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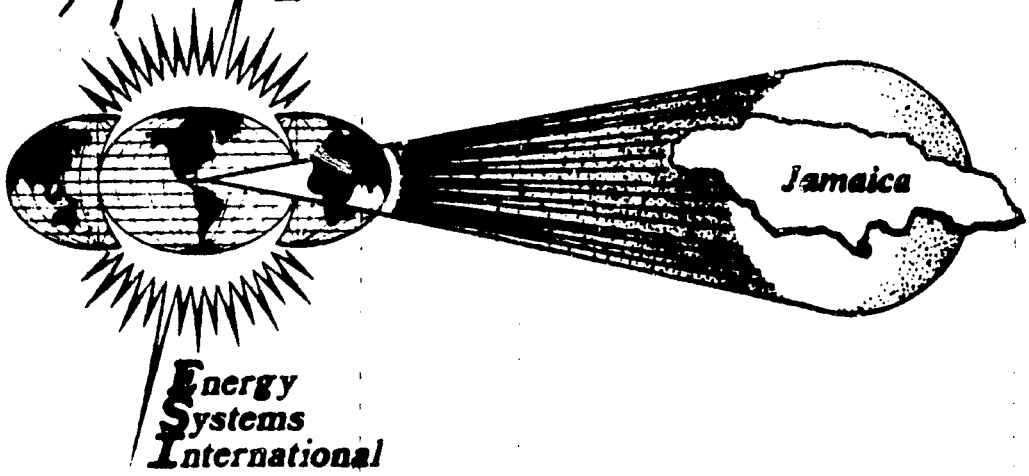

Preliminary Energy Sector Assessments of Jamaica

Volume III
Renewable Energy:

Solar Energy — Commercial & Industrial
Solar Energy — Agricultural
Biogas Applications
Energy Conversion From Waste

Prepared For

Department of State
U.S. Agency for International Development

Under Contract No. AID-532-79-11

JANUARY 1980

PRELIMINARY
ENERGY SECTOR ASSESSMENTS OF JAMAICA

CHAPTER 3

SOLAR ENERGY -- COMMERCIAL & INDUSTRIAL

for

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

CONTRACT NUMBER AID 532-79-11

TASK 3a

ENERGY SYSTEMS INTERNATIONAL
8301 Greensboro Dr., Suite 30
McLean, Virginia 22102

JANUARY 1980

FOREWARD

The eight reports of the Preliminary Energy Sector Assessments of Jamaica conducted by the United States Agency for International Development Energy Team are contained in the following five volumes:

Volume	I	Executive Summary
	II	Economic Assessment
	III	Renewable Energy:
		(a) Solar Energy - Commercial & Industrial
		(b) Solar Energy - Agricultural
		(c) Biogas Applications
		(d) Energy Conversion from Waste
	IV	Coal Prefeasibility Study
	V	Electric Utility Rate Analysis

These studies were initiated by the USAID in conjunction with the Government of Jamaica to further the objectives of Jamaica's Five Year Development Plan and its Energy Sector Plan. The studies also represent USAID's first energy assessment of a developing country.

Due to the diverse technology requirements and the high degree of specialization required by each of the studies, a United States Energy Team of experts was assembled. The individual team members were selected based upon a demonstrated balance between academic and "hands-on" experience in the specific study area.

Energy Systems International (ESI), had overall responsibility for systems planning, project management and integration of all elements of the Preliminary Energy Sector Assessments.

These reports should not be considered as the final product of any study area, but as baseline documents to be used for identifying specific energy programs and projects for implementation in the near-term to assist Jamaica in alleviating its critical energy problem.

Any comments or questions concerning this study should be directed to:

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The success of the Preliminary Energy Sector Assessments of Jamaica was assured through the joint cooperation, professionalism, competence and diligence of the entire U.S. Energy Team and their key Jamaican counterparts. The assessment was a concentrated effort over a fifteen week period in Kingston, Jamaica, during which many government agencies, institutions, private sector organizations and individuals became involved and generously supported study development. The many excellent people involved are too numerous to mention herein, but a few have been singled out for recognition because their outstanding effort and support helped to provide study continuity and progress.

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Most importantly, special acknowledgment is given to those who took the time to make important contributions to the study through their interviews and discussions with the U.S. Energy Team members. Some of these people and organizations are identified on pages 3-11 through 3-14, pages 3-16 and 3-17, and pages 3-48 and 3-49 of this Chapter.

CREDITS

This report was prepared by Mr. Thomas Y. Lewis of the Planning Research Corporation - Energy Analysis Company. Mr. Lewis's effort over a period of eight weeks resulted in a study of exceptional significance to the Jamaicans. Energy Systems International integrated this report with other studies and produced the final document.

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3.1 EXECUTIVE SUMMARY

3.1.1 Introduction

Most countries of the world are presently in various stages of implementing national energy plans, re-evaluating the availability of energy resources and investigating alternative sources of energy in order to reduce the need for imported fossil fuels.

Jamaica's lack of conventional energy resources has led to the development of a Five-Year National Energy Plan which emphasizes the implementation of proven solar technologies. Near term emphasis is placed on the use of solar water heaters and longer term emphasis is on solar space or process cooling.

Jamaica's high level of solar radiation and relatively moderate ambient temperature provides an ideal climate for the implementation of proven solar technologies.

3.1.2 Terms of Reference

The purpose of this section of the energy study is to assess the potential of using solar energy for heating domestic and process water for residential, commercial, institutional, and industrial applications. Although residential solar water heating was not included in the original Terms of Reference, it is necessary to address all potential solar applications to determine the overall technical and energy reduction impact of implementing solar energy technologies.

Additionally, the Terms of Reference required the assessment of solar cooling for various commercial applications.

3.1.3 Background Information

Jamaica's year round average climatic conditions are ideal for application of current proven solar technologies. This potential lies primarily in systems that require water heating for residential, commercial, institutional and industrial installations. Many of these current installations utilize electricity for heating water and at J. $0.17 per kilowatt hour (U.S. $0.10), the equivalent solar hot water systems are economically justifiable. For example, feasibility studies indicate that solar system pay back in various residential and institutional cases are in the 2-3 year time frame. A summary of commercial applications, which use a mix of liquified petroleum gas (LP), diesel

fuel, Bunker C fuel oil, and electricity, demonstrates a total system pay back of 3.8 years. Of the industrial applications surveyed which use a mixture of oil (approximately the cost and Btu value of diesel oil) for preheating boiler make-up water, the system pays for itself in 7-8 years.

3.1.4 Study Method

In order to adequately determine solar system costs, performance, retrofit capability, market potential, and learn of existing programs, over twenty personal interviews were conducted in the government, academic, and private sectors. Of the ten separate sites that were visited, eight feasibility studies were completed. In addition, the Ministry of Mining and Natural Resources (MMNR) conducted a market survey of fifteen companies involved in application of industrial process heat.

From the extensive investigation of the existing solar collector and associated system manufacturing costs, the total system cost and system pay back relative to first cost and fuel type displaced were calculated.

3.1.5 Findings

3.1.5.1 Existing Solar Program

Jamaica Public Service Company (JPS) is starting a residential solar water heating demonstration program. It will feature low interest rate loans to qualified applicants.

3.1.5.2 Solar Radiation Data

The only accurate solar radiation data available are those recorded at the Norman Manley Airport in Kingston. The Ministry of Mining and Natural Resources ordered equipment for six solar radiation recording stations through an Organization of American States (OAS) grant, but they have not been delivered.

3.1.5.3 Collector Performance Testing and Certification

Solar collector performance data does not exist for collectors manufactured in Jamaica. The Jamaican Bureau of Standards is presently establishing an interim collector performance testing and certification program.

3.1.5.4 System Installation Standards

System installation standards are non-existent. All evaluated solar systems were installed differently and existing plumbing codes are generally not followed.

3.1.5.5 Solar System Design Training

Architects and engineers are not adequately trained in energy conservation and solar utilization techniques.

3.1.5.6 Water Heater Tank Tax

In order to control the sale of hot water heaters a 37.5% sales tax is added to all water heater tanks, including tanks utilized in solar water heating systems. This tax is a barrier to the wide-spread use of solar energy in Jamaica.

3.1.5.7 Hardware Manufacturers

Only two manufacturers mass produce solar collectors and systems in Jamaica today. Both companies presently produce low performance, flat plate collectors which are suitable for water heating only.

3.1.5.8 Estimated Annual Fuel Consumption

Energy used to heat water in the residential, commercial, institutional, and industrial sectors consists of the following:

(1) Electricity is utilized to heat water in most residences, hospitals, and a small number of hotels.

(2) Diesel oil is utilized for water heating in most hotels.

(3) Diesel or Bunker C oil is primarily utilized for industrial process water heating and steam generation.

As derived in the Solar Potential Section (3.7.9) of this report, approximately 189,842 barrels of fuel oil equivalency (f.o.e.) per year could be replaced through solar water installations. The estimated annual fuel consumption for residential, commercial, institutional, and industrial sectors is summarized in Table 3-3.

3.1.6 Conclusions and Recommendations

Based on the extensive solar heating feasibility studies (Section 3.7.7.2) and total energy sector analysis (Section 3.7.9), solar domestic water heating and boiler make-up water heating are technically feasible and, depending on the displaced energy source (electrical or various fuel types), economically justified.

On the other hand, solar cooling requires high performance collectors which are not manufactured at this time in Jamaica. Furthermore, solar cooling during the near term is not economically justifiable based on the solar cooling feasibility studies conducted (Section 3.7.8.2).

The following specific recommendations are forwarded for approval and implementation.

(1) Establish 10 climatic stations to record solar radiation levels and ambient temperatures.

(2) Establish solar collector performance testing and certification program.

(3) Eliminate the existing 37.5% tax on water heater tanks utilized in solar water heater systems.

(4) Establish consumer energy information office.

(5) Establish training courses for solar system installers.

(6) Establish college level energy conservation and solar application programs for architects and engineers.

(7) Investigate possible export of solar products manufactured in Jamaica to Caribbean and South American countries.

(8) Provide on going technical support to the JPS Residential Solar Demonstration Program.

(9) Start in-depth feasibility studies and evaluations of all industrial processes and commercial systems to determine possible solar hot water applications which should be funded.

(10) Start in-depth feasibility studies and evaluations of all hospitals to determine most economically justifiable solar hot water applications.

(11) Solar cooling demonstration program should not be considered at this time except for experimental and scientific purposes.

(12) Establish tax incentives for cost effective commercial and industrial solar applications.

(13) Establish tax incentives for solar hot water systems installed in new housing.

(14) Start institutional solar hot water demonstration program.

3.1.6.1 Recommended Solar Energy Program

Based on the recommendations cited above, a solar energy program has been defined that could be implemented over a three year time frame (Table 3-9).

3.2 INTRODUCTION

At present all countries are in various stages of implementing national energy plans, re-evaluating the availability of energy resources and investigating alternative sources of energy in order to reduce the need for imported fossil fuels.

Jamaica has practically no fossil fuel resources. The country is in a very precarious economic position because of its total dependence upon external fossil fuel sources. This has resulted in an increasingly severe foreign exchange problem which has had major impact on all sectors of the island's economy.

The lack of conventional energy resources in Jamaica has led to an emphasis in the Five-Year National Energy Plan (1978-1983) on the implementation of proven solar technologies, for which Jamaica is well situated. Near-term emphasis has been placed on the use of solar water heaters, crop dryers, and wind energy for water pumping and on the generation of biogas from animal waste on farms. Additionally, emphasis has been placed on the demonstration of solar air conditioning and the construction of concentrating collectors, for which a design has been completed. Finally, the Plan provides for the continuation of wind profile and solar radiation mapping activities.

Jamaica's high level of solar radiation (450 langleys per day mean) and relatively moderate ambient temperatures provide an ideal climate for the implementation of proven solar technologies.

3.3 TERMS OF REFERENCE

3.3.1 Objectives

The objectives of this study were to provide a technical and economic assessment of the feasibility of near-term applications of solar energy in the commercial and industrial sectors. In addition to a general assessment of the solar potential in Jamaica, various specific feasibility studies of commercial solar air conditioning and solar industrial hot water applications were required. However, this study did not investigate the potential of other solar technologies such as wind energy, photovoltaics, solar thermal, ocean thermal, etc.

To adequately determine the total solar water heating and space cooling potential in Jamaica and recommend a viable program for near-term implementation, the original Terms of Reference (Appendix A, sub-tasks 6-9) had to be expanded to include the residential sector. The scope of work was further expanded to include evaluation of the Jamaica Public Services' planned solar residential hot water program. An evaluation of the proposed solar collector hardware specifications drafted by JPS was completed, and recommendations made to change the specifications to include performance standards as well as design standards. A workshop on solar water heater systems was conducted to establish requirements for interim performance specifications (Appendix B).

In addition to the tasks contained in the specific study Terms of Reference, the Energy Team members were also responsible for completion of the requirements outlined in the Project Management and Detailed Study Plan discussed in Chapter 1. The team members were to conduct three assessment reviews to ensure that timely progress checks and necessary study plan alterations were made. The team members were also requested to make two presentations. The first was a seminar to take place midway through the assessment; the second was to be held at study completion in which the results, conclusions and recommendations were highlighted at the Final Report Conference, held November 13-14, 1979.

As a result of the project summary given during the first day of the Final Report Conference, a number of questions were asked to clarify study procedures, options, constraints, and considerations made when formulating specific recommendations. The questions were fielded by the team experts

and Jamaican counterparts during splinter group discussions held during the second day. The tapes of the Solar Energy Commercial and Industrial Applications splinter group discussions were transcribed and are contained in Appendix K.

3.3.2 Schedule

Due to the expansion in the original Terms of Reference and the presentation of the Final Report Conference, the study duration was extended from six to eight weeks. The study was initiated in Jamaica on September 10, 1979 and concluded November 16, 1979.

3.4 BACKGROUND INFORMATION

3.4.1 Solar Development in Other Countries

Utilization of solar energy did not become widespread until the advent of solar water heaters, which were first used extensively in the United States. From 1900-1920, thousands of systems were manufactured and installed in Southern California, and from 1920-1960, installations were common in Florida. By 1951, more than 50,000 solar water heaters were in use in Miami alone. However, inexpensive, readily available fossil fuels resulted in a decrease in new installations until solar water heaters were an anomaly in the U.S. Natural gas provided a far more economical method of heating domestic water. Other countries -- notably Japan, Israel, and Australia -- continued the use of solar water heating through the 1950s and 1960s and considerably improved the design of equipment. Today, about 20 percent of the households in Israel have solar water heaters, and in some districts of Australia the sun alone is used for heating water.

A few home heating experiments, using hardware similar to that employed in water heating, were successfully attempted in the United States and other countries, but it was not until the 1970s with the environmental degradation, dwindling fuel supplies, and most of all the oil embargo of 1973 that the first significant solar research, development and demonstration programs in the U.S. and other nations of the world began.

Active domestic water and space heating systems have progressed past the research stage, even though in-depth systems development is ongoing to optimize performance. Due to the initial high cost of solar system installation and lack of professional knowledge in the trade, solar space heating has not gained widespread public and commercial acceptance.

Space cooling and high temperature industrial applications, however, remain in the research and development stage pending hoped-for equipment and system breakthroughs to help decrease systems cost, and increase system performance and reliability.

On the other hand, solar heating of water for residential, commercial and industrial process applications has been successfully demonstrated to be practical and costeffective in many regions of the United States and in many parts of the world.

3.4 BACKGROUND INFORMATION

3.4.1 Solar Development in Other Countries

Utilization of solar energy did not become widespread until the advent of solar water heaters, which were first used extensively in the United States. From 1900-1920, thousands were manufactured and installed in Southern California, and from 1920-1960, installations were common in Florida.

By 1951, more than 50,000 solar water heaters were in use in Miami alone. However, inexpensive, readily available fossil fuels resulted in a decrease in new installations until solar water heaters were an anomaly in the U.S. Natural gas provided a far more economical method of heating service water. Other countries -- notably Japan, Israel, and Australia -- continued the use of solar water heating through the 1950s and 1960s and considerably improved the design of equipment. Today, about 20 percent of the households in Israel have solar water heaters, and in some districts of Australia the sun alone is used for heating water.

