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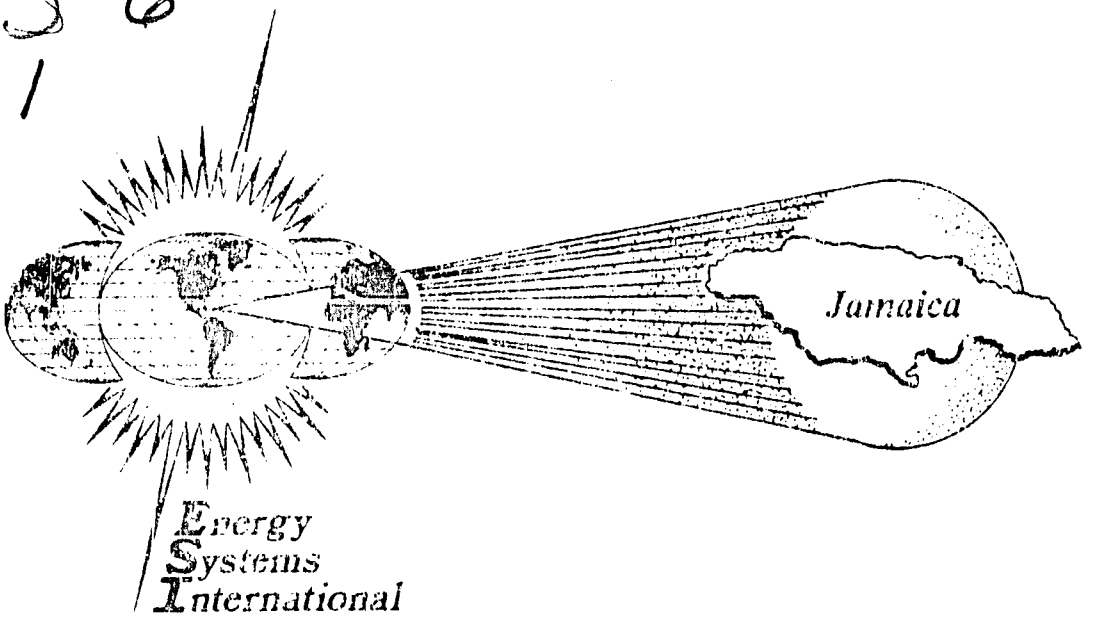

Preliminary Energy Sector Assessments of Jamaica

Volume I
Executive Summary

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16. Abstract (Limit: 200 words)

Because heavy dependence on costly imported fuel has greatly inhibited Jamaica's economic development, USAID Jamaica and the Government of Jamaica (GOJ) sponsored a preliminary energy assessment to identify and develop viable alternative energy options. Specialized studies included solar energy (commercial/industrial and agricultural), biogas applications, energy conversion from waste, a coal prefeasibility study, and an electric utility rate analysis. Individual studies were published in three volumes (with volume three on renewable energy being in four parts, for a total of six volumes). This first introductory volume provides a lengthy executive summary of the entire assessment. (A second introductory volume provides an economic assessment of each specialized study area.) After summarizing the findings of the specialized studies, a lengthy series of recommendations is presented. General recommendations include assessing the potential of other promising energy areas; establishing a GOJ office to develop an overall energy conservation plan; identifying the specialized personnel requirements of the GOJ Ministry of Mining and Natural Resources Energy Division; developing the required infrastructure among the various Jamaican groups involved in energy programs; and developing and implementing training and technical assistance plans for GOJ energy program personnel. Specific recommendations include implementing solar water heating, solar agricultural drying, and biogas applications programs; studying waste collection problems in Kingston; establishing an Alternative Energy Laboratory at the University of the West Indies' Mona Campus; upgrading existing oil-fired electric power plants; investigating a possible coal-fired plant and coal supply and shipping; monitoring coal-oil mixture development and coal gasification technology progress; and having the Jamaican Public Service Company assess various options for electric utility rates. A Combined Energy Program based on these recommendations would be economically beneficial and should be implemented. Appendices include a five-item bibliography (1978-79), profiles of the U.S. energy assessment team members, and a summary of a splinter group discussion.

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PRELIMINARY
ENERGY SECTOR ASSESSMENTS OF JAMAICA

CHAPTER 1

EXECUTIVE SUMMARY

Prepared for

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CONTRACT NUMBER AID 532-79-11

ENERGY SYSTEMS INTERNATIONAL
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FOREWARD

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

Volume	Chapter	
I	1	Executive Summary
II	2	Economic Assessment
III		Renewable Energy:
	3	(a) Solar Energy - Commercial and Industrial
	4	(b) Solar Energy - Agricultural
	5	(c) Biogas Applications
	6	(d) Energy Conversion from Waste
IV	7	Coal Prefeasibility Study
V	8	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 integraton 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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REPORT ORGANIZATION

Section 1.0 of this Volume, Executive Summary, contains the overall approach, results, and recommendations of the study. Additionally, the Executive Summaries for each specialized study have been included in this Volume for reader reference (Sections 2.0 through 8.0). These Executive Summaries are augmented by supplementary information to assist those readers who may not have or need complete access to the other Volumes of the study report.

