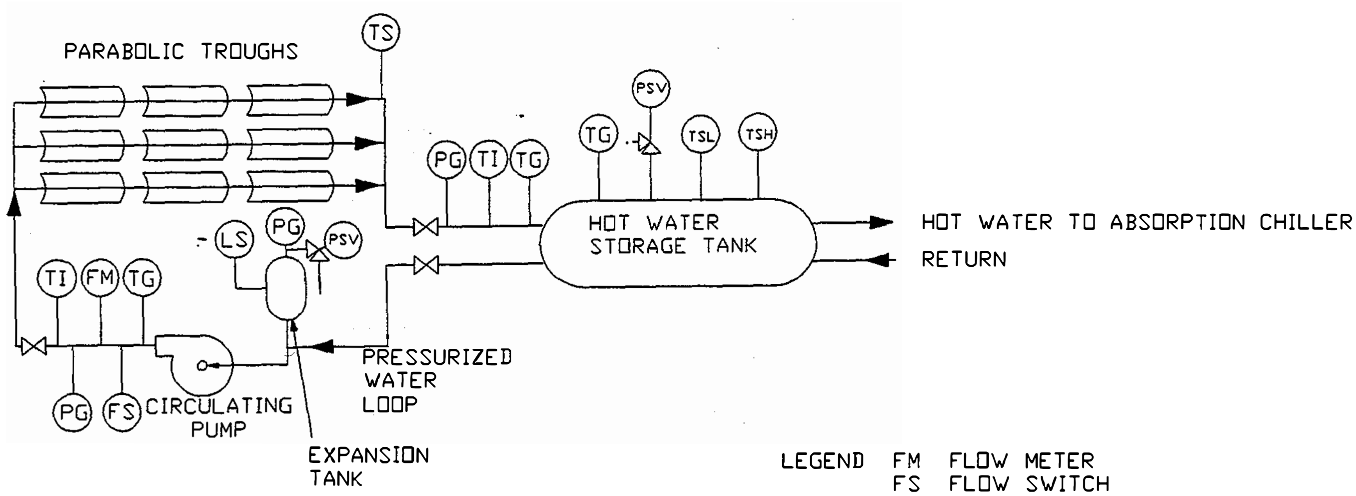
United Solar Technologies (UST) is a renewable energy company incorporated in Santa Cruz, California, with an office in Olympia, Washington, that specializes in the design, brokering, and third-party financing of solar projects for applications in industry, commerce, and government.

UST investigated the technical, economic, and institutional feasibility of a solar absorption air conditioning and water heating system for Molokai General Hospital. This 30-bed hospital is located in Kaunakakai, Molokai, in Hawaii. The hospital, which has a year-round air conditioning load, operates one 30-ton chiller and 30 small window- and roof-mounted air conditioning units. It pays approximately $0.22/kWh for electricity. The hospital is interested in reducing its high energy bills.

UST and its study team designed a solar cooling and water heating system to replace the window- and roof-mounted air conditioner. Replacing them offers the greatest potential for energy savings. The system is as follows:

- Solar collectors: IST parabolic trough collectors
- Collector area: 780.7 sq m (8,400 square feet)
- Collector mounting: ground
- Land area requirement: 2323.4 sq m (25,000 square feet)
- Thermal storage tank: 17,225 liters (4,550 gallons)
- Chiller: Two American Yazaki WFC-10 single stage lithium bromide absorption chillers
- Chiller capacity: 20 tons nominal (peak of 28 tons)

The existing McQuay chiller has been integrated into the solar system. Consequently, the proposed system has 42 nominal tons of cooling capacity. Figure 1 is a schematic of the system.