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On the other hand, solar heating of water for residential, commercial and industrial process applications has been successfully demonstrated to be practical and cost-effective in many regions of the United States and in many parts of the world.

3.4.2 Potential for Application in Jamaica

Jamaica's high level of solar radiation (450 langleys per day mean) and relatively moderate ambient temperatures provide an ideal climate for the implementation of proven solar technologies.

The potential for proven solar applications in Jamaica is primarily water heating, either domestic water heating or preheating of boiler make-up water. These applications are divided into the following four categories:

(1) Residential
(2) Commercial (Hotels)
(3) Institutional (Hospitals)
(4) Industrial

It is a proven fact in the U.S. and Europe that solar hot water systems can be demonstrated to be most cost effective when displacing electricity. Basically, since all residential, institutional, and a number of commercial applications in Jamaica utilize electricity for heating water, these are prime areas to study. Realizing that electricity costs on the average J. $0.17 per kWh (U.S. $0.10), solar water heaters are economically justifiable.*

Although residential solar applications were not included in the Terms of Reference (see Section 3.3), it was necessary to address all potential solar hot water applications in order to determine the overall technical and economic impact of possible solar utilization.

The remainder of the commercial and all the industrial sectors utilize light oil, diesel, or Bunker C residual fuel oil for heating water or generating steam. Although the cost effectiveness of displacing Bunker C oil with solar is presently somewhat marginal, it is felt that commercial and industrial sector solar applications will be cost effective in the near future.

* The foreign exchange rate during the study was U.S. $1.00 = J. $1.75.

3.5 STUDY METHOD

In order to adequately determine solar system costs, performance, retrofit capability, market potential, and existing programs, over twenty interviews were conducted in the government, academic and private sectors. Ten separate sites were visited. In addition, the Ministry of Mining and Natural Resources (MMNR) conducted a market survey of fifteen companies involved in application of industrial process heat. Additionally, extensive investigation of the manufacturing costs of existing solar collectors and associated systems in Jamaica was conducted to analyze system pay back periods and systems installed cost per square foot of collector area. Finally, eight solar hot water feasibility studies and three solar cooling feasibility studies were conducted.

3.5.1 Personnel Interviewed

(1) Mr. W. R. Ashby - Ministry of Mining and Natural Resources (MMNR) - Discussed solar applications and national solar program.

(2) Mr. Ngai Adu (Sept. 12, Sept. 14) - Jamaica Public Service Co. (JPS) - Reviewed proposed JPS Residential Solar Water Heating Specification. Recommended specification be rewritten in performance requirements format.

(3) Mr. Winston Hay (Sept. 17) - JPS Managing Director - Reviewed above comments. He concurred with the study's recommendations on collector performance specifications, and requested that Mr. Adu prepare the specifications in those terms. JPS held a Solar Workshop on October 11, to receive inputs from solar manufacturers, installers, engineers and architects in order to finalize the JPS Performance Specifications.

(4) Mr. Larry McDonald (Sept. 13) - Appliance Traders Limited - Discussed residential and commercial solar system installation techniques and costs.

(5) Mr. Leon Cushnie (Sept. 14) - Collector manufacturer, reviewed solar collector materials and construction.

(6) Dr. Thomas (Sept. 17) - Jamaica Bureau of Standards (JBS) - Presented the need for standards and concise standard performance testing of solar collectors. Dr. Thomas agreed that JBS would undertake the development of standards

and testing methodology and also interface with JPS. (Mr. Adu will help finalize the above mentioned JPS Performance Specifications.)

(7) Dr. A. Sangster (Sept. 18) - College of Arts, Science and Technology (CAST) - Discussed solar systems in general. Also discussed possible systems for CAST solar energy research building with architect Marvin Goodman.

(8) Mr. Hoilett (Sept. 18, Sept. 25) - Meteorological Office - Discussed available solar radiation data and recording techniques.

(9) Mr. Townson (Sept. 19) - Montego Bay Club Hotel - Discussed possible solar water heating system for hotel.

(10) Mr. Darnell, Mr. Cox, Mr. Maxwell (Sept. 20) - Ministry of Works - Discussed possible solar water and space cooling feasibility study for Cornwall Regional Hospital.

(11) Mr. Martin Brinn (Sept. 30) - Half Moon Bay Hotel - Discussed solar water heating systems and related pricing of Half Moon Bay cabana solar water heating installations.

(12) Mr. Jag Mehta (Sept. 22) - National Hotel Properties (NHP) - Discussed possible solar water heating systems for seven NHP Hotels. Mr. Mehta requested a feasibility study for each hotel; however, Mr. Ashby indicated that there was not sufficient time in this particular study to comply with this request.

(13) Mr. Fuller (Sept. 25) - ORBIT Industries, Inc. - Solar collector, manufacturer and system installer. Reviewed solar collector materials and construction. Discussed residential and commercial system installation techniques and costs.

(14) Mr. Box (Sept. 25) - Collector manufacturer and system installer. Reviewed collector construction and materials. Discussed residential and light commercial system installation, techniques and costs.

(15) Mr. Cooke (Sept. 26) - Agricultural Marketing Corporation (AMC) - Discussed AMC's requirements for cold and cool produce storage. After discussions with Mr. Cooke, it appears that product treatment, drying and various other

processes are the only possible solar thermal processes for immediate consideration. Photovoltaics could, however, play an important role in supplying energy to the self-contained cold and cool storage boxes in the AMC retail outlet stores.

(16) Mr. Leslie Hylton (Sept. 21) - Hylton Solar Company - Discussed residential and commercial system installation techniques and cost.

(17) Mr. Eaton Haughton (Sept. 24) - Discussed residential and commercial solar system installation techniques and cost.

(18) Mrs. Skyers (Oct. 5) - Ministry of Education - Discussed possible solar powered air conditioning system for the top floor of their office building.

(19) Dr. K.C. Lee (Oct. 12)- Scientific Research Council (SRC) - Discussed solar cooling projects, systems cost and pay back.

(20) Mr. Lue Lim (Oct. 12) - Ministry of Works, Hospital Maintenance Unit - Discussed present energy types and usage patterns for heating domestic hot water in all hospitals. Mr. Lim stated all hospitals use electric water heaters.

3.5.2 Sites Visited

The following sites were visited to determine the viability of retrofitting possible solar system equipment into existing installations.

(1) Montego Bay Club (Montego Bay) - Investigated possible solar retrofit for existing electric hot water system.

(2) Cornwall Regional Hospital (Montego Bay) - Investigated possible solar retrofit of water heating systems for existing dormitories. Additionally, investigated solar water heating and space cooling for the hospital.

(3) Hyatt Hotel (Ocho Rios) - Dedicated new solar installation serving the hotel laundry facilities.

(4) Inter-Continental Hotel (Ocho Rios) - Investigated possible solar retrofit for existing Bunker C oil-heated water system.

(5) Trelawny Beach Club (Falmouth) - Investigated possible solar retrofit for existing light oil-heated water system.

(7) Negril Beach Village (Negril) - Investigated refrigeration heat-reclaim potential for water heating systems, and discussed possible solar retrofit for existing hot water system.

(8) Coconut Cove Hotel (Negril) - Investigated possible solar retrofit for existing light oil-heated water system.

(9) Bustamante Childrens Hospital (Kingston) - Investigated possible solar retrofit of existing electric hot water systems for patient wards.

(10) Ministry of Education (Kingston) - Investigated possible solar cooling of top floor of office building occupied by the Ministry.

(11) Agricultural Marketing Corporation (Kingston) - Investigated possible solar cooling of food storage in remote retail outlets.

The breakdown of hotels by city, fuel type and occupancy was provided by the MMNR. This information was used in the solar water heating analysis discussed in Section 3.7.7 (see Table 3-1).

3.5.3 Industrial Process Heat Survey

In support of the study, the Ministry of Mining and Natural Resources conducted a market survey of fifteen companies that utilized industrial process heat for normal operation. The results of the survey were analyzed and are summarized in Table 3-2.

TABLE 3-1

AVERAGE HOTEL OCCUPANCY AND

ENERGY USED FOR WATER HEATING

CITY	FUEL TYPE	NUMBER OF BEDS	PERCENT (%) AVERAGE OCCUPANCY	OCCUPIED BEDS
Kingston	Electricity	1,185	35%	415
Montego Bay	Electricity	1,911	45%	860
Negril	Electricity	266	55%	146
Ocho Rios	Electricity	2,340	50%	1,170
		SUBTOTAL FOR ELECTRICITY		2,591
Kingston	LPGAS	27	35%	10
Montego Bay	LPGAS	1,911	45%	860
Negril	LPGAS	30	55%	17
Ocho Rios	LPGAS	136	50%	68
		SUBTOTAL FOR LPGAS		955
Kingston	Diesel	1,310	35%	460
Montego Bay	Diesel	3,052	45%	1,375
Port Antonio	Diesel	490	35%	172
Negril	Diesel	620	55%	341
Ocho Rios	Diesel	2,416	50%	1,208
		SUBTOTAL FOR DIESEL		3,556
Ocho Rios	Bunker C	700	50%	350
		SUBTOTAL FOR BUNKER C		350

TABLE 3-2
INDUSTRIAL PROCESS HEAT SURVEY

Company	Products Manufactured	Existing Fuel Type	Existing Fuel Annual Usage	Possible Solar Process	Space for Solar Collectors
Robert Products 7 Norwich Ave Kingston 10	Canned Vegetables fruits and preserves	Diesel	12,000 GPC	o Pre-heat Boiler Make-up o Equipment Washing	No
Dairy Industries 111 Washington Blvd., Kingston	Process & pack cheese, yogurt, cheese spread	Bunker C	24,000 Gal	o Pre-heat Boiler Make-up o Equipment washing	No
Jamaica Pre-Pak 11 Dames Rd Kingston 4	Packaged Meat Products	LPG	490 lb	o Equipment Washing	Yes
Cremo Ltd. 284 Spanish Town Rd Kingston 11	Ice cream, milk and milk products, and fruit drinks	Diesel and LPG	Not Known	o Equipment Washing o Pasteurizing	Yes
Bellrose Mfg. 18 Malyns Rd.	Cosmetics and Hair clinic	Diesel Elec.	480 Gal 78,000 kWh	o Steam Injection o Hair Washing	No
Estate Industries 232 Spanish Town Rd Kingston	Tia Maria	Diesel Elec.	2,000 Gal Not Known	o Hot water for canteen	Yes
Cosmetic Int'l 115 Windsord Rd. Kingston 2	Cosmetics	Elec.	42,000 kWh	o Equipment Washing (Minor)	Yes
J. Wray & Nephew 234 Spanish Town Rd Kingston	Rums, Wines, Gin & Liqueurs	Diesel	6000 Gal	o Pre-heat Boiler Make-up	Yes

TABLE 3-2 (CONT)

INDUSTRIAL PROCESS HEAT SURVEY

Company	Products Manufactured	Existing Fuel Type	Existing Fuel Annual Usage	Possible Solar Process	Space for Solar Collectors
DeCosta Brothers 2-6 Twickenham Close Kingston	Canned vegetables, jams, jellies, and packet soup	Diesel	60,000 Gal	o Pre-heat Boiler Make-up	Yes
Desnoes & Geddes 214 Spanish Town Rd Kingston	Beer, Stouts, Soda	Bunker C oil	840,000 Gal	o Pre-heat Boiler Make-up o Bottle washing and pasteurization (requires close temperature control)	Yes
Virginia Dare Ja. Ltd. 5 Leonard Rd. Kingston 10	Food flavors, syrups, toppings and sauces	Diesel	1200 Gal	o Pre-heat Boiler Make-up	Yes
Tropical Textiles Ind. Ltd. Twickenham Park Spanish Town	Knitted Polyester fabrics	Diesel	Not Known	o Pre-heat Boiler Make-up	Yes
Cigarette Co. of Jamaica Ltd. Twickenham Park Spanish Town	Tobacco	Bunker C oil	Not Known	o Pre-heat Boiler Make-up	Yes
Salada Foods Ja. Ltd. 20 Bell Road Kingston 11	Instant coffee, jelly crystals, rise-n shine breakfast drink and cocoa drink	Diesel Butane	81,600 Gal 770,000 Gal	o Pre-heat Boiler Make-up	Yes
Cotton Polyester Textile Co. Ja. 4 Winchester Rd. Kingston 10	Polyester/cotton Textiles	#6 Oil	Not Known	o Pre-heat Boiler Make-up	Yes

3.6 FINDINGS

3.6.1 Existing Solar Program

Jamaica Public Service Company (JPS) is starting a residential solar water heating demonstration program. It will feature low interest rate loans to qualified applicants.

3.6.2 Solar Radiation Data

The solar radiation data recorded at Norman Manley Airport, Kingston, is the only accurate data available for the study.

3.6.3 Collector Performance Testing and Certification

Solar collector performance data does not exist for collectors manufactured in Jamaica.

3.6.4 System Installation Standards

System installation standards are non-existent. All evaluated solar systems were installed differently and existing plumbing codes are generally not followed.

3.6.5 Solar System Design Training

Architects and engineers are not adequately trained in energy conservation and solar utilization techniques.

3.6.6 Water Heater Tank Tax

In order to control the sale of water heaters, a 37.5% sales tax is added to all water heater tanks, including tanks utilized in solar water heating systems. This tax is a barrier to the wide-spread use of solar energy in Jamaica.

3.6.7 Hardware Manufacturers

Only two manufacturers mass produce solar collectors and systems in Jamaica today. Both manufacturers presently produce low performance, flat plate collectors which are suitable for water heating only.

3.6.8 Estimated Annual Fuel Consumption

Existing fuels used in residential, commercial, institutional, and industrial sectors are as follows: electricity is utilized to heat water in most residences, hospitals, and a small number of hotels; diesel oil is utilized for water heating in most hotels; diesel or Bunker C oil is the primary fuel used for most industrial process water heating applications and steam generation. This information was used to locate specific candidate sites for

solar water heating and cooling feasibility studies discussed in Paragraphs 3.7.7 and 3.7.8, respectively.

As derived in the Solar Potential (Section 3.7.9) of this report, approximately 188,670 barrels of fuel oil equivalency (f.o.e.) per year could be replaced through solar water installations. The estimated annual fuel consumption for residential, commercial, institutional, and industrial sectors is summarized in Table 3-3.

TABLE 3-3

ESTIMATED ANNUAL FUEL CONSUMPTION

SECTOR	FUEL	CONSUMPTION	BARRELS FUEL OIL EQUIVALENT
Residential	Electricity	83.5×10^6 kWh	159,000
Institutional	Electricity	7.2×10^6 kWh	13,700
Commercial	Electricity	2.7×10^6 kWh	5,120
Commercial	LP Gas	64,700 gallons *	1,132
Commercial	Diesel Oil	125,350 gallons *	3,510
Commercial	Bunker C	12,250 gallons *	345
Industrial	Bunker C and Diesel Oil	245,000 gallons *	7,035
TOTAL ESTIMATED ANNUAL FUEL CONSUMPTION			189,842 barrels

* Imperial Gallon

3.7 DISCUSSION OF FINDINGS

3.7.1 Existing Solar Programs and Plans

Jamaica Public Service Company (JPS) is starting a solar demonstration program that will feature low interest loans -- up to J. $2500 -- for residential solar water heating applications.

JPS engineers assembled an in-depth solar system specification for their demonstration program. The specification, although well prepared with many good ideas, would not, as it was written, be an appropriate requirement for any solar equipment and systems manufactured in Jamaica. It was recommended that the specification be rewritten in performance terms and language for systems presently manufactured in Jamaica. A workshop, sponsored by JPS and USAID, was held to discuss performance specification, language, terms, and to obtain comments and inputs for the final version of the specification from all participating solar system manufacturers and system installers. A draft copy of the interim performance specification and a list of invitees is enclosed in Appendix B.