ACKNOWLEDGMENTS

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 assessments were 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.

Special thanks go to Dr. Henry G. Lowe, Director, Energy Division of the Ministry of Mining and Natural Resources and to the MMNR staff for providing the inspiration and leadership from the Jamaican side to ensure that there was enthusiastic support and contributions to this study from all Jamaican counterparts.

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Most importantly, special acknowledgment is given to those from the Jamaican public and private sectors, who took the time to make significant contributions to the study through their interviews and discussions with members of the energy team and through their participation at the various progress reviews, seminars and the Final Report Conference held on November 13-14, 1979. To the extent possible, these people and organizations are identified in the individual chapters. The people who participated in the Final Report Conference are listed in Appendix D of this Chapter.

CREDITS

Special thanks go to the U.S. Energy Team members and their Jamaican counterparts who worked with dedication to make the study a successful joint venture. The key Jamaican and U.S. members who made significant contributions to the study in Jamaica and the final reports were:

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Finally, special thanks go to the members or the Energy Systems International technical and administrative staff who were responsible for the arduous and time consuming task of: analyzing, integrating and organizing team report inputs; preparing needed report sections and illustrations; typing, editing, reviewing and publishing the final report. Principal contributors to these efforts included: Jorge R. Asin, Chun Choy Chan, Linda K. Gibeaux, David C. Humphries, Laura Little, Robert L. Mangus, S. Britt Mangus, Gary Roberts, and Eve A. Shelton.

Principal Investigator

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1.0 EXECUTIVE SUMMARY
PRELIMINARY ENERGY SECTOR ASSESSMENTS OF JAMAICA

1.1 INTRODUCTION

Jamaica's principal source of energy is imported oil. The country's dependence on foreign oil constitutes approximately 99% of commercial energy consumption. There is little likelihood that this dependence will decrease during the early 1980s.

Jamaica's oil imports rose in price from an average of U.S. $61.6 million in 1971-1973 to U.S. $195.2 million in 1974 and to U.S. $225.6 million in 1977. Based on end use forecast[1] the 1982 oil import bill is estimated to be a new high of U.S. $357 million. Further, Jamaica has no known coal or gas deposits. Test drilling for oil has proved to be unsuccessful since the 1960s. The only commercially exploitable and proven resource of solid fuel is swamp peat. These reserves are sufficient to generate about 80 MW of electric capacity for 30 years. Renewable energy resources have yet to be examined in sufficient detail to accurately determine future potential.

Jamaica and approximately 80 other oil-importing developing countries are hard hit each time there is an OPEC oil price increase. Unlike developed countries, Jamaica and such oil-dependent developing countries are impacted two ways. They must not only pay higher prices for imported oil but they must also pay higher prices for goods, services and technologies imported.

Among developing countries, Jamaica is one of the highest in per capita energy consumption. As a consequence, in an environment of rapidly escalating oil prices, Jamaica's total economic situation is increasingly desperate. Directly due to the oil crisis and the deteriorating economic situation, Jamaica faced an exchange rate devaluation which led to the following situation in 1978:

- Average real wage had declined by 30 percent by the end of the year;
- Real per capita personal consumption was 13 percent below the previous year;
- Real GDP continued to decline at 1.7 percent;
- Rate of unemployment climbed steeply from 23 to 26 percent between April and October;
- There was a widening trade gap and the balance of payment deficit grew because the Jamaican economy

became burdened with foreign exchange costs for imported energy;
- The average level of consumer prices increased steeply and was approximately 35 percent higher than the previous year; and
- The average price of electricity per kilowatt hour increased by 33 percent across the board to U.S. 11.61 cents. The residential users bore the brunt of this because of the regressive electric utility rate structure of the public utility.

The Government of Jamaica (GOJ), in response to the deteriorating economic situation, declared a state of economic emergency in January 1977. A Five Year Development Plan (1978-1983) as prepared, adopted and implemented for all sectors of the economy in an attempt to control and reverse the economic downturn. A separate Energy Sector Plan[2], a by-product of the energy crisis, formed the basis for the government's strategy to solve the energy problem. Needless to say, continued imported oil price increases since 1973 have made Jamaica's economic recovery and growth objectives exceedingly difficult to achieve.

Despite the difficulties encountered, Jamaica has an energy plan that is being implemented on a country-wide basis. Although in a difficult situation when compared to many of the other oil-importing developing countries, Jamaica appears to be ahead of many such countries in the energy planning phase.

