Proposal to the Department of Energy's Northeast Regional Appropriate Technology Program Solar Technology Division Center for Energy and Environment Research University of Puerto Rico March 1979

Center for Energy and Environment Research University of Puerto Rico — US Department of Energy

Solar Thermal System Test Facility for Low and Medium Temperature Range

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Endorsements: Dr. Ugyr Ortanasi, Head, Solar Technology Division, Date

Solar Division, CEER

Solar Thermal System Test Facility for Low and Medium Temperature Range

Prepared by: Solar Technology Division Center for Energy and Environment Research

Project Site: College Station Mayaguez, Puerto Rico 00708

Telephone: 809-832-1414

Total Funding Requested: To be determined

This project is a development project in the area of solar process steam and solar hot water. The Center for Energy and Environment Research is a part of the University of Puerto Rico, a public institution of higher learning.

Solar Division, CEER

1. Project Overview

As part of its research and development program in medium temperature solar thermal energy systems, the Solar Division of the Center for Energy and Environment Research of the University of Puerto Rico (CEER), proposes to build a test facility for such systems. The main objective of this project is to achieve the capability of doing detailed and precise measurements of the efficiency of solar thermal systems in a tropical environment. This unique test facility in the Caribbean will offer the opportunity to study low to medium temperature (140°F-550°F) solar collector systems under operating conditions. The funding requested for this

The project will be utilized to install, test, and operate the previously designed thermal loop at CER.

The proposed test facility was designed after studying the experiences of other researchers with similar facilities in the United States. Many of the problems they encountered have been eliminated in our design. Fuel costs for the production of hot water and low-pressure, medium-temperature (350°F) steam for domestic and commercial use in Puerto Rico can be conservatively estimated at $150 million per year.

The Solar Division of CEER is engaged in an active research program to develop cost-effective systems that can meet this energy need with a renewable, local, non-polluting resource. An experimental test facility is indispensable for the evaluation of prototype systems and for the eventual development of systems best suited to the climatic conditions prevalent in Puerto Rico.

Solar Division, CEER 11, BENEFITS FROM THE PROJECT

The Center for Energy and Environment Research of the University of Puerto Rico was established on July 1, 1976, under an agreement between the President of the University and the U.S. Energy Research and Development Administration, now a part of the U.S. Department of Energy. CEER's main goals are: (1) to help Puerto Rico achieve energy independence by serving as the island's focal point for energy research; and (2) to help Puerto Rico develop scientific, engineering, and other trained personnel in the energy and environmental fields.

The Solar Technology Division of CEER is engaged in an active, ongoing research program which includes, among others, measurement of solar insolation, computer simulation of thermal systems, and design and development of concentrating collectors. At this point in the program, a strong need is felt for an experimental test facility that will provide detailed, precise data on the performance of solar thermal systems in a tropical environment. This data is indispensable for the continuation of the research program in thermal systems.

Systems. The Solar Technology Division of CEER has identified thermal systems (in particular hot water and medium temperature steam systems) as one of its focal areas of research. The main reason for this decision is the potential for a substantial impact on fuel use within a relatively short development period. In Puerto Rico, fuel costs for such systems amount to at least $150 M per year (18% of all fuel use).

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The technological feasibility of using solar systems for these applications has already been well established. The main challenge lies in developing efficient, low-cost systems. Besides providing basic efficiency data, the test facility will be used to test system materials and reliability. It will also provide long-term performance data which is a very important consideration in system appraisal.

Another benefit from this project will be the educational opportunities it will provide to students at the U.P.R.'s School of Engineering. In the last two years, 10 undergraduate students have worked or done projects in the Solar Division. The plans are to use students to help in the testing of solar collectors and systems. This represents for them an invaluable, hands-on experience in solar. For Puerto Rico, it represents a growing number of professionals trained in the solar field.