Due to the limited financial resources of JPS for this program, J. $250,000, it was recommended that JPS investigate the possibility of using this money as a loan guarantee or interest subsidy and have cooperating lending institutions provide financing for the proposed solar system, thus providing more resources for the JPS Solar Demonstration Program.

The JPS Solar Demonstration Program is the only active solar program in Jamaica.

3.7.2 Solar Radiation Data

Accurate island-wide solar radiation data does not exist. The Meteorological Office has accurate solar data for only one location, Norman Manley Airport in Kingston. This data, although measured accurately, is compiled for only two years (see Appendix C), and it is unknown if the measured data were atypical or typical for long-term micro-climate conditions. Existing radiation data recorded by a Gunn-Bellani instrument for Sangster Airport in Montego Bay and Smithfield Airport in Hanover are somewhat in question, due to instrument and recording inaccuracies.

MMNR has ordered six pyranometers through an Organization of American States (OAS) grant, but these have not been delivered as yet. See Appendix D for the OAS-sponsored Solar Radiation Mapping Operations Plan. Without accurate solar radiation data solar system performance cannot be accurately determined.

3.7.3 Collector Performance Testing and Certification

Solar collector performance data does not exist. The Jamaican Bureau of Standards (JBS) is in the process of developing solar collector testing procedures based on the ASHRAE 93-77 testing methods developed in the United States. Only one collector manufacturer expressed a true interest in having performance testing.

3.7.4 System Installation Standards

Each solar water heating system evaluated was installed in some different manner, e.g., the collector slopes, thermal storage tank and structure, and air vents. Also the existing plumbing codes are not being followed nor is there a plumbing inspector who could approve or disapprove solar installations.

3.7.5 Solar System Design Training

With island-wide acceptance of air conditioning, engineers and architects no longer seem to be concerned with proper natural ventilation and solar shading for buildings. Twenty-five thousand tons of commercial air conditioning are presently in operation to cool various office buildings, hotels, etc. With proper building designs using natural ventilation, the air conditioning load could possibly be reduced by 25%. Therefore, architects and engineers should incorporate various energy conservation techniques along with solar water heating systems into new structures to achieve improved building performance and significant long-term energy savings at minimal additional capital cost.

3.7.6 Hardware Manufacturers

Only two manufacturers mass produce solar collectors in Jamaica, Appliance Traders Limited and Orbit Manufacturing Company. (Appendices E and F contain some of the above companies' printed literature.)

3.7.6.1 Appliance Traders Limited

The Appliance Traders collector is a typical flat plate type collector with: internal manifolding; pressed fit and mechanically secured waterways to a backing or absorber plate; fiberglass insulation backing; and Kal-Wall R fiberglass sun-lite premium glazing. The waterway to

header connection is brazed and pressure tested prior to absorber plate attachment. The absorber plate and attached waterways are spray or brush painted flat black with standard paint. The collector box openings for the piping connections do not appear to have sufficient dimension to allow for adequate absorber thermal expansion and contraction thus collector box openings cause serious absorber plate distortion as observed in the field. The collector can be easily arrayed in parallel and/or series flow, thus ensuring adequate flow distribution for small as well as large arrays. The collector performance is very difficult to determine. A rough estimate of 35-40% efficiency, based on prior experience and elementary heat transfer calculations, should be considered realistic for the purposes of this report. The installation typically sold by Appliance Traders is a thermosyphon system with two to six panels connected in parallel with an insulated horizontal thermal storage tank. Larger systems have been satisfactorily installed.

3.7.6.2 The Orbit Company, or Kingston Metal Products Limited

It is the opinion of the U.S. Energy Team Specialist that the Orbit collector would not be considered a typical flat plate collector. The absorber plate is an inverted English radiator with both supply and return connections at the top. Fiberglass insulation backs the absorber plate, and glass glazing is installed in the field after the collectors are installed. English radiators perform very well as radiators, however, they do not perform efficiently or effectively when utilized as a solar collector absorber plate. With both supply and return connections located at the top of the absorber plate, neither water flow distribution nor heat transfer can adequately take place. The collector performance should have approximately 20-25% efficiency, based on the above information and elementary heat transfer calculations. The collector is not judged to be suitable for installation in large arrays. The installation typically sold by Orbit Company is a one or two panel thermosyphon system with an insulated vertical thermal storage tank.

3.7.6.3 Other Collector Manufacturers

Other flat plate type collectors appear to be manufactured in very limited quantities by various "back-yard" fabricators. These have not been considered in this report.

3.7.6.4 High Performance Collectors

High performance collectors, whether flat plate, evacuated tube, or concentrating type, are not presently produced in Jamaica. Having briefly evaluated the existing collector manufacturers, it seems unlikely that high performance collectors will be produced locally in the near future. The exorbitant cost and/or related import restrictions on high performance raw materials (such as copper tubing and sheets and low-iron glass), coupled with the lack of adequate electroplating facilities, drastically reduce the probability of the mass production of high performance Jamaican collectors at this time. Many U.S. and European collector manufacturers produce equipment suitable for high temperatures and performance applications which would provide an alternative to manufacturing collectors in Jamaica. In order for there to be any effective program for the development of high performance collectors in Jamaica for domestic or export use, the high performance collector technology must be imported; import and export restrictions removed; and production know-how transferred to Jamaican solar collector manufacturers.

3.7.7 Potential Solar Water Heating Sites

The purpose of this area of study is not to define each and every potential solar site and possible application. Instead, it is to study, on a macro-level, various applications which should provide sufficient broad technical data and technology transfer for all possible applications of domestic or process water heating applications in Jamaica.

In order to evaluate the possible economic impact and overall feasibility of solar energy, various applications within the commercial, institutional, and industrial sectors were analyzed. The eight specific sites selected within the above sectors for the study are as follows:

(1) Commercial Applications*

- Negril Beach Village - Negril
- Montego Bay Club - Montego Bay
- Coconut Cove Hotel - Negril
- Trelawny Beach Club - Falmouth
- Intercontinental Hotel - Ocho Rios

* Hotels were the only commercial applications considered since they are the largest commercial consumer of hot water in Jamaica.

(2) Institutional Applications

- o Bustamante Hospital for Children
- o Cornwall Regional Hospital

(3) Industrial Applications

- o Desnoes and Geddes Bottling Company

3.7.7.1 General Criteria for Solar Water Heating Feasibility Studies

3.7.7.1.1 Fuel Types and Related Cost: In order to prepare accurate systems cost analysis, baseline data on fuel cost, efficiency, and thermal capability was needed. Table 3-4 contains the baseline information assumed for feasibility study calculations.

3.7.7.1.2 Solar System Cost: From an extensive investigation of the manufacturing costs of existing solar collectors and associated systems the following figures were derived for use in this study:

(1) Figure 3-1: This figure indicates the approximate system-installed cost based on collector area. It also separates the system into basic components and their associated cost as related to collector area.

(2) Figure 3-2: This figure indicates solar system pay back in years as related to system first cost and type of fuel displaced. It can be seen that solar water heating systems are cost effective when displacing electricity, LP gas, and diesel fuel.

As can be seen in Figure 3-1, system cost per square foot varies as a function of system size. The indicated cost per square foot is a compilation of cost and pricing information from solar collector manufacturers and system installers interviewed.

3.7.7.1.3 Solar Collector Efficiency: Based on typical collector construction and actual recorded ambient temperatures, a 35% annual collector efficiency was assumed.

TABLE 3-4

FUEL TYPES AND RELATED COSTS (J $)

TYPE	GROSS Btu/UNIT	EFFICIENCY	NET Btu/UNIT	MMBtu** EQUIVALENCIES	COST/ UNIT	COST/ MMBtu**
Bunker C Oil	180,000/Gal*	60%	108,000/Gal	9.25 Gal	0.73/Gal	6.75/MMBtu
Diesel (Light Oil)	168,000/Gal*	60%	100,800/Gal	9.92 Gal	1.62/Gal	16.07/MMBtu
LP/Gas	105,000/Gal*	50%	52,500/Gal	19.05 Gal	1.80/Gal	34.29/MMBtu
Electri-city	3412/kWh	100%***	3412/kWh	293 kWh	0.17/kWh	49.81/MMBtu

* Imperial Gallons
** MMBtu = 1 million Btu's
*** Site Efficiency

FIGURE 3-1

SOLAR WATER HEATING COMPONENT AND SYSTEM COST PER FT^2 (J. $)

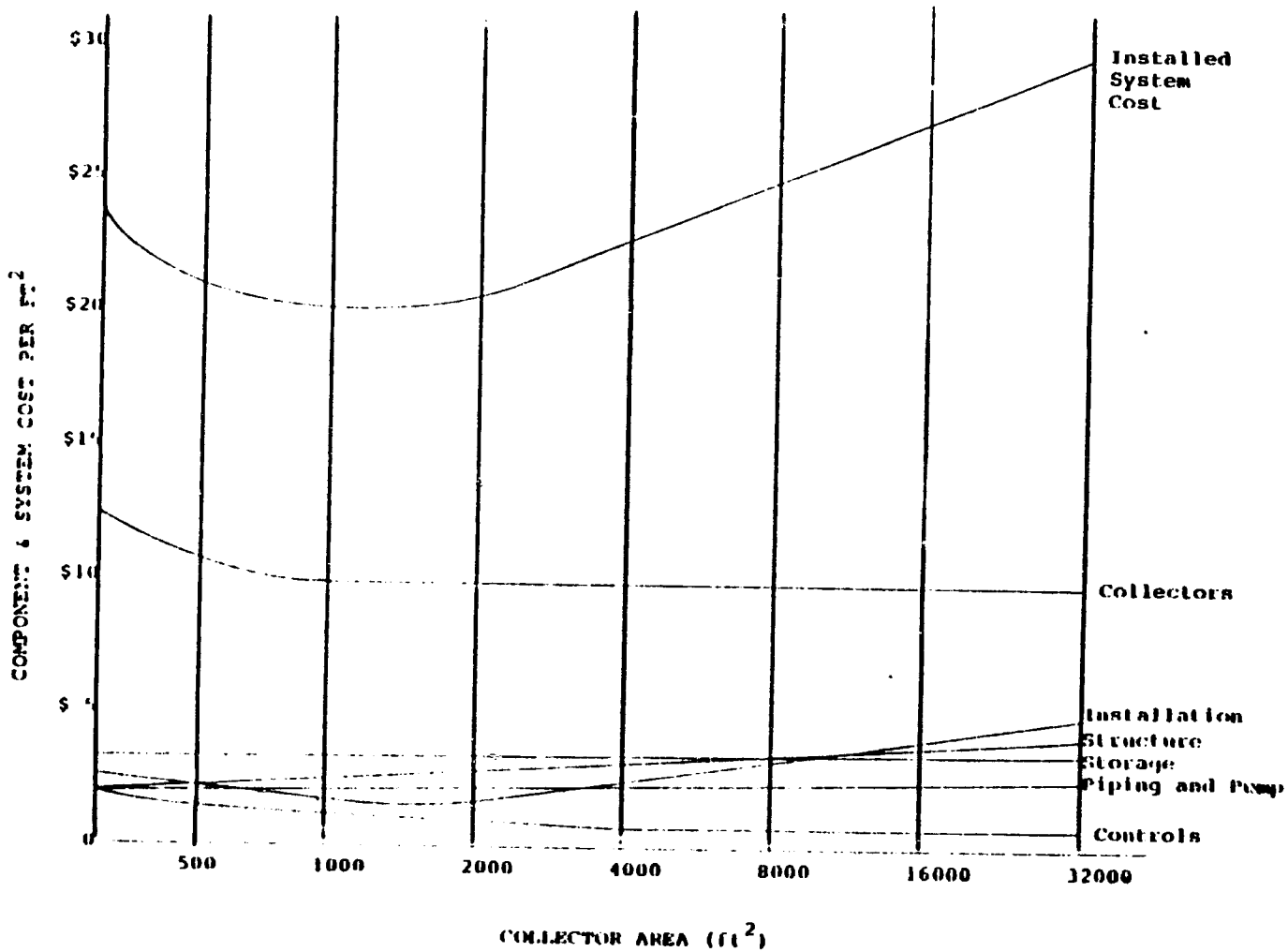
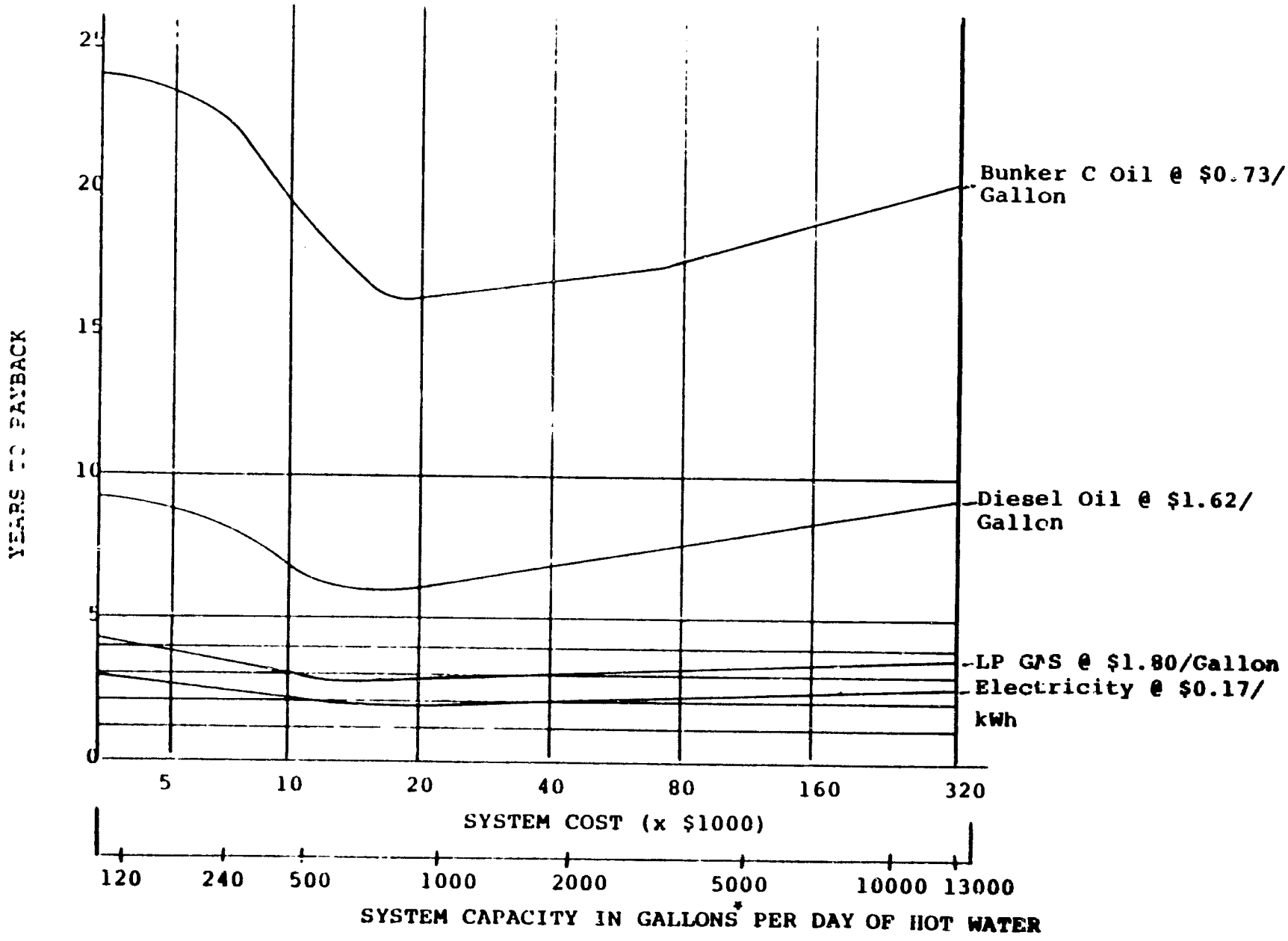


FIGURE 3-2

SOLAR WATER HEATING SYSTEM PAYBACK SYSTEM (J. $)



* Imperial Gallons

3.7.7.1.4 Economic Analysis: With fuel inflation rate, cost of money and cost of imported raw materials unknown, present-day cost figures were used to calculate the system pay back period using the following formula:

$$Y = \frac{Sc}{Afs - Aom}$$

Where

Y = Number of years to pay back
Afs = Annual fuel savings J. $
Aom = Annual Operation and Maintenance Cost (normally about 1% of System Cost J. $)
Sc = System Cost J. $

3.7.7.1.5 Annual Solar Radiation Data: Solar radiation data has been recorded by a pyranometer at Norman Manley Airport for a period of two years. The average radiation by month and day for an 18 degrees surface tilt used for the analysis is shown in Table 3-5.