Various developed countries, international assistance agencies, and international financial institutions are in the process of assisting Jamaica in various ways to achieve some energy independence. To be effective, such assistance, must be clearly focused, properly directed and well integrated. The U.S. Agency for International Development (USAID) energy assessment of Jamaica is one step towards such an integrated approach.

The U.S. Agency for International Development, in conjunction with the Government of Jamaica, sponsored this particular study for the following reasons:

-- A national energy sector plan must be further developed in order for Jamaica to survive and prosper;
-- There is a sense of urgency requiring innovative ways to help shorten the gap between the study phase and the implementation phase for viable energy projects; and

-- USAID is conducting its first overseas energy assessment and Jamaica represents a potential study model for future replication in other developing countries needing U.S. assistance.

Based on the above considerations, USAID, in conjunction with the various energy-related agencies of the Government of Jamaica, identified a number of energy areas for technical assessment and potential development. Recognizing that the energy assessments could not cover all possible energy areas due to urgent schedules and budgetary constraints, the assessment was referred to as the "Preliminary Energy Sector Assessments of Jamaica" and included the following eight tasks:

1) Study Integration and Project Management
2) Economic Assessment
3) Solar Energy: Commercial and Industrial
4) Solar Energy: Agricultural
5) Biogas Applications
6) Energy Conversion from Waste
7) Coal Prefeasibility Study
8) Electric Utility Rate Analysis

1.1.1 Study Tasks Description

A brief description of each of the eight study tasks is included below.

1.1.1.1 Study Integration and Project Management

The project management team was responsible for the overall management of the study. The management team developed a Project Management and Detailed Study Plan that coordinated and guided individual study development and provided for periodic study reviews. Study integration and preparation of the final reports were also the responsibility of the project management team.

1.1.1.2 Economic Assessment

The objectives of this study were to integrate the specialized study results into a combined energy program. The economic study was designed to prioritize energy implementation programs so that the greatest gains could be realized in the shortest time frame. All recommended programs would be reflected in Jamaica's "Five Year Development Plan" and "Energy Sector Plan".

1.1.1.3 Solar Energy - Commercial and Industrial

The objectives of this study were to provide a technical and economic assessment of the feasibility of near-term applications of solar water heating in the commercial and industrial sectors. Various specific feasibility studies of commercial solar air conditioning and solar hot water applications were requested by the Ministry of Mining and Natural Resources.

1.1.1.4 Solar Energy - Agricultural

The objectives of this study were to assess the potential of using solar energy in Jamaica for drying agricultural products, and to identify the technical and economic needs for making the application of solar energy a reality. The assessment for drying included the following products: corn, peas, beans, peanuts, onions, pepper, coffee, cocoa, tumeric, cassava, timber and fish.

1.1.1.5 Biogas Applications

The objectives of this study were to assess the feasibility of biogas generation in Jamaica and prepare recommendations for projects that might be undertaken. Included were energy and economic evaluations, as well as a review of low cost facility designs to determine which would be most suitable for the conditions which prevail in the country. The study also addressed the feasibility of generating biogas as an integral part of the sewage treatment facilities of the Mona Campus of the University of the West Indies (UWI) in Jamaica.

1.1.1.6 Energy Conversion from Waste

The objective of this study was to assess the feasibility of a prototype demonstration unit for energy recovery from the solid wastes generated on the Mona Campus of UWI.

1.1.1.7 Coal Prefeasibility Study

The objectives of this study were to determine if the use of steam coal for electric power and steam generation appears significantly attractive, both technically and economically, to justify a full-scale feasibility study. The study assessed the technical, economic and environmental feasibility of diversification from oil-fired units to coal. The possibility of retrofitting existing units to burn 3 percent sulfur coal or a coal-oil mixture was

also investigated. Since any benefits realized will accrue to both the alumina companies and the Jamaica Public Service Company, plant sites and harbors were considered during the analysis of coal transportation, coal handling and storage facilities, and the infrastructure required to support coal operations. Price projections for coal and the potential for obtaining long-term coal supply contracts were also addressed.

1.1.1.8 Electric Utility Rate Analysis

The objectives of this study were to conduct an examination of the Jamaica Public Service Company (JPS) electric utility rate structure with a view toward determining whether it: (a) promotes an economically efficient use of electricity in the society; (b) is consistent with basic principles of equity and fairness; and (c) provides the company (JPS) with sufficient resources to maintain an acceptable quality of service.