In summary, this project deals with a renewable, locally-available, non-polluting resource, solar energy. The application involved represents a substantial percentage of the total energy needs of Puerto Rico and has a large potential impact on both the domestic and commercial markets. The proposed test facility will be an indispensable part of the research program of the Solar Division of CEER and will allow it to continue to meet its commitment as a research and educational institution working on behalf of the Commonwealth of Puerto Rico.

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III, TECHNICAL DESCRIPTION OF PROJECT

The proposed solar collector test facility can be used for collectors having an

The aperture area is up to 5 m2 (54 ft2) with temperatures ranging between ambient and 288°C (550°F). It will be a low-pressure closed-loop system that utilizes a liquid phase heat transfer fluid. The system will include a pumping station, flow heaters, pressure, temperature, insolation, and monitors for wind speed and direction. Additional features include coolers, filters, temperature controls, an expansion tank, and an associated piping system. All data will be monitored and manually recorded on paper using a data logger.

The test station will be constructed atop the machine shop at CEER's Mayaguez site. The monitoring station will be situated in a room within the machine shop, directly beneath the loop where the test station will be erected. The testing loop configuration is depicted in Figures 1 and 2 A.

The instrumentation will include the following:
1. Solar radiation measurements will be conducted using a pyranometer and a pyrheliometer.
2. Temperature measurements will be taken using platinum resistance thermometers (RTD) and J type iron-constantan thermocouples (TC).
3. Liquid flow rate measurements will be done using two distinct types of flowmeters, which will be cross-verified. A turbine type and a strain gauge type flowmeter will be employed.

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4. Pressure measurements will be taken using bonded strain gauge transducers.
5. Wind velocity and direction will be measured using electro-mechanical anemometers.
6. All data will be monitored by a data logger, which is built around a microprocessor, and will be printed on paper tape. Individual monitoring equipment will also be utilized for flow, pressure, and wind measurements.

The primary function of the collector test loop is to supply the solar collectors under test with a constant flow rate of constant temperature fluid. For a complete efficiency test, this loop provides an input temperature between ambient and 298°C, with a wide range of flow rates from 0.025 to 2.5 liters per minute per square meter of collector. The system will use Dowtherm A as a heat transfer fluid, which consists of 73.5% diphenyl.

The system will be full at ambient temperature and three-quarters full at 260°C. The loading of the system will be accomplished from the storage tank by a small load tank. This tank also acts as a catchpot for the system. Valves, check valves, and pressure relief valves will all be selected for high temperature usage and located as shown in Fig. 1. All relief valve exits will be collected at a common pipe to avoid spilling of fluid to the working area, which can be hazardous to workers.

Controls: The level control of the expansion tank will serve as a level gauge and a low level alarm switch. Any leakage from the system can be detected by this control.

10 Solar Division, CEER: A low level alarm will automatically turn off the pumps and electric heaters, and an audio alarm system is triggered. A pressure alarm switch, which will detect a loss of flow, will be put after the pumps. This condition will turn on the spare pump and turn off the main pump. The first proportional temperature will control the heaters as mentioned in the previous section. Two thermocouples located at the exit of the heaters will be used as high alarms to avoid boiling of the heat transfer fluid. In such a case, power to the heaters will be shut off. Another high temperature alarm will become effective if the collector outlet fluid temperature exceeds the preset limits. This alarm will result in an audio alarm which necessitates shading of the collector. A proportional temperature controller will control the temperature of the fluid which goes to the hold tank. The amount of cooling is adjusted by the three-way valve which diverts the fluid proportionally to cooler and bypass D.

Data Collection: Monitor Lab. Model 9300 Data Logger will be used to monitor and record system outputs. This data logger has the capabilities of scaling, averaging, converting TC and RTD outputs to °C or °F.

Solar Division, CEER: The data logger is alarming, scanning etc. With its 60 channels, it can handle all the data to be recorded or monitored. All instrumentation will

Fulfill the requirements of ASHRAE Standards No. 93-77, No. 41.8-78, No. 41.1-74.