3.7.7.2 Solar Water Heating Feasibility Studies The above mentioned eight feasibility studies were completed during the assessment period. The most cost effective solar system size was derived by using the lowest cost per square foot of collector surface as depicted in Figure 3-1. A summary of the feasibility study results is shown in Table 3-6. The key findings are as follows:

(a) Solar water heating is most cost effective when used to substitute for electric water heating or LPG water heating. Pay back periods range from 1.9 to 2.6 years for the specific site applications analyzed.

(b) Solar water heating is marginally cost effective when used to substitute for diesel oil water heating. Pay back periods range from 6.0 to 6.1 years for the specific site applications analyzed.

(c) Solar water heating is not cost effective when used to substitute for Bunker C oil. Pay back periods range from 15.4 to 15.8 years for the specific site applications analyzed.

The detailed analysis of the above applications are contained in Appendix H.

TABLE 3-5

ANNUAL SOLAR RADIATION DATA (Btu/(day) ft^2)

MONTH	DAILY MEAN	DAYS MONTH	MONTHLY RADIATION
January	1759	31	54,529
February	1831	28	51,268
March	1894	31	58,714
April	1783	30	53,490
May	1712	31	53,072
June	1715	30	51,450
July	1654	31	51,274
August	1673	31	51,863
September	1769	30	53,070
October	1829	31	56,699
November	1662	30	49,860
December	1717	31	53,227
Total			638,516 Btu/ft^2/gr. or .64 MMBtu

*Mean daily Solar Radiation for 18° tilt from Appendix C.

TABLE 3-6

SUMMARY OF SELECTED SOLAR HOT WATER FEASIBILITY STUDIES

Location*	100% Replacement by Solar Collector to Fossil Fuel System			Most Cost Effective Solar System		
	Collector Area (ft^2)	System Cost J. $	Pay Back (years)	Collector Area (ft^2)	System Cost J. $	Pay Back (years)
Negril Beach Village (d)	3,570	80,400	6.7	2,000	41,000	6.0
Montego Bay Club (E)	2,100	58,260	2.6	2,100	58,260	2.6
Coconut Cove Hotel (D)	900	18,000	6.1	900	18,000	6.1
Trelawny Beach CLUB (L)	4,300	96,750	3.1	2,000	41,000	2.7
Intercontinental Hotel Ocho Rios (B)	3,555	78,210	17.0	2,000	41,000	15.0
Bustamante Hospital For Children (E)	318	7,000	2.5	318	7,000	2.5
Cornwall Regional Hospital (E)	6,350	158,750	2.3	2,000	41,000	1.9
Desnoes and Geddes Bottling Co. (B)	12,700	334,000	21.0	2,000	41,000	15.4

*Existing fuel or energy utilized
(B) Bunker C Oil
(D) Diesel Oil
(E) Electricity
(L) LPG

3.7.8 Potential Solar Cooling Sites

Unlike solar water heating, not every cooling installation is a possible solar cooling site. Due to time constraints, only two candidate solar thermal sites and one candidate photovoltaic site were studied. Although limited, this assessment should nevertheless provide sufficient data concerning the practical and economic viability of solar cooling in Jamaica. The Cornwall Regional Hospital, Montego Bay, has two existing absorption refrigeration machines and very large roof areas for collectors. The Ministry of Education Office Building, in Kingston, has a requirement for cooling only the top floor, which is a minimal 3-ton load and has sufficient roof area for solar collectors. A typical Agricultural Marketing Corporation retail outlet store has a requirement for electrical energy to power a small self-contained walk-in refrigerated food storage box and typically has sufficient roof area for photovoltaic solar collectors.

3.7.8.1 General Criteria for Solar Cooling Feasibility Studies

3.7.8.1.1 Fuel Types and Related Costs: The baseline information for feasibility study calculations are contained in Table 3-4.

3.7.8.1.2 Solar System Cost: Typical high efficiency collector system costs per ft^2, excluding refrigeration system cost, are assumed as follows:

Collector Costs per ft^2

	Flat Plate	Concentrating
U.S.	$50	$90
J.	$87.50	$157.50

Operation and Maintenance Costs (Percent of Total Costs):

	Flat Plate	Concentrating
Small	1%	2%
Large	.5%	1.5%

Small = below 1500 ft^2; Large = 15,000 ft^2 or larger

3.7.8.1.3 Solar Collector Efficiency: As previously mentioned, solar collectors manufactured in Jamaica do not have sufficient performance characteristics to be used for powering absorption cooling systems, therefore, performance characteristics of collectors manufactured in the U.S. were utilized for this study. For solar thermal systems,

a representative figure for the ratio of available collector area per ton of refrigeration is utilized for the feasibility studies. For the two types of collectors considered, the ratios are as follows:

(1) Flat Plate Collectors -

250 ft^2 per ton of refrigeration

(2) Tracking Concentrators -

100 ft^2 per ton of refrigeration

3.7.8.1.4 Economic Analysis: The same pay back formula and system constraints as mentioned in the solar water heating analysis are applicable for solar cooling calculations.

3.7.8.2 Solar Cooling Feasibility Studies

The following three solar cooling feasibility studies were completed using the criteria established in Section 3.7.8.1.

(1) Cornwall Regional Hospital (Institutional)

(2) Ministry of Education and SRC Office Building (Public building)

(3) Agricultural Marketing Corporation retail outlet store (Commercial)

The summary results of the feasibility studies are shown in Table 3-7. Generally, the results show that all solar cooling applications analyzed (whether flat plate or concentrating collectors) are not cost effective. The pay back periods are in excess of 63 years. The detailed analysis of the individual site applications is contained in Appendix I.

3.7.9 Solar Potential By Building Sectors

As a means of assessing the impact of solar water heating on reducing imported oil, the following building sectors were also independently examined:

TABLE 3-7

SUMMARY OF SELECTED SOLAR COOLING FEASIBILITY STUDIES

Location	Collector Areas (ft^2)	System Cost J.$	System Pay Back (years)
Cornwall Regional Hospital	40,000 (Flat Plate)	3,500,000	63
Cornwall Regional Hospital	16,000 (Concentrating)	2,520,000	71
Ministry of Education and SRC Office Buildings	750 (Flat Plate)	75,625	210
Ministry of Education and SRC Office Buildings	300 (Concentrating)	57,250	will not pay back
Agricultural Marketing Corporation	2 KW PV	87,500	117

(1) Residential
(2) Institutional (Hospitals)
(3) Commercial (Hotels)
(4) Industrial

Although the residential sector was not initially part of the study, the following evaluation indicates that the residential sector consumes approximately 1% of the imported oil for electric water heating. This percentage is significant and it was found necessary to include the residential sector in the study.

The summary results of the building sector analysis are shown in Table 3-8.

It can be seen that the residential, institutional and commercial sectors can utilize solar water heating on a cost effective basis. The pay back periods range from 2.2 to 3.8 years. On the other hand, the industrial sector shows marginal cost effectiveness with a pay back period of 7.14 years.

A detailed analysis of the individual building sectors is contained in Appendix J.

3.7.9.1 Estimated Annual Fuel Consumption

Based upon the analysis in Appendix J, the total annual energy consumption and barrels of fuel oil equivalency used to heat water in the residential, institutional, commercial, and industrial sectors are listed in Table 3-3. In summary, solar hot water installations could displace approximately the equivalent of 189,842 barrels of fuel oil annually.

3.7.10 Energy Needs Related to Existing Solar Technologies

From the site visits and process evaluations indicated in Section 3.5.2 and interviews with various personnel, it was found that the primary existing energy need is heating:

(1) Domestic hot water for residences, hotels, hospitals, and food processing equipment for cleaning, and
(2) Boiler make-up water preheat for industrial applications.

The existing collectors manufactured in Jamaica, although of low performance, are capable of supplying the required low grade heat (140°F) to satisfy the above mentioned applications.

TABLE 3-8

SOLAR POTENTIAL FOR BUILDING SECTORS

Building Sector*	Collector Areas (ft^2)	System Cost J.$	System Pay Back (years)
Residential (E)	1,270,000	30,480,000	2.2
Institutional (Hospital) (E)	110,000	2,640,000	2.2
Commercial (Hotels) (E) (L) (D)	118,270	2,838,500	3.8
Industrial (D)	113,110	2,713,400	7.14

*Assumed existing fuel type
(D) Diesel
(E) Electricity
(L) LPG

3.7.11 Energy Needs Related to Future Solar Technologies

From various site visits and discussions with technical personnel, it was found that a major percentage of those contacted feel that existing air conditioning systems should be solar powered. This is understandable because air conditioning is a major consumer of electric power throughout the year. On the other hand, heat-driven air conditioning systems require high grade temperatures (190°-277°F) for effective operation. Thus, any solar collector system would have to be capable of operating efficiently in the higher temperature range.

Presently, the United States and many European countries are in the process of evaluating high performance solar collectors utilized for solar cooling applications. Also, many solar manufacturers produce collectors capable of supplying high grade temperatures of 200°F +. Additionally, the U.S. Department of Energy is funding various refrigeration manufacturers to study new solar cooling equipment and its related temperature requirements to determine actual long-term efficiencies and costs. In spite of all this worldwide activity, solar refrigeration is still not sufficiently cost effective, nor is the equipment adequately developed to warrant significant near-term commercialization of the technology.

Accordingly, due to the present high cost and overall system inefficiencies, solar cooling system information should be evaluated continuously but should not be considered for Jamaica at this time except for experimental and scientific purposes. The three solar cooling feasibility studies discussed in Paragraph 3.7.8.2 help to substantiate this opinion.

The solar collectors presently manufactured in Jamaica are not capable of producing the high grade temperature required for space cooling. Even if high performance collectors were available today, retrofitting a small percentage of the existing refrigeration plants would not be economically justifiable or feasible. Some of the points discussed in Section 3.7.6.4 must be considered before solar cooling can ever become a reality in Jamaica.

3.8 CONCLUSIONS AND RECOMMENDATIONS

3.8.1 Present Solar Energy Program

Based on the above feasibility studies and sector analysis, solar domestic water heating and boiler make-up water heating is technically feasible and, depending on the displaced fuel, economically justifiable today.

On the other hand, solar cooling, even with high performance collectors and systems, is not economically justifiable, and probably will not be so for many years.

3.8.2 Specific Recommendations

The specific recommendations of this report are as follows:

(1) Establish 10 climatic stations to record solar radiation levels and ambient temperatures.

Approximately 10 climatic stations would provide adequate solar radiation and ambient temperature data for the major portions of the island. The Meteorological Office should collect and assemble all data for public distribution. Without accurate solar radiation data, solar system performance cannot be accurately determined.

(2) Establish solar collector performance testing and certification program.

Solar collector performance data does not exist. The Jamaica Bureau of Standards (JBS) should establish a collector testing program as soon as possible. JBS has expressed an interest in establishing a testing program based on the ASHRAE 93-77 testing procedures developed in the U.S. JBS personnel should visit and possibly be trained by the U.S. Bureau of Standards and other test facilities to ensure in-depth knowledge of standard testing procedures.

(3) Eliminate the existing 37.5% tax on water heater tanks utilized in solar water heater systems.

This tax is imposed on all water heaters. In order to reduce the overall cost of solar water heaters this tax should be eliminated.

(4) Establish consumer energy information office.

In order to acquaint the public with energy conservation and alternative energy sources an energy information center should be established. Energy professionals should be interviewed on T.V., radio, and in the newspapers to explain existing energy consumption and methods of reducing consumption by using conservation and alternative energies. Discussions should focus on alternative energy system costs, pay backs and what the overall impact on Jamaica would be if all people conserved energy.

(5) Establish training courses for solar system installers.

An in-depth, hands-on training course for solar system installers would eliminate many problems experienced in the field. Satisfactory completion of this course could lead to solar installer certification which in the long run would provide some consumer protection.

(6) Establish college level energy conservation and solar application program for architects and engineers.

With the island-wide acceptance of air conditioning, architects and engineers no longer appear to be concerned with proper natural ventilation, orientation and sun-shading of buildings. CAST could sponsor one or two courses each semester, primarily focused on energy conservation and solar applications to heighten the awareness of design professionals.

(7) Start in-depth feasibility studies and evaluations of all industrial processes and commercial systems to determine most economically justifiable solar hot water applications.

Each industrial plant and commercial building should be evaluated to determine if a solar system installation would be physically feasible. If the particular site evaluation is positive, an in-depth feasibility study should be undertaken to determine actual heating loads, solar system size and cost, and system pay back. It is recommended that only cost effective solar systems be installed to eliminate any negative publicity regarding the high cost and minimal rate of return on solar energy systems.

(8) Start in-depth feasibility studies and evaluations of all hospitals to determine most economically justifiable solar hot water applications.

Each hospital should be evaluated to determine if a solar system installation would be physically compatible with the existing structure and an in-depth feasibility study should be done to determine actual heating loads, solar system size and cost, and system pay back. Although most hospitals use electricity to heat water, thus making a solar system economically justifiable, a small percentage may not be readily retrofitted for solar water heating.

(9) Investigate possible export of solar products manufactured in Jamaica.

The solar manufacturers, in cooperation with the Ministry of Trade and other various ministries, should investigate the possibility of exporting solar equipment and systems to other Caribbean countries and South America. By expanding the solar market to a much larger area, manufacturers could expand production facitities and reduce manufacturing cost, thus reducing the cost of solar systems to the Jamaican consumer. It is critical that the Government of Jamaica also examine and reduce import and export barriers in order to achieve an effective Jamaican international solar commericalization program strategy.

(10) Provide ongoing technical support to the Jamaica Public Service Company (JPS) solar demonstration program.

JPS is starting an island-wide solar demonstration program for the residential sector. The program would provide a low interest rate three year loans for installation of solar water heating systems on single and small multi-family structures. Due to the limited program budget of J. $250,000 it was recommended that, instead of lending the program funds directly, JPS investigate the possibility of using these funds as a loan guarantee or interest subsidy to serve as an incentive for commerical lending institutions to provide considerably larger funds for the demonstration program while minimizing the possibility of loss to the lending institutions.

(11) Establish tax incentives for cost effective commercial and industrial solar applications.

(12) Establish tax incentives for solar hot water systems installed in new housing.

(13) Start Solar Hot Water Demonstration Program.

In order to maximize the impact of solar water heating and provide sufficient public information it is recommended that a solar water heating system be installed at a hospital presently using electricity to heat water. The recommended hospital is the Bustamante Hospital for Children. The preliminary system design for a typical ward at the Bustamante Hospital for Children has been completed and is enclosed as Appendix G.

(14) A solar cooling demonstration program should not be considered at this time.

Due to the present solar cooling system cost and very low system efficiencies, it is recommended that information from various publications and literature be evaluated continuously, but solar cooling should not be considered in Jamaica except for experimental and scientific purposes.

3.8.3 Recommended Solar Energy Program

Based on the recommendations cited above, a solar energy program should be developed that will be implemented over a three year time period. Table 3-9 estimates the total funding requirements, by year, for each program element of the recommendations outlined in Paragraph 3.8.2.