1.1.2 Areas Not Included in the Study

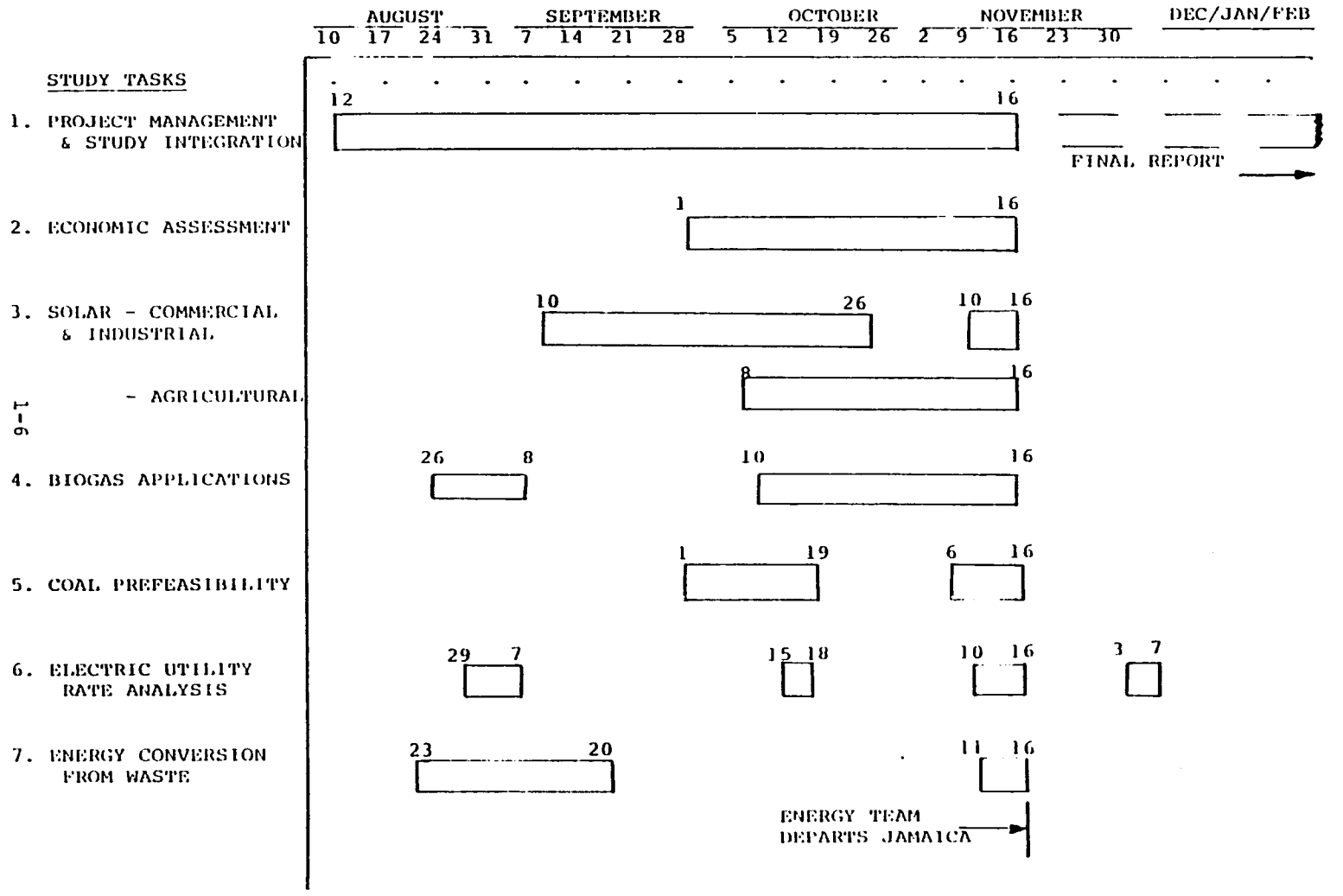
Some energy areas were not included in the study because they either were already being studied by other foreign entities or they were not prospective candidates for immediate study. The energy areas not included in the study are:

- Energy conservation
- Wind
- Hydropower
- Geothermal
- Photovoltaics
- Peat
- Ocean thermal
- Bagasse
- Charcoal
- Waste lube oil

1.1.3 Contract Award

Amworld Energy Systems International, Inc., t/a Energy Systems International (ESI) of McLean, Virginia was awarded the contract to conduct the "Preliminary Energy Sector Assessments of Jamaica". The contract duration was from August 10, 1979 to February 15, 1980 of which fifteen weeks were to be spent in Kingston, Jamaica by the energy team. An overall study schedule is shown in Figure 1-1.

FIGURE 1-1 U.S. Energy Team Schedule - Jamaica



1.2 TERMS OF REFERENCE -- (ADDITIONS AND ALTERATIONS)

The entire original study Terms of Reference are contained in Appendix A. These task elements established the basic study parameters from which an in-depth systems analysis and design could be developed. During the early stages of the study, the project management team and the energy team specialists defined, evaluated, and in many cases expanded the original Terms of Reference. This was done to emphasize and exploit those areas which might demonstrate the greatest potential for practical near-term projects. Specific additions and alterations to the original Terms of Reference included:

1.2.1 Solar Energy - Commercial and Industrial

Although residential solar water heating was not included in the original Terms of Reference, it was necessary to address all potential solar applications including residential to determine the overall technical and economic impact of implementing a nation-wide solar energy program. Additionally, the manufacturing specifications for Jamaican solar collectors were reviewed and modified to establish the necessary ground work for the JPS sponsored residential solar commercialization project.