Future Plans: The proposed system will constitute a unique opportunity to test and evaluate low to medium temperature solar collector systems in Puerto Rico and the Caribbean. Although the system is suitable to test solar water heaters, its main purpose is to evaluate solar process heat collectors. As a part of its program, the Solar Division is now developing a series of prototypes suitable for operation in the tropical environment. The photograph on the next page shows one of the prototypes recently developed by CEER. Plans call for the testing of other collectors developed in the U.S. and elsewhere. Comparative testing of these collectors will supply the data to determine the most cost-effective type that can be applied to Puerto Rico's needs.

3. Solar Division, CER IV, Qualifications of Key Personnel

A. Dr. Angel Mario Lopez Berrios, Project Manager: Dr. Lopez has a B.S. degree in Physics from the University of Puerto Rico and an M.S. and Ph.D. in Physics from the University of Massachusetts. His doctoral thesis was in experimental particle physics. He has been working in

the solar energy field for the last two years and was appointed as a Scientist at CEER in September, 1978.

B. Mr. Levent Ozakgay, Graduate Student: Mr. Ozakgay obtained a B.S. in Chemical Engineering from the Middle East Technical University in Ankara, Turkey. He has been working in the Solar Energy Division of the General Research and Exploration Institute of Turkey for the last 3 1/2 years. During 1977, Mr. Ozakgay worked with the Solar Energy Group at Argonne National Laboratory, Chicago, Illinois on an United Nations Fellowship.

C. Dr. Ugur Ortabasi, Consultant: Dr. Ortabasi did undergraduate and graduate studies in Physics at the Universities of Gottingen and Hamburg, Germany. He received his Ph.D. from the University of Florida in the area of Nuclear Physics. His work in the solar field dates to 1973 when he became

1a Solar Division, CEER served as the Technical Leader of the Solar Energy Program there. His work has included the theory, design, and experimental testing of evacuated collectors and he is recognized internationally as an expert in this field. Currently, he is a Senior Visiting Research Scientist and Head of the Solar Technology Division at CER.

Dr. Kenneth G. Soderstrom, Consultant Dr. Soderstrom received BSME, MSE, and Ph.D. degrees from the University of Florida. He has been a member of the Mechanical Engineering Faculty of the University of Puerto Rico since 1961. In the last five years, Dr. Soderstrom has been engaged in research in the measurement of solar insolation, in the computer simulation of solar thermal systems, and in the testing of solar collectors. He has also served as a consultant to government and private industries in energy-related problems. Currently, he is Associate Director of CEER's Mayaguez site and has an appointment as Senior Scientist and Project Director in Solar Technology.

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V. SCHEDULE

Months after adjudication date activity:
2, 3, 4, 5, 6, 7, a, o, io, a, i

Order Materials, Receive Materials, Construction, Testing, Report

S = Starting date of activity
E = Ending date of activity
* = Continuation of activity
- = 15 days noncritical path

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BUDGET

Total Funding Requested $41868.00

1. Salaries & wages (hrs/week, Total weeks, $/hr, Total):
   - Dr. A. Lopez - Project Manager: 8, 4a, $11.00, $4226.00
   - L. Ozakgay - Grad. Student: 35, 48, $3.93, $6600.00
   - Technician: 20, 2, $5.20, $2496.00
   - Dr. U. Ortabagi, - Consultant: 1, 48, $22.00, $1056.00
   - Dr. K. Soderstrom - Consultant: 1, 48, $22.00, $1056.00

Total: $15432.00

2. Marginal Benefits: $908.41
3. Equipment: $4217.00
4. Materials
5. Rent
6. Supplies
7. Trips
8. Subcontractors
9. Other direct costs (500 hours of shop charges at $12/hr.): $4800.00

Total direct costs: $63313.41

10. Indirect costs: $5463.59

Total cost of project: $6877.00

CEER/UPR

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