TABLE 3-9

Solar Energy (Commercial and Industrial Application)

PROGRAM

PROGRAM ELEMENT	COSTS (1979 US DOLLARS)						
	Capital and Other (foreign exchange costs) Initial Costs			Capital and Other (Jamaican currency costs) Initial Costs			Operating (Jamaican currency costs)
	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year	2nd Year and after
a. Climatic stations	150,000	-	-	-	-	-	25,000
b. Collector testing	50,000	-	-	-	-	-	5,000
c. Eliminate tax	-	-	-	-	-	-	-
d. Consumer office	10,000	-	-	15,000	-	-	20,000
e. Train installers	50,000	-	-	25,000	-	-	-
f. Train archs. & engineers	25,000	-	-	12,000	-	-	-
g. Feasibility studies							
Industry	75,000	-	-	-	-	-	-
Commerce	75,000	-	-	-	-	-	-
h. Hospital program							
Feasibility	50,000	-	-	-	-	-	-
Design	17,000	17,000	-	-	-	-	-
- Installation	-	750,000	750,000	-	-	-	-
i. Expert study	-	-	-	10,000	-	-	-
j. Technical support to JPS Co.	25,000	-	-	-	-	-	25,000
k. Tax incentives for Commerce & Industry	-	-	-	5,000	-	-	-
l. Tax incentives for New Housing	-	-	-	5,000	-	-	-
m. Solar hot water demonstration program for hospitals	All costs are included in the complete hospital program (h) above.						
Sub Totals	$547,000	$767,000	$750,000	$72,000			$75,000

3.9 REFERENCES

Solar Energy for Heating and Cooling of Buildings, American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), 1977.

Meteorological data from Norman Manley Airport, Kingston, Jamaica.

Five-Year Development Plan, 1978-1983, Government of Jamaica, 1978.

Handbook of Fundamentals, American Society of Heating, Refrigerating and Air Conditioning Engineers, ASHRAE, 1977.

Solar Water Heating Application Guidelines and Manufacturing Specifications, Jamaica Public Service Company, Limited, 1979.

3.10 APPENDICES

APPENDIX A -- TERMS OF REFERENCE

The study shall include a technical and economic assessment of the feasibility of near-term application of solar energy with a primary focus on food processing and storage. The study shall examine the potential for solar crop drying, both on the scale of small individual farmers and on the scale of bulk marketing and food processing and storage. In addition, the study shall assess the feasibility of commercial solar air conditioning and of solar industrial applications. The assessment will include examinations of the following:

1. Corn drying at regional drying centers to be operated by the Agricultural Marketing Corp.

2. Drying of agricultural products at the farm level including peppers, onions, corns, peanuts and hay.

3. Drying of pimento, coffee, cocoa, bananas and timber on a commercial scale.

4. Crop drying on a commercial scale (approximately one ton/day).

5. Fish drying on a commercial scale.

6.* Solar cooling for food storage in accordance with requirements to be specified by the Agricultural Marketing Corp.

7.* The technical and economic feasibility of solar air conditioning for a new extension to a government office building and for a regional hospital.

8.* The feasibility of solar air conditioning, generally, in Jamaica.

9.* The feasibility of commercial and industrial applications of solar energy, in particular industrial process heat and hotel hot water in the tourist industry, to substitute for imported petroleum.

* Applicable to the study reported in Chapter 3.

APPENDIX B - WORKSHOP ON SOLAR WATER HEATERS

SPONSORED JOINTLY BY

JAMAICA PUBLIC SERVICE CO. LTD. & U.S. ENERGY TEAM

11th OCTOBER, 1979

COORDINATED BY:

TOM LEWIS	U.S. ENERGY TEAM	NGAI ADU	J.P.S.
GARY ROBERTS	U.S. ENERGY TEAM	C.T. GILBERT	J.P.S.

GUIDELINES FOR THE FORMULATION OF INTERIM PERFORMANCE SPECIFICATIONS FOR SOLAR WATER HEATERS TO BE BUILT IN JAMAICA

NOTE:

Final specifications will be prepared by Bureau of Standards.

LIST OF INVITEES

MANUFACTURERS

Conditionedair & Associated Contractors Ltd.
85 Hagley Park Road
Kingston 10.

Kingston Industrial Construction Ltd.
595 1/2 Spanish Town Road
Kingston 11.

Hylton's Plumbing, Welding & Solar Heaters
6A Princess Street
Montego Bay.

Cushnie's Solar Water Heater
1, Bromton Road
Kingston 5.

Hinds Brothers Limited
136 Maxfield Avenue
Kingston 10.

Appliance Traders Limited
35 Half-Way-Tree Road
Kingston 5.

Pumps & Irrigation Limited
68 Hagley Park Road
Kingston 10.

Reginald Aitken Limited
437 Spanish Town Road
Kingston 11.

Electrical Manufacturers (Jamaica) Ltd.
11 Miles
St. Thomas

Orbit Industries Limited
2, Ashemheim Road
Kingston 11.

Alumina Partners of Jamaica Ltd.
13 Caledonia Avenue
Kingston 5.

Homelectrix Limited
53 Newport Boulevard
Newport West.

Dage Airconditioning & Refrigeration Ltd.
62 Hagley Park Road
Kingston 10.

Vulcan Manufacturing Company
South Camp Road
Kingston 5.

Northern Engineering & Maintenance Co.
P. O. Box 1086
Montego Bay.

Martin Brinn
c/o Half Moon Hotel & Cottage Colony
Rose Hall

AGENCIES

Ministry of Mining & Natural Resources
2, St. Lucia Avenue
Kingston 5.

Bureau of Standards
6, Winchester Road
Kingston 10.

COLLECTOR

WATERPROOFNESS:	The Collector shall be waterproof. This means that it must be so constructed that under no condition shall rain or water from a garden hose or any other normal source be able to seep into the Collector Module after it has been assembled.
TEST:	To Be Specified (TBS)
EFFICIENCY OF UNIT:	The Unit shall be at least 30% efficient. This means that at least 30% of the insolation impinging on the Collector Absorber must be directly converted into heat, which shall be evidenced at the output pipe (e.g., in the bathroom and kitchen).
TEST:	Performance test by Bureau of Standards in accordance with ASHRAE 93-77.
OPAQUENESS TO UV RADIATION:	The glazing shall not be opaque to UV radiation and shall not be discoloured or in any other way be degraded by it.
TEST:	TBS
RESISTANCE TO HUMIDITY AND SALT AIR:	The Unit shall not be degraded by an atmosphere of high humidity or by an atmosphere with a high salt content.
TEST:	TBS

THICKNE. : OF ABSORBER PLATE:	If copper is used the thickness of the absorber plate shall not be less than 26 gauge. If steel is used the thickness of the absorber plate shall not be less than 22 gauge.
TEST:	TBS
TEMPERATURE(S):	The cover plate material shall be chosen to withstand (stagnation) temperatures of at least 175°C (330°F).
TEST:	TBS
PRESSURE:	The Collector shall be designed to withstand a continuous pressure of 60 p.s.i.g.
TEST:	TBS

OUT-GASSING OF INSULATION:	The insulation used shall not out-gas at temperatures up to stagnation temperatures.
TEST:	TBS
PLUMBING JOINTS:	All plumbing joints shall be so prepared that they do not leak under normal operating conditions.
TEST:	TBS
RIGIDITY OF FRAME:	The frame shall be sufficiently rigid. This means that the deflection of the frame shall be in accordance with standard engineering practices, regardless of its size and shape, when mounted on a standard collector sub-structure.
TEST:	TBS

MAINTENANCE OF HOT WATER: The system shall be so designed and manufactured such that if there is no solar radiation over a 24-hour period (and no hot water is used from the system) the water should remain hot enough so as not to effect the operation of the auxiliary electric coil.

TEST: TBS

WARRANTIES FOR COLLECTOR:

SUB-SYSTEM	DURATION OF WARRANTY (YEARS)
WATERWAYS	FIVE (5)
INSULATION	ONE (1)
GLAZING DEGRADATION	TWO (2)

STORAGE TANK

LINING The storage tank shall be lined with glass, vitreous enamel or epoxy.

TEST: TBS

PRESSURE:	The test pressure of the tank shall be similar to that of electric and gas water heaters.
TEST:	TBS
PRESSURE RELIEF VALVE:	The tank shall be fitted with an adequate pressure relief valve.
TEST:	TBS
AUXILIARY HEATING COIL:	The tank shall be fitted with an auxiliary electric heating coil, which shall be thermostatically controlled.
TEST:	TBS

AUXILIARY HEATING COIL:	The auxiliary electric heating coil shall be operational and shall be thermostatically controlled.
TEST:	TBS
WARRANTY OF TANK:	The storage tank shall have a 5-year warranty.
TEST:	TBS

INSTALLATION

COLLECTOR ORIENTATION:	The Collector shall be installed facing south $\pm$ 15°. In addition, the Collector shall be installed with a pitch of 2% in the direction of flow.
TEST:	TBS

ANGLE OF INCLINATION:	The angle of inclination is the local latitude ± 10° (i.e. on an average for Jamaica the angle of inclination is 18° ± 10°).
TEST:	TBS
CONNECTING PIPES:	All connecting pipes shall be sloped in the direction of flow, for air venting. The pipe size is determined by the type of material (copper, steel, etc.) and equally important on the Jamaica Building Code, depending on the volume of water to be piped.
TEST:	TBS

CIRCULATING PUMP:	In forced circulation a pump shall be installed in the water outlet line from the tank to the Collector.
PIPING ACCESSORIES:	A check valve shall be installed in the line between the circulating pump and the collector, in order to prevent flow in the reverse direction during cold weather and at nights. A shut-off valve and a check valve with pressure relief shall be installed in the utility water supply line.
WIND RESISTANT:	The installation shall be highly resistant to wind. It shall be able to withstand winds in accordance with the Building Code.
WATERPROOFING OF ROOF:	After installation of the Unit, (if it is placed on the roof), the roof must remain as leak-proof as before the installation.

APPENDIX C - HISTORICAL SOLAR RADIATION* AND TEMPERATURE DATA

NORMAN MANLEY AIRPORT, KINGSTON, JAMAICA

MONTH	Suface Tilt 0^0	10^{o2}	18^{o2}	25^{o2}	Ambient Temperature (°F)
JAN.	1428	1628	1759	1851	74.6
FEB.	1595	1744	1831	1883	77.4
MAR.	1801	1871	1894	1392	73.2
APR.	1830	1820	1793	1728	78.6
MAY	1866	1795	1712	1622	80.9
JUN.	1922	1321	1715	1605	81.9
JUL.	1827	1745	1654	1538	84.5
AUG.	1760	1727	1673	1606	84.4
SEP.	1734	1770	1769	1748	81.9
OCT.	1651	1767	1829	1861	80.9
NOV.	1388	1555	1662	1733	79.1
DEC.	1364	1376	1717	1818	78.6

*Units are Btu/(day)(ft^2).

[1]Historical data (1977-79) Measured by Meteorological Service Pyronometerss at Norman Manley Airport, Kingston.

[2]Calculated from historical data by methods in Solar Energy for Heating and Cooling of Buildings, ASHRAE, 1977. Foreground reflection of 20% assumed.

Revised Oct. 2, 1979

APPENDIX D - PLAN OF OPERATIONS

OAS SOLAR ENERGY PROJECT, 1979

1.0 GENERAL DATA

1.1	Project Title:	Utilization of Solar Energy Country: Jamaica.
1.2	Programming Area:	Solar Radiation Mapping
1.3	Coordinating Agency:	Energy Division, Ministry of Mining & Natural Resources, P.O. Box 495, Kingston 5. Tel: 9269170 9269179 W.R. Ashby, Senior Energy Engineer. The Energy Divison of M.M.N.R. is the national coordinating agency for energy policy and planning. Projects approved in the Ministry are carried out by appropriate agencies, and technical assistance funding is also monitored and coordinated by the Ministry.
1.4	Operating Center:	Meterorological Office, Hagley Park Plaza, Kingston 10. Tel: 9266656
1.5	Project Inception:	September 1979
1.6	Project Duration:	Three (3) years, 1979 - 1981

2.0 DESCRIPTION

Solar Radiation Mapping

2.1 Introduction

The measurement of solar radiation incidence on the earth's surface is of great value for the following purposes:

(a) The study of the transformation of energy within the system earth-atmosphere and its variation in time and space;

(b) The analysis of the atmosphere with regard to its turbidity and constituents such as dust and water vapors;

(c) The study of the distribution and the variations of incoming, outgoing and net radiation;

(d) The satisfaction of the needs of biological, medical, agricultural, architectural and industrial activities with respect to radiation.

Sections (a) and (b) are mainly of academic interest, but there are no available data on the radiation climate of Jamaica. Theoretical studies to predict the incident radiation have been done by the Meteorological Office, but actual data, which could then be compared with the theoretical predictions, are not available. As a result of this, there are no data on the turbidity of the atmosphere nor its temporal and spatial variations.

Sections (c) and (d) are particularly important at this time. The use of solar energy for domestic and commercial energy systems; hot water systems, agricultural dryers, air conditioning and refrigeration systems, suggests the need for an immediate and continuous program of collecting solar radiation data. The acquisition of this data would also benefit the agricultural sector, where the use of it would enable the agricultural engineer to plan the planting and reaping of crops so as to optimize yields.

2.2 Measurement of Solar Radiation

2.2.1 Measurement of Direct Solar Radiation at Normal Incidence.

Direct solar radiation is measured by means of pyrheliometers, the receiving surfaces of which are arranged to be normal to the line joining the sun to the receiver. An Eppley (normal incidence) pyrheliometer, has been requested for this purpose. It will be necessary for this equipment to be calibrated against a standard, and it has been suggested that the Regional Standard in San Juan, Puerto Rico, be used. Efforts are being made to get the instrument delivered to Puerto Rico for calibration purposes.

The Eppley Pyrheliometer will be stationed at the Bureau of Standards in Kingston.

2.2.2 Measurement of Global Radiation from Sun and Sky on a horizontal surface.

Three new radiation recording stations will be established in the following areas:

(a) Mandeville

The staff of the Meteorological Office in Mandeville have been involved in data collection of this nature and are very keen and efficient.

(b) Worthy Park, St. Catherine

This is an agricultural area producing sugar cane. The Sugar Industry Research Institute has expressed interest in the collection of radiation data, particularly in the areas where sugar cane is planted.

(c) Long Pond, Trelawny

This is another area in which the Sugar Industry Research Institute has interest.

There are two stations already in existence at the Norman Manley and Sangster International Airports. Kipp + Zonen pyranometers will be used at all the recording stations, with two stations, Sangster International Airport and Mandeville, having continuous recorders and the others equipped with integrators to give daily total radiation.

2.2.3 Measurement of Sky Radiation.

For measuring or recording separately the diffuse component of solar radiation, the direct solar rays must be screened from the receiver by an additional masking apparatus. Two shadow bands have been requested for this purpose. The two most suitable stations for collecting this data are Norman Manley and Sangster International Airports. Kipp + Zonen pyranometers will again be used with integrators to give radiation values at 15 minute intervals.

2.3 Specific Results

2.3.1 Results achieved in previous years:

Mr. P. Hoilett of the Meteorological Office attended a seminar in Spain, as part of this project, and is due to submit a report shortly. Equipment has been ordered.

2.3.2 Results expected in current years:

Calibration of standard equipment against regional standard in San Juan, Puerto Rico. Visit to international center (Washington) for familiarization with current techniques. Collection of data on a continuous basis.

2.4. Multinational Effort

We already have active relations with the U.W.I., Trinidad in exchange of information regarding solar energy projects. We would hope to extend these relations to other participant countries, such as Mexico and Brazil.