1.2.2 Solar Energy - Agricultural

The drying and preservation of agricultural products and food was redefined to add tumeric and cassava because of the high energy requirements needed for drying these products. Conversely, pimento, hay, and bananas were given less consideration because little or no imported energy is required to dry them.

1.2.3 Energy Conversion From Waste

Rather than limiting the study to only the UWI Mona Campus project, a wider context of energy recovery alternatives and proposals for energy recovery from urban wastes in the Kingston urban area was evaluated.

1.2.4 Coal Prefeasibility Study

To provide a more detailed study of alternative methods of power generation in addition to coal, the following generation schemes were also analyzed: coal-oil mixture, combined cycle gas turbine, diesel, oil, and coal gasification.

1.2.5 Electric Utility Rate Analysis

A load forecasting study, involving the development of a computer-based model to study future generation requirements, was added to the Terms of Reference to provide JPS with the capability to update data for future tariff studies. JPS officials specifically requested that the study focus on findings and options so that JPS could examine these options and draw specific conclusions and recommendations themselves for presentation to the Ministry of Public Utilities.

1.3 BACKGROUND INFORMATION

Due to the urgency of the study to meet milestone objectives of the GOJ Five Year Energy Sector Plan, and also due to the fact that this particular study represented USAID's first overseas energy assessment of a developing country, USAID focused special attention on a novel proposed study approach. It became apparent that due to the diverse technological requirements and high degree of specialization required by each of the studies, the formulation of a United States Energy Team of experts would best meet the study's stringent demands. It was imperative that prospective team members have the proper balance of academic and "hands-on" project experience so that the studies would have near-term practical value. The following basic criteria were used to assemble the U.S. Energy Team:

- -- Recognized expert in the field of specialty
- -- Highly recommended by appropriate agencies
- -- Appropriate hardware experience
- -- Applicable international consulting experience
- -- Available for extended in-country assignment
- -- Strong team player
- -- Willingness to establish a close-working relationship with host country counterpart personnel
- -- Recognition of the importance of study integration

After extensive screening and interviewing of candidates, primary and back-up teams were formed. All team members fully understood that special emphasis was to be given to employing general systems engineering/technical direction techniques to mold a diverse group of technical experts into a cohesive project team able to work in close cooperation with all Jamaican counterparts.

The team members selected for the assessment are eminently qualified in their fields of specialty and came highly recommended from various government agencies or institutions. Each U.S. Energy Team member's profile is summarized in Appendix B.

1.4 STUDY METHOD

1.4.1 Project Management

To provide program coordination and direction, a Project Management and Detailed Study Plan was developed early in the study. The plan was prepared in three distinct parts:

(1) Project Management - specifies team responsibilities, working relationships;
(2) Team Organization - delineates technical requirements; and
(3) Detailed Study Plan - depicts study schedules, responsibilities, and task completion requirements.

Prior to the arrival of the individual U.S. Energy Team specialists, the project management staff conducted a series of interviews with key personnel and Jamaican team counterparts associated with each particular study. During the discussions the contract's original Terms of Reference were updated if required; current program activities were reviewed for continuity and applicability to each study task; interface organizations and contacts were identified; and key study issues and areas of concern were highlighted.

Throughout the study, the project management staff continued to develop the study plan and to involve the Jamaican counterparts in all scheduled events. A key event during each of the specialized studies was a training seminar given by each U.S. team member. In addition to technology transfer, the seminars provided the opportunity to stimulate Jamaican private sector/GOJ agency/U.S. Energy Team interface and interaction, as well as joint review of current Jamaican program plans and policies. Appendix C provides information on one of the seminars which is representative of the six seminars held.

In addition to the seminars, progress reviews were held for each specialized study. Each specialized study's scheduled assessment reviews -- preliminary, intermediate, and final -- were well attended by all Jamaican study participants and counterparts.

Prior to the energy team's departure from Jamaica, a Final Report Conference was held at the Jamaica Pegasus Hotel on November 13 and 14, 1979. The conference encouraged the participation of the Jamaican public and private sectors,

USAID and many international organizations. Its objective was to create an open forum for presentation of the initial results of the Jamaican Preliminary Energy Assessments and to accumulate additional inputs from the Jamaican public and private sectors, USAID and international organizations. The results of the seven specialized studies were presented by the U.S. Energy Team specialists and their Jamaican counterparts on the first day. The second day was reserved for splinter discussion groups in which the team members fielded questions from the conferees. The second day also included international cooperation discussions involving attendees from the World Bank, Inter-American Development Bank, Organization of American States, United Nations Development Program, Caribbean Development Bank and the U.S. Agency for International Development. A transcription of each of the study splinter group question and answer periods are contained in the appendices of the individual specialized study reports. An overview of the events of the Final Report Conference is contained in Appendix D.