LEGEND
FM FLOW METER
FS FLOW SWITCH
LC LEVEL CONTROL
LG LEVEL GAGE
PG PRESSURE GAGE
PS PRESSURE SWITCH
PSV PRESSURE SAFTY VALVE
TI THERMOCOUPLE
TG TEMPERATURE GAGE
TS TEMPERATURE SWITCH

Source: United Solar Technologies (Olympia, WA)

Figure 1: Schematic of the Solar Cooling and Water Heating System for Molokai General Hospital Developed as Part of the United Solar Technologies Solar Process Heat Prefeasibility Study.

Each of the Yazaki WFC-10 chillers is rated at 10 tons when the generator input temperature is 88°C (190°F), the cooling water inlet temperature is 29.4°C (85°F) and the chilled water output temperature is 9°C (48°F). By raising the input temperature to 96°C (205°F), the cooling capacity rises to 14 tons.

The IST parabolic troughs deliver 88-96°C (190-205°F) thermal energy to the absorption chillers. Each module is 2.3 m (7.5 feet) wide and 6.1 m (20 feet) long. Manufactured entirely of aluminum, each module weighs about 77.3 kgm (170 lbs.) and can be easily carried by two persons. The low weight facilitates field installation. These concentrators use SA-85 aluminized acrylic manufactured by The 3M Company as the optical material. The receiver consists of a steel absorber tube (two inch outer diameter) enclosed in a glass annulus to minimize heat loss. The glass is covered with an antireflective coating to improve transmittance. The geometric concentration ratio is 46. Under optimal conditions these IST collectors can deliver approximately 55% of the incident solar radiation to the storage tank as thermal energy.

Table 2 summarizes the predicted annual performance. On an annualized basis, solar meets 49% of the air conditioning load and approximately 100% of domestic hot water requirements. The principal uncertainty in the expected system-performance estimate concerns the direct normal insolation (DNI) at the hospital's site. Long-term DNI data were not available. Although some DNI data were available for Molokai, it may not be entirely applicable because Molokai is characterized by a large number of micro-climates. Consequently, the study team developed (conservative) estimates of the hospital's solar resource by extrapolating from existing data. To help solve this problem NREL is providing an instrumentation package (i.e., pyrheliometer and recording equipment) to accurately assess the solar resource at this site.

Table 2: Predicted Technical Performance of the Solar Absorption Cooling and Heating System Designed for Molokai General Hospital

• Annual Building Cooling Load	2354.74 GJ (2,232.53 MMBTU)
• Annual Domestic Hot Water Requirement	130.00 GJ (123.25 MMBTU)
• Annual Building Cooling Load Met by Solar	1163.69 GJ (1103.29 MMBTU)
• Annual Building Cooling Load Met by Electricity	1191.06 GJ (1129.24 MMBTU)
• Annual Domestic Hot Water Load Met by Solar	130.00 GJ (123.25 MMBTU)

Table 3 shows the estimated system installed cost, by major subsystems, for the solar system. Normalized in terms of solar collector area, the $347,200 system costs $444.73/sq m ($41.33/sq ft).

The State of Hawaii offers an energy tax credit of 35% for a solar system, and the federal government offers 10%. Furthermore, the federal tax code allows solar systems to be depreciated over 5 years. The UST team investigated two scenarios whereby Molokai General Hospital might acquire the system.

In the first scenario, the hospital would buy the system outright. However, because the hospital is a nonprofit public institution, there are no tax benefits to be gained (i.e., $121,520 in tax credits) by owning the system. Assuming $70,000 of the system installed cost were cost-shared by DOE and/or Hawaii, the net cost to the hospital would be $277,300 (($355.19/sq m) [$33/sq ft]). The system would have an estimated payback period of 10 years.