Budget Requested

1. Purchase of Equipment, Material and Books.

   (a) Principal Equipment
   Solar Radiation measuring equipment; pyranometer, recorders, integrators and shadow bands for measuring the diffuse component of radiation including spare parts -- J. $14,000

   (b) Accessories and Consumables
   Charts, Cables, batteries, material for erecting stations -- J. $3,000

K. L. Brown
12/7/79 MMNR

ORDER - RADIATION EQUIPMENT

No.		
1	Eppley Standard Pyrheliometer No.659	$5,490
3	Kipp & Zonen Pyranometers No.633 at $612	1,836
4	Recorders & Integrators No.6194 at $525	2,100
1	Electronic Integrator No.6552	1,800
1	Chart Recorder No.6441	1,800
2	Shadow Bands No.649 at $700	1,400
*	Auxiliaries	
3	Packs printer paper for 6552	400
2	Pkg chart rolls for 6194 recorder	200
	J.	$15,026

* Prices for auxiliaries estimated

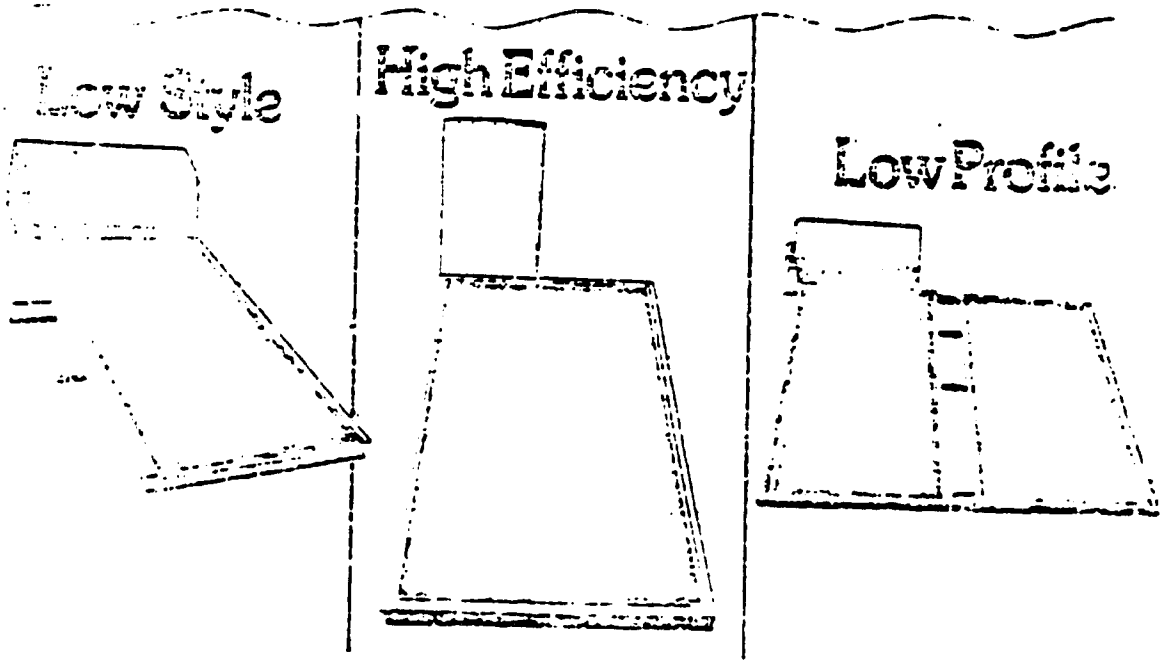
All equipment to operate at 50HZ

Meteorclogical Service
19th April, 1979

AquaTemp

Domestic Solar Hot Water Systems

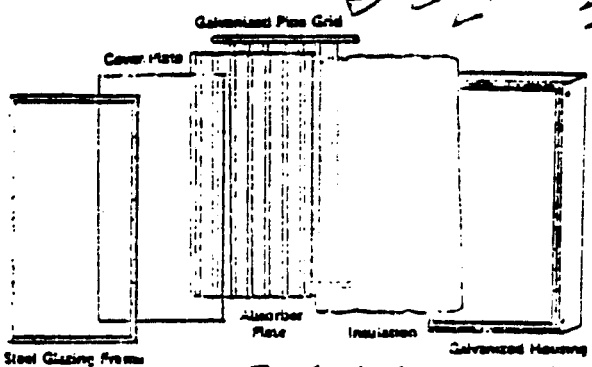
A combination of a flat plate liquid flow Solar Collector and the time-proven AquaTemp Glass-Lined Storage Tank.



For commercial applications of Solar Energy Systems, e.g. hot water for Apartment Buildings and heating applications for Crop Drying, consult the Engineering Department - Appliance & Air Conditioning Manufacturers Limited.
Telephone: 926-3370/4, 926-2088.

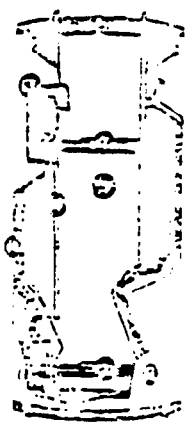
Manufactured by
APPLIANCE & AIR CONDITIONING MANUFACTURERS LIMITED
3 Ivy Green Close, Kingston 5.

Solar Energy



The operation of a Solar System is simple and automatic. Unlike conventional water heaters relying on the expensive ratio of energy in/heat out, solar heating depends on available sunlight. The sun's energy enters the collector through a transparent cover, and is absorbed by specially fabricated black plate called the absorber. It's function is to absorb and convert the Solar energy to heat energy. This collected energy is then transferred to the water circulating through galvanized pipe grids. This heated water will automatically rise and enter the storage tank which is located above the absorber unit. If storage tank is not located above panel, a small circulation pump (40 watts) will have to be installed.

Exploded view of flat plate collector.



Solar Energy

SOLAR WATER HEATER FEATURES:

1. FIVE YEAR GUARANTEE against tank leakage.
2. BOOSTER ELEMENT. Immersion type (if required).
3. THERMOSTAT. Surface type, ruggedly constructed. Positive action.
4. THICK FIBREGLASS INSULATION. Full blanket of 4" fibreglass insulation surrounds tank to minimize heat loss.
5. GLASS-LINED TANK. Durable glass lining is fused to the inner tank for a tough, long life.
6. MAGNESIUM TANK SAVER. Full length extruded magnesium anode inhibits corrosion and prolongs tank life.

Both Collector and Tank are designed for working pressure of 150 lbs. per square inch.

HINTS FOR SELECTING YOUR WATER HEATER:

As a general rule for domestic purposes, it is reasonable to calculate on a capacity of about 12 - 15 gallons of water per person.

Check with the Manufacturer about:

a) The area of the Collector Plate per gallon of water.
b) The pressure at which the system is designed to operate.
c) Guarantee against leakage offered for the Collector Plate and Storage Tank.
d) Location and orientation of installation.
e) The use of Booster Heaters with the Solar systems.

* For other installations, please consult the Factory.

MODELS AVAILABLE

Capacity (gallons) 1 gallon water = 10 lbs.	20	30	40	60	80	*120
No. of panels required (6' x 3' each, weight of panel with water = 145 lbs.)	1	2	3	3	4	6
No. of 2,000 watt Booster elements (if required)	1	1	1	1	2	2

Available from

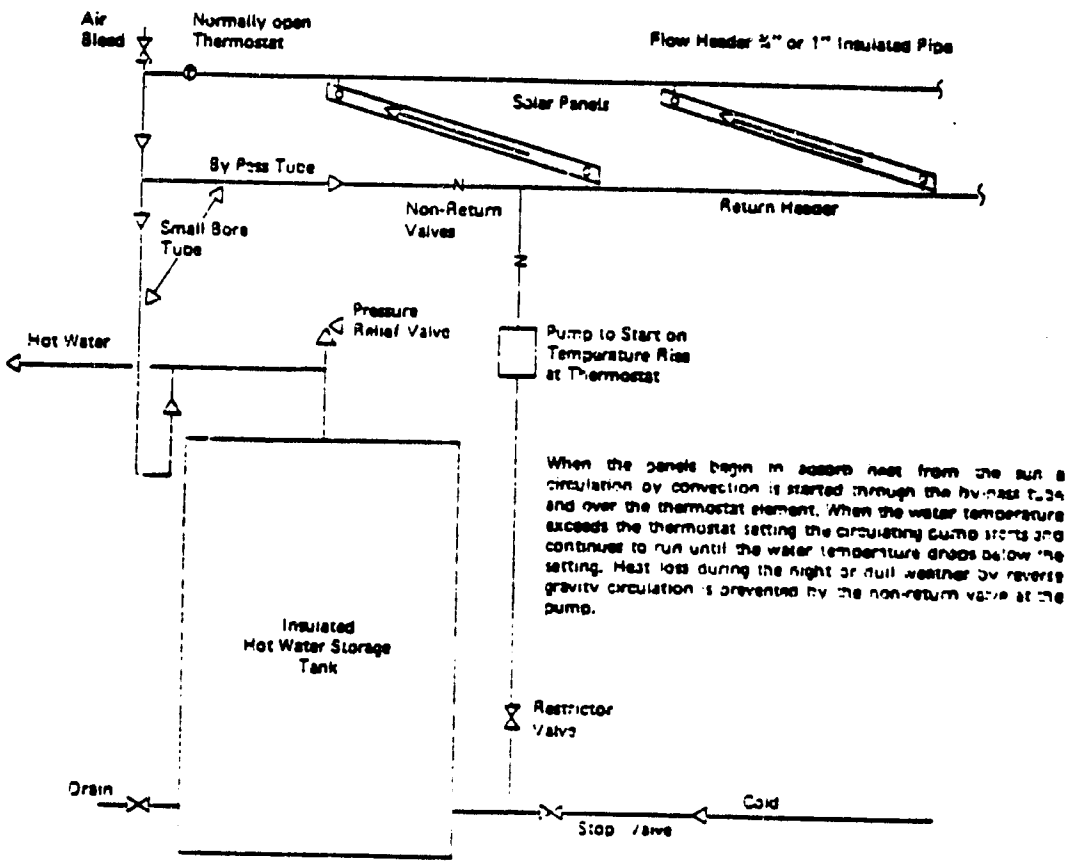
[illegible]

And their Authorised dealers.

Printed by [illegible]

Information Sheet No. 6

SOLAR WATER HEATING (AUTOMATIC FORCED CIRCULATION)



When the panels begin to absorb heat from the sun a circulation by convection is started through the by-pass tube and over the thermostat element. When the water temperature exceeds the thermostat setting the circulating pump starts and continues to run until the water temperature drops below the setting. Heat loss during the night or dull weather by reverse gravity circulation is prevented by the non-return valve at the pump.

It is and has been possible for many years to heat water by absorbing the sun's rays by means of an absorber unit.

Primarily, the benefit of using Solar Heating Units is the tremendous saving in power costs.

We specialize in the manufacture of these units which can be utilised in every type of industry, hotels, and private homes, in fact anywhere hot water is needed.

Units can be installed as awnings thus serving a double purpose, on the roof or on the ground, depending on the best position to ensure that the user may obtain the maximum of sun heat from the units.

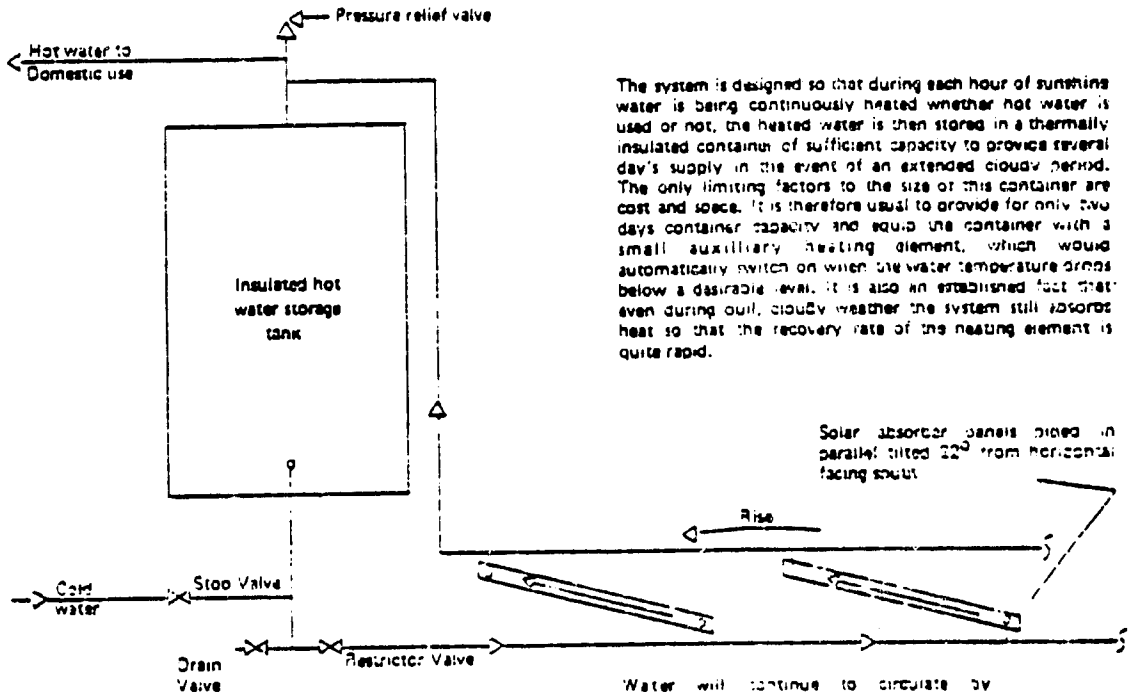
The domestic units are designed to supply hot water at an average of 140° over 12 months. The Solar Heating Unit can be connected to existing hot water storage tanks.

Should you require further information our technical representative will be happy to call on you at a time convenient to yourself to discuss the absorber unit in more detail. He will show how you can cut your running costs on hot water to a minimum.

KINGSTON METAL PRODUCTS LIMITED

Information Sheet No. 5

SOLAR WATER HEATING SYSTEM (CONVECTION)



The system is designed so that during each hour of sunshine water is being continuously heated whether hot water is used or not, the heated water is then stored in a thermally insulated container of sufficient capacity to provide several day's supply in the event of an extended cloudy period. The only limiting factors to the size of this container are cost and space. It is therefore usual to provide for only two days container capacity and equip the container with a small auxiliary heating element, which would automatically switch on when the water temperature drops below a desirable level. It is also an established fact that even during dull, cloudy weather the system still absorbs heat so that the recovery rate of the heating element is quite rapid.

Solar absorber panels piped in parallel tilted 22° from horizontal facing south.

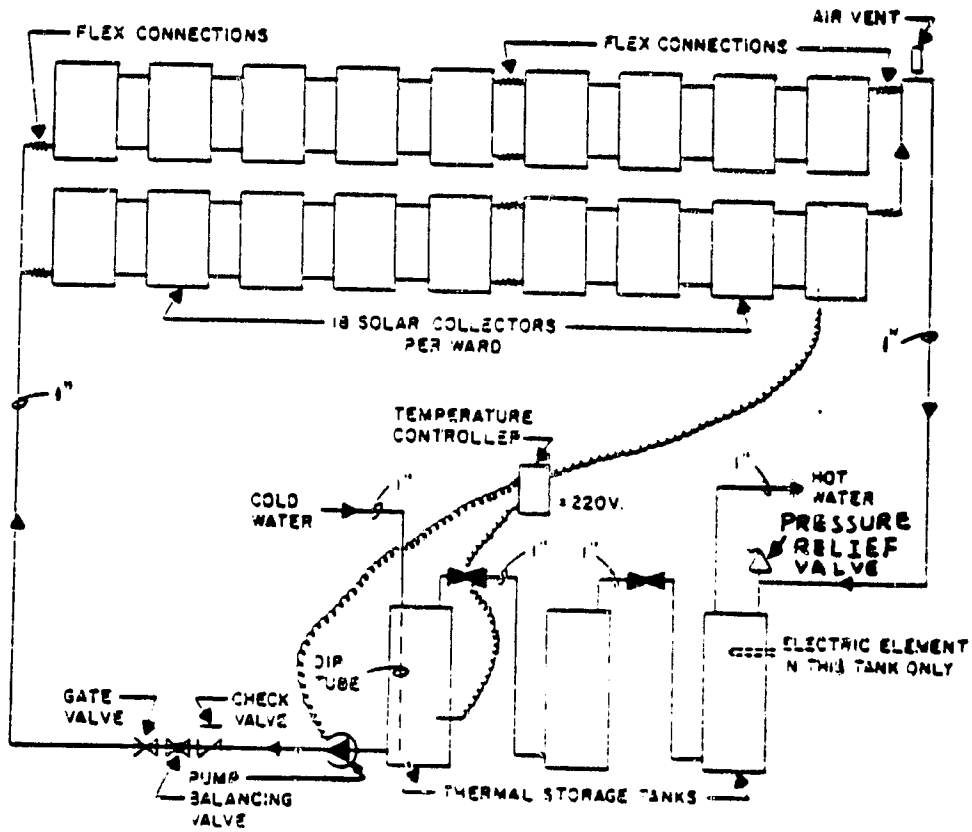
Water will continue to circulate by convection as long as the panels are absorbing heat. When the panels are cold circulation ceases.