1.4.2 Specialized Studies

Due to the diverse requirements associated with each of the specialized studies, a completely standard methodology or study approach was not possible. In each case, however, similar activities were undertaken during the various stages of the study. Each of the study reports details these activities, but in general the following areas were covered during study development:

(1) Personnel interviews - Key personnel from all sectors pertaining to the specific study were interviewed.
(2) Sites visited - Specific site visits were conducted, and others were added as required, to establish the data base.
(3) Surveys - Two studies, Solar Energy and Biogas, required the use of surveys to determine market potential.
(4) Pertinent Data - Pertinent data for team use was gathered from all participating government agencies and private organizations.
(5) Plans, Programs and Policies - All exisiting plans, programs, and established policies were reviewed for compatibility prior to the development of recommendations.

1.4.3 Functional Study Tasks

A description of the approach utilized throughout the study to plan, schedule, coordinate and manage all efforts is illustrated in Figure 1-2.

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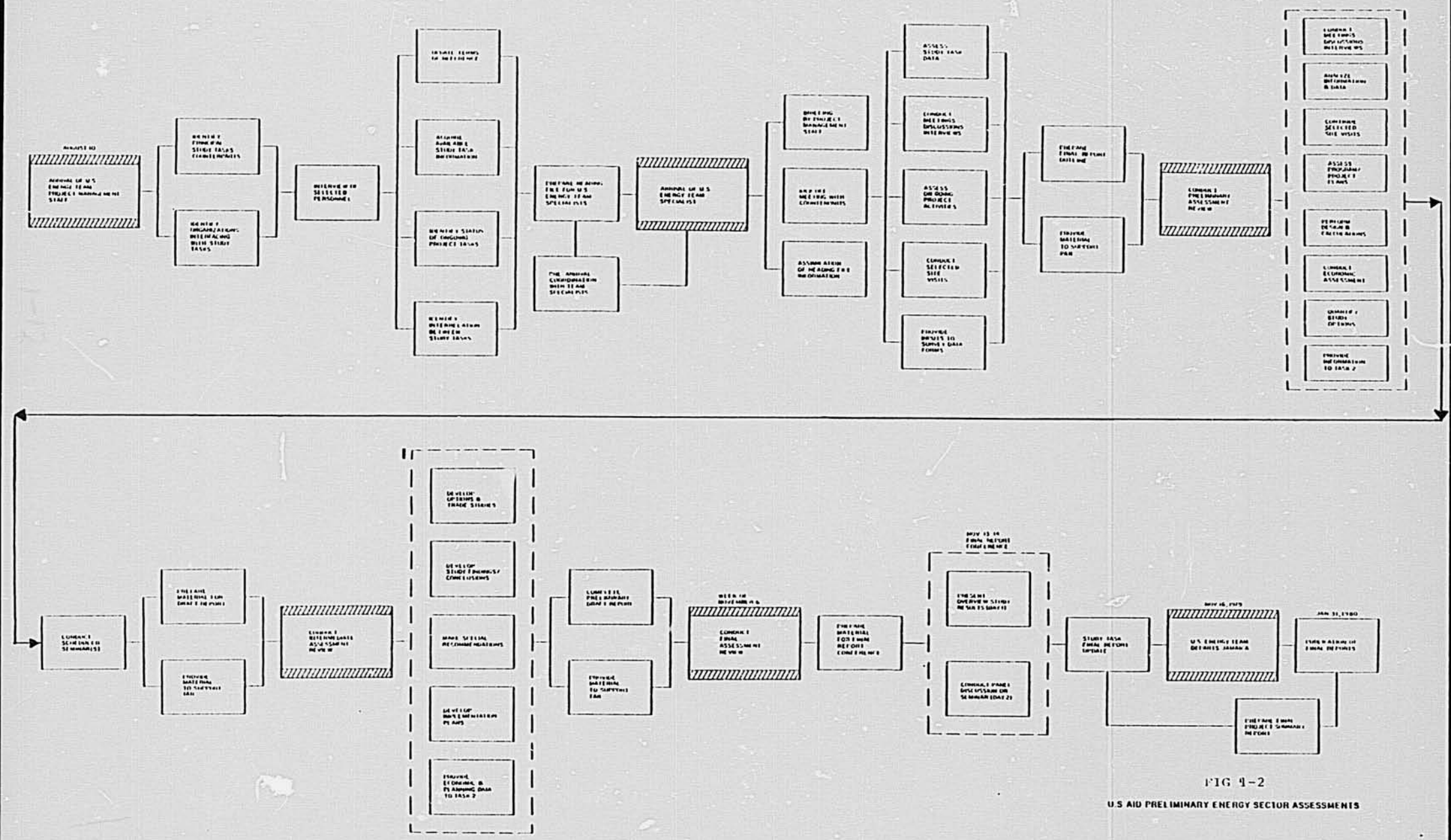