Table 3. Estimated System Installed Cost for the 780.7 sq m (8,400 sq ft) Parabolic Trough Solar Absorption Cooling and Water Heating System Proposed for Molokai General Hospital

System Installed Cost Components	Estimated Cost($)
• Solar Collector Field and Thermal Storage Subsystem	252,600
• Two WFC-10 American Yazaki Absorption Chillers	22,600
• Balance of Cooling System Costs	30,000
• Transportation	15,000
• Overhead and Fees	23,000
• General Excise and Use Taxes	4,000
• TOTAL COST	$347,200
• TOTAL COST (NORMALIZED)	$444.73/sq m ($41.33/sq ft)

Source: United Solar Technologies (Olympia, WA)

In the second scenario, private investors would own and operate the system. The system output would be sold to the hospital at 20% less than the deferred cost for electric cooling and water heating. In this case, the partnership would achieve a rate of return of about 37% on this project, given the following major assumptions: (1) $50,000 cost-share by DOE and/or Hawaii; (2) state and federal tax credits totaling $121,520; (3) 30-year system life; (4) discount rate of 10%; and (5) annual solar collector field operation and maintenance (O&M) cost of $1,200, escalating at 3.9% per year.

Executives of Molakai General Hospital and Queens Medical Systems (the corporation that owns and operates the hospital) received the results of the study in September 1992. As of the writing of this paper, UST was in the process of structuring a partnership agreement and assembling a Hawaii-based investor group. Tentatively, both the Solar Process Heat Program and the Division of Energy (the state energy office for Hawaii) within the Hawaii Department of Business, Economic Development and Tourism have agreed to consider some limited cost-sharing of the project to reduce any perceived risks on the part of investors and to ensure that it goes forward.

Both the Solar Process Heat Program and the Hawaii Division of Energy are interested in the implementation of the project for the following reasons:

It can improve the market acceptance and penetration of solar absorption cooling.

There is no competing natural gas system (the availability of low-cost natural gas is a major barrier to solar market acceptance in most regions of the United States).

This project can assess the potential of solar absorption cooling as an electricity demand-side management approach.

4.0 CONCLUSIONS AND LESSONS LEARNED

The following conclusions are drawn from the results of all six of the prefeasibility studies, not just the UST project.

(1) For solar process heat systems, the prefeasibility study projects completed to date show that energy-equipment decision-makers are still tending to focus on years-to-payback, rather than net present value or levelized cost of energy, in evaluating solar systems. This will continue to impede widespread, accelerated market acceptance of solar because of the high capital costs of solar systems compared to conventional competitors (unless solar is subsidized). Such subsidies could include tax credits, low-interest loans, property tax exemptions and "penalties" (e.g., air emissions restrictions) assessed on fossil fuel systems.

(2) Solar for applications other than water heating may require positive subsidies in order to achieve initial market acceptance—even if they are shown to be technically and economically viable in engineering studies. Such subsidies include cost-sharing (or buy-downs) and low-interest loans. The purpose of these subsidies is to make solar a "bargain" (rather than just "equal" to a conventional system) and to reduce perceived risks.

(3) For proposed solar process heat system projects involving use of parabolic troughs, there can be serious problems in accurately determining expected technical performance because of limited information regarding the DNI resource at specific sites. Lack of good data can result in the oversizing of the solar collector field, which results in higher-than-necessary system installed cost. This, in turn, results in degraded economic performance and makes economic viability less likely. If lack of long-term DNI data is determined to be a national problem, it may be necessary to: (1) establish and operate additional solar resource measurement efforts in regions where solar has the potential to be cost competitive; and (2) develop better algorithms for deriving DNI data from available solar resource data.

(4) Actual O&M costs, especially for hydronic solar systems, and uncertainties about O&M requirements in the later years of a solar system planned to have a useful life of 20-30 years have the potential to create resistance to the use of solar. This suggests that the need for a sustained effort to collect data and develop a systematic solar system O&M data base. This data base would be used to help accurately predict O&M requirements and expected O&M costs in the later years of the life of a solar system.

(5) Even though a solar process heat system project shows technical feasibility, economic feasibility may be jeopardized because of institutional issues. For two of the prefeasibility studies projects, two such issues were the cost and availability of liability and property damage insurance.

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