Standard 10 sq. ft modular solar absorber panels ready for installation in multiples of the single unit which will produce an average of 20 gals. of hot water per day.

Estimate the daily hot water requirement in gallons and divide by 20 to find the number of panels required.

KINGSTON METAL PRODUCTS LIMITED

APPENDIX G - INDIVIDUAL WARD SOLAR HOT WATER SYSTEM DESIGN FOR THE BUSTAMANTE HOSPITAL FOR CHILDREN



INDIVIDUAL WARD SOLAR SYSTEM

Schedule

1) 18 solar collectors - 9 per row-slope entire row 1 1/2 up in direction of flow - provide flexible connections (ribbed radiator hose) where indicated for thermal expansion - install collectors on existing ward roof in such a way as not to impair existing waterproofing.
2) Pump - 5.3 GPM - 15 ft. head - 1/3 HP maximum.
3) Thermal storage tanks - 3 - 120 gallong galvanized or epoxy-coated tanks - insulated with fiberglass - install tanks in storage space in each ward.
4) Controls - temperature differential type with sensors attached to collector absorber plate and thermal storage as shown.

APPENDIX H - SOLAR HEATING FEASIBILITY STUDIES

Note:
- o Dollars are J. unless noted otherwise.
- o Fuel costs are indicated in Table 3-4
- o Solar system costs are indicated in Figure 3-1
- o Annual solar radiation data are indicated in Table 3-5
- o Gallons indicated are imperial gallons @ 9.99 pounds/gallon
- o Ground water temperature is approximately 75°F
- o Annual solar radiation is 0.64 MMBtu/ft^2

(1) Negril Beach Village

43% Average Annual Occupancy
262 Rooms - 524 Beds
In-house laundry and kitchen
Existing fuel type - Diesel oil
Annual Hot Water Usage:
(524 Beds x 43% Occ) x 15 Gal/Day(D)/Bed x 365 Day/yr
= 1,233,000 Gal/yr

Annual Heat Required (MMBtu)
1,233,000 Gal/yr x 9.99 lb/Gal x (140-75)/1.0 x 10^6
= 800 MMBtu

Existing Annual Fuel Cost
800 MMBtu x $16.07/MMBtu = $12,900

(A) Solar Collector Area required to satisfy 100% of load:

$$\frac{800 \text{ MMBtu}}{0.64 \text{ MMBtu/ft}^2 \times 0.35 \ *} = 3570 \text{ ft}^2$$

* Assumed Collector Efficiency

System Cost = 3570 ft^2 array x $22.50/ft^2
= $80,400

$$\text{System Pay Back} = \frac{\$80{,}400}{\$12{,}900 - (\$80{,}400 \times 1\%)} = 6.7 \text{ years}$$

(B) Most Cost Effective Solar System

$$\% \text{ Solar Fraction} = \frac{2000\ ft^2 \times 0.64\ MMBtu/ft^2 \times 0.35^*}{800\ MMBtu} = 56\%$$

System Cost = 2000 ft^2 x \$20.50 per ft^2
= \$41,000

$$\text{System Pay Back} = \frac{\$41{,}000}{(\$12{,}900 \times 56\%) - (\$41{,}000 \times 1\%)} = 6 \text{ years}$$

(2) Montego Bay Club:

46% Average Annual Occupancy
114 Rooms - 285 Beds
In-house laundry and kitchen
Existing fuel type - Electricity
Annual Hot Water Usage =
(285 Beds x 46% occ) x 15 Gal/D/Bed x 365 D/yr
= 720,000 Gal/yr

Annual Heat Required =
720,000 Gal/yr x 9.99 lb/Gal x (140°- 75°)/1.0 x 10^6
= 470 MMBtu

Existing Fuel Cost =
470 MMBtu x \$49.81/MMBtu
= \$23,410

(A) Solar Collector Area required to satisfy 100% of heating load:

$$\frac{470\ MMBtu}{0.64\ MMBtu/ft^2 \times 0.35} = 2100\ ft^2$$

System Cost = (2100 ft^2 x \$20.60 ft^2) + (\$15,000*)
= \$58,260

$$\text{System Pay back} = \frac{\$58{,}260}{(\$23{,}410) - (\$58{,}260 \times 1\%)} = 2.6 \text{ years}$$

* New Stand-By Boiler

(B) Most Cost Effective Solar System

The 2100 ft^2 area required is the most cost effective system for this application.

(3) Coconut Cove Hotel:

57% Average Annual Occupancy
46 rooms - 96 Beds
In-house laundry and kitchen
Existing fuel type - Diesel oil
Annual Hot Water Usage =
(96 Beds x 57% occ) x 15 Gal/D/Bed x 365 D/yr
= 300,000 Gal/yr

Annual Heat Required =
300,000 Gal/yr x 9.99 lb/Gal x (140°-75°)/1.0 x 10^6
= 195 MMBtu

Existing Annual Fuel Cost =
195 MMBtu x $16.07/MMBtu
= $3135

(A) Solar Collector Area required to satisfy 100% of heating load:

$$\frac{195 \text{ MMBtu}}{0.64 \text{ MMBtu/ft}^2 \times 0.35} = 900 \text{ ft}^2$$

System Cost = 900 ft^2 x $20 per ft^2
= $18,000

System Pay back = $\frac{\$18{,}000}{\$3{,}135 - (\$18{,}000 \times 1\%)} = 6.1 \text{ years}$

(B) Most Cost Effective Solar System
The 900 square foot area required is the most cost effective system for this application.

(4) <u>Trelawny Beach Hotel:</u>

38% Average Annual Occupancy
350 Rooms - 700 Beds
In-house laundry and kitchen
Existing fuel type - LPG
Annual Hot Water Usage =
(700 Beds x 38% Occ) x 15 Gal/Day/Bed x 365 D/yr
= 1,456,350 Gal/yr

Annual Heat Required (MMBtu) =
1,456,350 Gal/yr x 9.99 lb/Gal x (140°-75°)/1.0 x 10^6
= 946 MMBtu

Existing Annual Fuel Cost =
946 MMBtu x $34.29/MMBtu
= $32,427

(A) <u>Solar Collector Area required to satisfy 100% of heating load:</u>

$$\frac{946 \text{ MMBtu}}{0.64 \text{ MMBtu/ft}^2 \times 0.35} = 4300 \text{ ft}^2$$

System Cost = 4300 ft^2 array x $22.50 per ft^2
= $96,750

$$\text{System Pay back} = \frac{\$96{,}750}{\$32{,}427 - (\$96{,}750 \times 1\%)} = 3.1 \text{ years}$$

(B) <u>Most Cost Effective Solar System</u>

$$\%\ \text{Solar Fraction} = \frac{2000 \text{ ft}^2 \times 0.64 \text{ MMBtu/ft}^2 \times 0.35}{946 \text{ MMBtu}} = 48\%$$

System Cost = 2000 ft^2 array x $20.50 per ft^2
= $41,000

$$\text{System Pay back} = \frac{\$41{,}000}{(\$32{,}427 \times 48\%) - (\$41{,}000 \times 1\%)} = 2.7 \text{ years}$$

(5) Intercontinental Hotel Ocho Rios:

32% Average Annual Occupancy
359 Rooms - 700 Beds
In-house laundry and kitchen
Existing fuel type - Bunker C oil
Annual Hot Water Usage =
(700 Beds x 32% Occ) x 15 Gal/D/Bed x 365 Days/yr
= 1,226,400 Gal/yr

Annual Heat Required (MMBtu)
1,266,400 Gal/yr x 9.99 lb/Gal x (140°-75°)/1.0 x 10^6
= 796.4 MMBtu

Existing Annual Fuel Cost =
796.4 MMBtu x $6.75/MMBtu
= $5,375

(A) Solar Collector Area required to satisfy 100% of heating load:

$$\frac{796.4 \text{ MMBtu}}{0.64 \text{ MMBtu/ft}^2 \times 0.35} = 3555 \text{ ft}^2$$

System Cost = 3555 ft^2 array x $22 per ft^2
= $78,210

System Pay back =
($78,210)/($5375 - ($78,210 x 1%))
= 17 years

(B) Most Cost Effective Solar System

% Solar Fraction = (2000 ft^2 x 0.64 MMBtu/ft^2 x 0.35)/ 796.4 MMBtu
= 56%

System Cost = 2000 ft^2 array x $20.50 per ft^2
= $41,000

System Pay back = ($41,000)/(($5375 x 56%) - ($41,000 x 1%))
= 15.8 years

(6) Bustamante Hospital for Children:

30 children per ward typical occupancy
Electric water heater in each ward
Hot Water Usage - Average should be approximately 8 gallons per day per child without laundry and food preparation facilities.

Annual Hot Water Usage per Ward
30 children x 8 Gal/D/child x 365 D/yr
= 87,600 Gal/yr*

Annual Heat Required (MMBtu)
87,600 Gal/yr x 9.99 lb/Gal x (140°-75°)/1.0 x 10^6
= 57 MMBtu

Annual Fuel Cost based on above water usage*
= 57 MMBtu x $49.81/MMBtu
= $2840

* The actual annual water usage and fuel cost per ward is lower than the above figure.

The existing water heaters are so drastically undersized that only 5 or 6 children can be bathed before depleting the hot water storage tank.

(A) Solar Collector Area required to satisfy 100% of heating load:

$$\frac{57 \text{ MMBtu}}{(0.64 \text{ MMBtu/ft}^2 \times 0.8^{\dagger}) \times 0.35} = 318 \text{ ft}$$

System Cost = 318 ft^2 x $22/$ft^2$
= $7000

$$\text{System Pay back} = \frac{\$7{,}000}{\$2840 - (\$7{,}000 \times 1\%)} = 2.5 \text{ years}$$

(B) Most Cost Effective Solar System
Larger systems indicated in Figure 3-1 are more cost effective, due to the lower installed cost per square foot, but a larger system is not applicable for individual hospital wards.

† East of south correction factor

(7) Cornwall Regional Hospital:

75% Average Annual Occupancy
400 Beds
Electric Water Heaters in each quadrant on each floor
In-house kitchen facilities
Average daily hot water usage per patient and related support services should be approximately 20 gallons

Annual Hot Water Usage
400 beds x 75% occ x 20 Gal/Day/Bed x 365 Day/yr
= 2,190,000 Gal/yr

Annual Heat Required (MMBtu)
2,190,000 Gal/yr x 9.99 lb/Gal x (140°-75°)/1.0 x 10^6
= 1422 MMBtu

Annual Fuel Cost
1422 MMBtu x $49.81/MMBtu
= $70,830

(A) Solar Collector Area required to satisfy 100% of heating load:

$$\frac{1422 \text{ MMBtu}}{0.64 \text{ MMBtu/ft}^2 \times 35\%}$$

$$= 6350 \text{ ft}^2$$

System Cost = 6350 ft^2 x $25/$ft^2$
= $158,750

System Pay back = $\frac{\$158,750}{\$70,830 - (\$158,750 \times 1\%)}$
= 2.3 years

(B) Most Cost Effective Solar System

% Solar Fraction = $\frac{2000 \text{ ft}^2 \times 0.64 \text{ MMBtu/ft}^2 \times 35\%}{1422 \text{ MMBtu}}$
= 31.5%

System Cost = 2000 ft^2 x $20.50/$ft^2$
= $41,000

System Pay back = $\frac{\$41,000}{(\$70,830 \times 31.5\%) - (\$41,000 \times 1\%)}$
= 1.9 years

(8) Desnoes and Geddes Bottling Company:

Pre-heat boiler make-up water
Existing Fuel - Bunker C oil
60% of condensate is returned to receiver at approximately 200°F
Total Boiler condensate, or water to boiler is approximately 30,000 gallons per day.

Fresh water make-up is 30,000 x (1 - .6) or 12,000 gallons per day requiring pre-heating. As previously mentioned, solar collectors presently manufactured in Jamaica can only operate efficiently up to water temperatures of 140°F. Thus, for the purpose of this study the boiler make-up water will be pre-heated to 140°F.

Annual Water Usage
12,000 Gal/Day x 365 Day/yr
= 4,380,000 gal/yr

Annual Heat Required (MMBtu)
4,380,000 Gal/yr x 9.99 lb/gal x (140°-75°)/1.0 x 10^6
= 2845 MMBtu

Annual Fuel Cost to preheat to 140°F
2845 MMBtu x $6.75/MMBtu
= $19,200

(A) Solar Collector Area required to satisfy 100% of heating load:

$$\frac{2845 \text{ MMBtu}}{0.64 \text{ MMBtu/ft}^2 \times 0.35} = 12{,}700 \text{ ft}^2$$

System Cost = 12,700 ft^2 x $26.30 per ft^2
= $334,000

$$\text{System Pay back} = \frac{\$334{,}000}{\$19{,}200 - (\$334{,}000 \times 1\%)} = 21 \text{ years}$$

(B) Most Cost Effective Solar System

$$\text{\% Solar Fraction} = \frac{2000 \text{ ft}^2 \times 0.64 \text{ MMBtu} \times 0.35}{2845 \text{ MMBtu}} = 16\%$$

System Cost = 2000 ft^2 array x \$20.50/ft^2
= \$41,000

$$\text{System Pay back} = \frac{\$41{,}000}{(\$19{,}200 \times 16\%) - (\$41{,}000 \times 1\%)} = 15.4 \text{ years}$$

APPENDIX I - SOLAR COOLING FEASIBILITY STUDIES

Note:
- o Dollars are J. unless noted otherwise.
- o Required collector area and operation & maintenance cost for solar cooling is indicated in Section 3.7.8.1.
- o Fuel costs are indicated in Figure 3-1

(1) Cornwall Regional Hospital:

Existing Power

160 ton absorption refrigeration machine supplied by Bunker C oil fired boilers.

Flat Plate Collector Area Required

= 160 tons x 250 ft^2/ton

= 40,000 ft^2

Concentrating Collector Area

= 160 tons x 100 ft^2/ton

= 16,000 ft^2

System Costs

Flat Plate - 40,000 ft^2 x \$87.50/ft^2

= \$3,500,000

Concentrating - 16,000 ft^2 x \$157.50/ft^2

= \$2,520,000

Refrigeration machine modification costs approximately \$30,000.

Annual Heat Required (MMBtu) - (It is assumed the refrigeration machine operates approximately 1600 ton hours per day):

1600 ton hours x 0.0187 MMBtu/ton (Trane Catalog) x 365 days
= 10,920 MMBtu

Existing Fuel Cost

10,920 MMBtu x \$6.75/MMBtu

= \$73,720

System Pay back

$$\text{Flat Plate Collector} = \frac{\$3{,}500{,}000 + \$30{,}000}{(\$73{,}720) - (\$3{,}500{,}000 \times .5\%)} = 63 \text{ years}$$

$$\text{Concentrating Collector} = \frac{\$2{,}520{,}000 + \$30{,}000}{(\$73{,}720) - (\$2{,}520{,}000 \times 1.5\%)} = 71 \text{ years}$$

(2) <u>Ministry of Education and SRC Office Buildings:</u>

Solar Power: new 3 ton absorption refrigeration system - The Ministry of Education Office Buildings and SRC cooling applications are the same size.

Study assumes 18 ton hours per day and 5 days per week electric driven refrigeration system. Annual energy requirements and costs are:

kWh = 4680 ton hours x 1.4 kWh/ton*
= 6550 kWh annual

* Typical electrical consumption for air cooled refrigeration equipment.