FIG 4-2

U.S AID PRELIMINARY ENERGY SECTOR ASSESSMENTS

1.5 SUMMARY OF MAJOR FINDINGS AND CONCLUSIONS

1.5.1 General

(1) The aggregate potential savings in oil imports from the selected energy areas studied in this energy assessment amounts to about 8.3%. This is exclusive of the potential contribution of other prospective energy areas such as those identified in paragraph 1.1.2. It is important that the Government of Jamaica continues to perform preliminary analysis and surveys to assess the potential of other promising energy technology options for the near, mid and long-term.

(2) In the immediate and near-term, energy conservation is a primary energy area in which Jamaica has a high priority need for technical assistance. The Government of Jamaica in cooperation with it's private sector needs to develop and implement comprehensive energy conservation program policies, strategies and plans that encompass all Jamaican energy end use sectors. Any technical assistance from the United Kingdom, Canada, the United States and other countries must be well coordinated, properly integrated and effectively managed in order to produce viable near-term results.

(3) The Energy Division of the MMNR was formed in August, 1979 and is still in it's infancy. Throughout the energy assessment period, the division was critically short of qualified technical staff. An extensive effort to build a long-term staff of qualified technical and managerial professionals, with the appropriate systems, projects and disciplinary experience mix, is necessary in order to effectively manage and implement the projects recommended by this energy assessment.

(4) An effective infrastructure must be developed among the various government ministries, laboratories, universities and other institutions who will be assigned the various responsibilities associated with the management and implementation of program elements for the various domestic energy research, development, demonstration and commercialization programs. Similar infrastructure building is necessary for those GOJ organizations involved with cooperative programs with developed and developing countries.

(5) A fairly extensive technical training and technical assistance program needs to be developed to ensure that Jamaican energy program personnel are properly trained in Jamaica and at technical training centers abroad. Short-term energy specialist from the U.S. and other countries should be seconded to the various Jamaican ministries and other organizations to provide appropriate technical assistance and assist in the training of Jamaican technical personnel.

1.5.2 Economic Assessment

Almost 4.2% of Jamaica's energy imports can be replaced by solar water heating systems (3.5%) and biogas systems (.7%) if exploited in accordance with the study recommendations. If the net fuel savings of a coal-fired electrical generating plant are included, the potential savings increase to 7.3% of energy imports. If the new electrical utility tariff structure that Jamaica Public Service Company adopts results in even a 1% savings in fuel, the potential savings of the program amount to 8.3%. Using the 1978 figure of 8,887,200 barrels (net) f.o.e. (non-bauxite energy consumption) for Jamaica's consumption of imported fuel, 737,637 barrels f.o.e. could be saved annually.

A total economic assessment of each of the specialized studies was conducted. The implementation costs were estimated and the effects of the recommended actions on Jamaica's economy measured. Finally, a cost/benefit analysis was completed to test program potential and feasibility.

A final, comprehensive set of integrated recommendations was then chosen for inclusion in a Combined Energy Program. Groups of highest priority, higher priority and high priority recommendations were identified.

Perhaps the most surprising aspect of the Combined Energy Program is the modest cost for all these improvements in Jamaica's energy situation. The initial costs (capital costs plus operating costs) of the entire program are only $6,228,828 (U.S. $ 1979). Specific findings and conclusions are discussed in Section 2.0.

1.5.3 Solar Energy - Commercial and Industrial

(1) 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.

(2) Study results show that the immediate potential 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

(3) 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 are J. $0.17 per kWh (U.S. $0.10), solar water heaters are economically justifiable.

(4) On the other hand, solar cooling based on commercially available hardware, even with high performance collectors and systems, is not yet economically justifiable for commercial development in Jamaica.

(5) Specific findings and conclusions are discussed in Section 3.0.

1.5.4 Solar Energy Agricultural

(1) Jamaica's climate and average solar radiation figures make the collection of heat from solar energy attractive because solar collectors operate at higher efficiencies. Therefore, Jamaica offers ideal conditions for the use of practical, proven, low cost solar systems for drying agricultural products.

(2) In Jamaica, the agricultural sector plays a major role in the country's economy. Crop drying by solar technologies can help to: minimize food spoilage in most environments; preserve agricultural products for non-harvest seasons; and reduce consumption of fossil fuels.

(3) Important areas in which programs can be immediately implemented include:

1. Establishment of climatic stations;
2. Development of air-type solar collectors;
3. Research and development on drying of agricultural products;
4. Sun drying of agricultural products, and research and development on cost effective drying methods.

(4) Specific findings and conclusions are discussed in Section 4.0.