Energy Cost
6550 kWh x $0.17/kWh
= $1115 per year

Solar Collector Area Required
Flat Plate ft^2 = 3 tons x 250 ft^2/ton
= 750 ft^2
Concentrating ft^2 = 3 tons x 100 ft^2/ton
= 300 ft^2

System Cost
Flat Plate = (750 ft^2 x $87.50/$ft^2$) + $10,000 for refrigeration machine and installation
= $75,625

Concentrating = (300 ft^2 x $157.50/$ft^2$) + $10,000
= $57,250

System Pay back

Flat Plate Collector $= \dfrac{\$75,625}{\$1115 - (\$75,625 \times 1\%)} = 210$ years

Concentrating Collector $= \dfrac{\$57,250}{\$1115 - (\$57,250 \times 2\%)}$ = will not payback

(3) Agricultural Marketing Corporation:

Solar Electric Power (Photovoltaic) existing retail outlet store walk-in refrigerated food storage room.

Study assumes 2 kW load with a typical 6 hour duty cycle totaling 12 kWh per day.

Existing Annual Energy Usage and Cost

Usage (kWh) = 12 kWh x 365 Days/yr
= 4380 kWh/yr

Cost = 4380 kWh x $0.17/kWh
= $745/yr

Photovoltaic System Cost including batteries, collectors, structure, wiring, and invertor is approximately U.S. $50,000 or J. $87,500.

System Pay back* = $87,500/$745
= 117 years

* Operation amd maintenance (O&M) omitted due to minimal O&M requirements.

APPENDIX J - SOLAR POTENTIAL BY BUILDING SECTORS

Note:
- o Dollars are J. unless noted otherwise.
- o Fuel costs are indicated in Table 3-4
- o Solar system costs are indicated in Figure 3-1
- o Annual solar radiation data is indicated in Table 3-5
- o Gallons indicated are inperial gallons @ 9.99 pounds/gallon
- o Ground water temperature is approximately 75°F
- o Annual solar radiation is 0.64 MMBtu/ft^2

(1) Residential:

Thirty thousand electric water heaters are presently in operation in Jamaica.

A typical residence uses approximately 40 gallons per day (GPD) of hot water.

Total Residential Hot Water Usage per year (GPY)
30,000 residences x 40 GPD x 365 Days/yr
= 438,000,000 gal/yr

Annual Heat Required (MMBtu)
438,000,000 gallons x 9.99 x (140°-75°)/1.0 x 10^6
= 285,000 MMBtu

Existing Annual Fuel Cost to User
= $285,000 MMBtu x $49.81/MMBtu
= $14,167,000

Electrical generation and distribution efficiency is approximately 30%

Existing Annual Fuel Cost to Jamaica (Barrels of Oil)

$$\frac{285{,}000 \text{ MMBtu}}{6.0 \text{ MMBtu/barrel} \times 30\%} = 159{,}000 \text{ barrels}$$

Solar Collector Area Required to displace the above fuel

$$\frac{285{,}000 \text{ MMBtu}}{0.64 \text{ MMBtu/ft}^2 \times 0.35} = 1{,}270{,}000 \text{ ft}^2$$

Solar Collector System Cost
1,270,000 ft^2 x $24/ft^2 average = $30,480,000

System Pay back
$30,480,000/($14,167,000 - $30,480,000 x 1%) = 2.2 years

(2) <u>Institutional (Hospitals):</u>

5200 beds are available and, on the average, are fully occupied.

A typical hospital patient directly and indirectly uses approximately 20 gallons per day (GPD) of hot water for bathing, food preparation, dishwashing, laundry and space cleaning.

Typically electricity is used for water heating:
Total Hospital Hot Water Usage per year (GPY)
5200 Beds x 20GPD x 365 Days/yr
= 37,960,000 gallons

Annual Heat Required (MMBtu)
37,960,000 gallons x 9.99 x (140°-75°)/1.0 x 10^6
= 24,650 MMBtu

Existing Annual Fuel Cost to User
24,650 MMBtu x $49.81/MMBtu
= $1,230,000

Existing Annual Fuel Cost to Jamaica (Barrels Oil)

$$\frac{24650 \text{ MMBtu}}{6.0 \text{ MMBtu/Barrel} \times 30\%} = 13{,}700 \text{ barrels}$$

Solar Collector Area Required to displace the abpve fuel

$$\frac{24650 \text{ MMBtu}}{0.64 \text{ MMBtu/ft}^2 \times 0.35} = 110{,}000 \text{ ft}^2$$

Solar Collector System Cost
11,000 ft^2 x $24/$ft^2$ average
= $2,640,000

$$\text{System Pay back} = \frac{\$2{,}640{,}000}{\$1{,}230{,}000 - (\$2{,}640{,}000 \times 1\%)} = 2.2 \text{ years}$$

(3) Commercial (Hotels):

(1) A typical hotel guest, directly and indirectly, uses approximately 15 gallons per day (GPD) of hot water.

(2) Average Hotel Occupancy for each major city and fuel types vary for each hotel. MMNR personnel have investigated most hotels, the types of energy used for domestic water heating, and average occupancy to determine overall energy usage throughout the hotel industry.

(3) The breakdown of hotels by city, fuel type, and occupancy is contained in Table 3-1.

(A) Total Hotel Hot Water Usage per Year (GPY) by Fuel Type

Electricity
2591 Beds x 15 gal/day x 365 days/yr
= 14,185,725 GPY

LP Gas
955 Beds x 15 gal/day x 365 days/yr
= 5,228,625 GPY

Diesel
3556 Beds x 15 gal/day x 365 days/yr
= 19,469,100 GPY

Bunker C
350 Beds x 15 gal/day x 365 days/yr
= 1,916,250 GPY

(B) Annual Heat Required (MMBtu) by Fuel Type

Electricity
14,185,725 GPY x 9.99 x (140°-75°)/1.0 x 10^6
= 9215 MMBtu

LP Gas
5,228,625 GPY x 9.99 x (140°-75°)/1.0 x 10^6
= 3396 MMBtu

Diesel
19,469,100 GPY x 9.99 x (140°-75°)/1.0 x 10^6
= 12,636 MMBtu

Bunker C

1,916,250 GPY x 9.99 x (140°-75°)/1.0 x 10^6
= 1245 MMBtu

(C) Existing Annual Fuel Cost to Hotels by Fuel Type

Electricity

9215 MMBtu x $49.81/MMBtu
= $459,000

LP Gas

3396 MMBtu x $34.29/MMBtu
= $116,500

Diesel

12,636 MMBtu x $16.07/MMBtu
= $203,060

Bunker C

1245 MMBtu x $6.75/MMBtu
= $8,400

Total Annual Fuel Cost = $459,000 + $116,500 + $203,060 + $8,400
= $786,960

(D) Existing Annual Fuel Cost to Jamaica (Barrels) by Fuel Type

Electricity (Generating efficiency is 30%)

$$\frac{9215 \text{ MMBtu}}{6.0 \text{ MMBtu/barrels} \times 30\%} = 5120 \text{ barrels}$$

LP Gas (Generating efficiency is 50%)

$$\frac{3396 \text{ MMBtu}}{6.0 \text{ MMBtu/barrels} \times 50\%} = 1132 \text{ barrels}$$

Diesel (Generating efficiency is 60%)

$$\frac{12636 \text{ MMBtu}}{6.0 \text{ MMBtu/barrels} \times 60\%} = 3510 \text{ barrels}$$

Bunker C (Generating efficiency is 60%)

$$\frac{1245 \text{ MMBtu}}{6.0 \text{ MMBtu/barrels} \times 60\%} = 345 \text{ barrels}$$

(E) Total Annual Fuel Cost to Jamaica (Barrels of Oil)

Barrels = 5120 + 1132 + 3510 + 345
= 10,107

(F) Total Annual Heat Load (MMBtu)

MMBtu = 9215 + 3396 + 12,636 + 1245
= 26,492

Solar Collector Area Required to displace the above fuels

$$\frac{26492 \text{ MMBtu}}{0.64 \text{ MMBtu/ft}^2 \times 0.35} = 118{,}270 \text{ ft}^2$$

Solar Collector System Cost

$118{,}270 \text{ ft}^2 \times \$24/\text{ft}^2$ average
= \$2,838,500

$$\text{System Pay back} = \frac{\$2{,}838{,}500}{\$786{,}960 - (\$2{,}838{,}500 \times 1\%)} = 3.8 \text{ years}$$

(4) Industrial Pre-heat Boiler Make-up Water:

The industries surveyed (Section 3.5.3) consume approximately 40,000 gallons per day of make-up water for boilers. MMNR personnel consider this quantity to be approximately 30% of the water consumed by industry today. Since water consumption figures are not kept, an assumption of 150,000 gallons per day was used for this study.

A mixture oil is normally used for boiler firing at a cost fairly close to that of diesel oil, thus diesel oils cost was used for study purposes.

Total Annual Hot Water Usage (GPY)
150,000 GPD x 260 Working Days/yr
= 39,000,000 GPY

Annual Heat Required (MMBtu)
39,000,000 GPY x 9.99 x (140°-75°)/1.0 x 10^6
= 25,325 MMBtu

Existing Annual Fuel Cost to User
25,325 MMBtu x $16.07/MMBtu
= $407,000

Existing Annual Fuel Cost to Jamaica (Barrels of Oil)

$$\frac{25325 \text{ MMBtu}}{6.0 \text{ MMBtu/barrel} \times 60\%} = 7035 \text{ barrels}$$

Solar Collector Area Required to displace the above fuel

$$\frac{25325 \text{ MMBtu}}{0.64 \text{ MMBtu/ft}^2 \times 0.35} = 113{,}100 \text{ ft}^2$$

Solar Collector System Cost
113,100 ft^2 x $24/$ft^2$
= $2,713,400

$$\text{System Pay back} = \frac{\$2{,}713{,}400}{\$407{,}000 - (\$2{,}713{,}400 \times 1\%)} = 7.14 \text{ years}$$

APPENDIX K - Final Report Conference
Splinter Group Discussion

Before the U.S. Energy Team members left Jamaica, a Final Report Conference was held at the Jamaica Pegasus Hotel on November 13 and 14, 1979. During the first day of the conference, the U.S. Energy Team members and Jamaican counterparts presented the findings, conclusions and recommendations of each of the specialized studies. For greater exposure and increased audience participation, splinter group discussions were held during the second day. Each of the studies had a 2-3 hour question and answer session in which study parameters were reviewed and results highlighted. The following is a synopsis of the Solar Commercial and Industrial - Hot Water splinter group discussion.

Respondent: Mr. W. R. Ashby, Ministry of Mining and Natural Resources
Respondent: Mr. Thomas Y. Lewis, U.S. Energy Team Member

Q.3.1. Since vee-shaped corrugated collectors are more efficient than flat-plate collectors, do you recommend using vee-shaped collectors for solar heating of water?

A.3.1. (Mr. Lewis) There are minor problems in using vee-shaped collectors to handle fluids. The water may expand the teflon at the vee's bonding point, thereby causing stress and perhaps creating internal water waves. I am not sure, but I believe these problems can be solved.

Q.3.2. Vee-shaped corrugated collectors with pipes in a grid arrangement have better support at the connection. Would this help to solve the problems you have mentioned?

A.3.2. (Mr. Lewis) Such supports may decrease the number of water wave occurrences, but they will not eliminate the water wave problem. Waves will still occur causing substantial heat loss. Air collectors, for this reason, are more effective.

Q.3.3. In your report, you say solar cooling is not yet feasible. Could we, nevertheless, build absorbers for possible future retrofitting?

A.3.3. (Mr. Lewis) The major obstacle to such provisions is that the pay back period is too long. To my knowledge the only potential solar cooling installation is at the Cornwall Regional Hospital. They have an absorption refrigeration machine plant. To retrofit its current steam system would cost about J. $3.5 million. A concentrator system would cost J. $2.75 million. However, the pay back periods are 63 years and 71 years respectively. Based on currently available equipment, solar cooling is not yet cost effective either in Jamaica or in the United States. Research work is now being performed in the areas of absorption equipment and cooling fluids.

Q.3.4. Your report mentions using focusing collectors and evacuated tube collectors. We need to conserve energy now. Is it cost effective for us to import tube collectors?

A.3.4. (Mr. Lewis) I think the high solar radiation in Jamaica would make evacuated tube collectors work very effectively here. If Jamaican technology cannot manage to manufacture them, tube collectors could be imported economically. An alternative that could eliminate the need to import is the use of flat plate collectors already manufactured here for about J. $10 per square foot. These must be improved, the quality of the bonds must be better and that will raise the cost about 10%, but the increased efficiency would shorten the pay back period.

Q.3.5. If we begin now to manufacture solar collectors, we will soon be able to enter the world export market. Your recommendations do not mention the establishment of a Department of Solar Energy to regulate exporting. What do you recommend? Wouldn't it be better if our manufacturers were certified by some agency?

A.3.5. (Mr. Lewis) Although I do not recommend the formation of a new Bureau, I do recommend systematic training of engineers and architects, and licensed courses for solar plumbers and professional engineers.

Q.3.6. You recommend that the now existing tax on solar hot water systems be eliminated. Without that elimination, would it still be feasible to build residential hot water systems?

A.3.6. (Mr. Ashby) They would still be feasible but, of course, more expensive. I have addressed a letter to the Ministry of Finance requesting removal of this tax.

Q.3.7. You are trying to implement some of your own designs? Does this mean designs other than your own will not be approved?

A.3.7. (Mr. Lewis) The designs were used as a reference desig for the assessment. The Bureau of Standards will have authority to grant approval of any or all solar designs. The only criteria will be the functions (collection, distribution, storage of energy in cost effective manners) of the systems.

A.3.7. (Mr. Ashby) The College of Arts, Science and Technology will be made aware of these criteria.

Q.3.8. Is it possible for secondary students to learn solar designs?

A.3.8. (Mr. Lewis) Yes! That is an excellent idea.

Q.3.9. You have recommended not establishing solar cooling demonstrations. Will this recommendation be altered before your final report is made?

A.3.9. (Mr. Lewis) I don't see anything wrong with small demonstration projects (2-3 tons) in Jamaica. I just think that your present need to replace electric water heating is greater and more easily accomplished than the cooling needs. If you can show me the possibility of more significant cooling projects, I will change my report.

Q.3.10. What does one gain by putting storage tanks under ground?

A.3.10. (Mr. Lewis) Most storage tanks currently are above ground. They are well-insulated and water-proofed. Underground storage tanks would also need to be insulated, but they should lose less heat because their temperature fluctuations would be moderated by the stable ground temperature. That, at least, is the theory; it has not yet been proven. One disadvantage to a below-surface tank is the difficulty of detecting water leakage.

Q.3.11. Do you recommend demonstration projects for solar water heating?

A.3.11. (Mr. Lewis) The Children's Hospital will institute such a project, and the JPS solar program will set up projects in the Kingston area.

Q.3.12. Would it be a good idea to establish a basic solar demonstration site to be used as a teaching tool for all visitors?

A.3.12. (Mr. Lewis) I have recommended establishing an energy information office (not a full Bureau) to display photos and distribute materials and technical information on solar energy.

A.3.12. (Mr. Ashby) Dr. Lowe of the MMNR would probably establish a demonstration center.

A.3.12. (Dr. Jerome Bosken) The word "demonstration" would mean a working system for a particular site. Perhaps we should use "exhibition" or "globe" instead of "demonstration".

Q.3.13. Did you investigate solar heating and cooling for food storage?

A.3.13. (Mr. Lewis) I spoke with Mr. Cooke of AMC about solar space heating, and we also discussed space cooling for food storage. The only technology I can think of for this is photovoltaic, which has been used on some demonstration projects in the United States. It is not very cost effective. One walk-in food storage unit with 12 kWh/day would cost J. $745 per year once it was operating. To set up the system would cost about J. $87,500. The pay back period is 117 years.

Q.3.14. Can you place your recommendations in "short term" and "long term" categories?

A.3.14. (Mr. Lewis) Dr. Edelman has done this for all recommendations. In the first year of the plan, we would train technical people for design and implementation, set up climatic stations, and conduct feasibility studies and designs. In the second year, we would begin implementation. In every year, there should be new climatic stations on line, and course work established for engineers and architects.