1.5.5 Biogas Applications

(1) Jamaica has many conditions which could lead to successful application of biogas as an alternate energy source. Much of the economy is agricultural in nature, and ambient temperatures are high enough throughout the year so that auxiliary heating of biogas digesters is not necessary. This obviates the need for costly equipment which is required in colder climates.

(2) It is significant that biogas energy can be provided directly to the rural areas of Jamaica, where butane and kerosene are becoming increasingly unavailable and require a substantial portion of the family's budget. A biogas energy program can play a significant role in contributing to Jamaica's effort to achieve greater energy independence because of the above mentioned conditions in rual areas.

(3) Jamaica is behind Asian countries which are developing this alternate energy source, in spite of studies of biogas by The Scientific Research Council (SRC) over the past several years. Designs which have been slow in developing have finally emerged to the point where at least one such design has been field tested and found to be satisfactory. There is sufficient design development now to proceed with at least an initially modest biogas program. Design will be the key to the degree of ultimate success of the program. Design development should, therefore, be accelerated with SRC in a major role and as much support as is required should be provided so that this responsibility can be accomplished in a timely manner. Jamaica can take advantage of the experience in low cost design of biogas plants in other countries. One of the major costs is for steel reinforcing bars and gasholders. Some designs, however, sucn as those used in China, require only local construction materials and little, if any, steel. Use of such a design can result in a family size unit costing even less than the steel gasholder designs which have been used successfully in large-scale biogas programs in other countries.

(4) Many institutions in Jamaica, such as schools and centers for the handicapped, are associated with medium to large size farms, which could provide biogas for cooking. This biogas could substitute for fuel costing several hundred dollars per month per institution.

(5) On the basis of field surveys, data analysis, and meetings with the Biogas Working Group and other associated personnel, it is concluded that a national biogas program would be successful in Jamaica. Indicators used in arriving at this conclusion were climate, percentage of the population living in rural agricultural areas, animal numbers, and Jamaica's dependence on imported oil and gas. Three options to a National Biogas Program are addressed in Section 5.0.

(6) Specific findings and conclusions are discussed in Section 5.0.

1.5.6 Energy Conversion from Waste

Urban Solid Wastes - Kingston

(1) It is concluded that the only alternative worthy of consideration for energy recovery from urban solid wastes in Kingston is waterwall incineration with steam generation. This application appears to be cost effective. The major problem is inefficient and unreliable refuse collection, making it impossible to recover energy from the wastes.

(2) It may prove cost effective to apply the biogas approach in small cities where incineration or Refuse Derived Fuels (RDF) are not feasible. This would be especially true in small communities that are constructing a new waste-water treatment plant. In such cases, the sludges from the waste-water and the organic solid wastes could be treated in a common digestion system, especially designed to handle the refuse and sludges.

(3) For health, environmental, and energy reasons, a careful study of urban refuse collection in Kingston should be conducted.

(4) The proposed field-scale biogas demonstration at the University of the West Indies - Mona Campus would not be a very meaningful or helpful exercise in terms of proving a technology for wider use in Jamaica.

(5) The results of this study lead to the conclusion that the UWI-Mona Campus should not get involved in a field-scale demonstration of the anaerobic digestion of campus refuse for methane generation.

(6) A viable alternative is that the UWI-Mona Campus develop an "Alternative Energies Laboratory" and that the University be assisted financially in the amount of U.S. $182,500 over the next three years.

(7) Specific findings and conclusions are discussed in Section 6.0.

1.5.7 Coal Prefeasibility Study

(1) The installed system capacity of the existing JPS oil-fired electric power plant is approximately 455 MW which is greatly in excess of the present 210 MW peak demand. Thus, a new power plant unit should not be needed to meet the expected system load at the present time. However, unit

outages cause frequent rolling blackouts. A major program is needed to improve unit availability, particularly of the newer, more efficient units. If the four newest units, having a total capacity of 250 MW, could be upgraded to have improved availability and operate at a high capacity factor, there would be a large dual savings without any capital expenditure for a new unit.

(2) Existing oil-fired boilers for JPS or the alumina companies cannot be retrofitted to burn coal directly.

(3) The installation of a coal-fired unit may seem attractive if a conservative differential oil-coal price escalation rate of only 1 percent exists, and if joint use of harbor facilities and sites can be achieved at Port Esquivel, or at the new proposed JBM South Manchester site at Cuckold Point.

(4) The possibility of obtaining a favorable long-term coal contract is very good at the present time.

(5) The schedules of the bauxite and alumina ships are tight but the transportation of coal from the U.S. Gulf Coast on the backhaul is feasible.

(6) Coal can also be transported by non-U.S. ships at a cost approximating that of the bauxite ships.

(7) Specific findings and conclusions are discussed in Section 7.0.

1.5.8 Electric Utility Rate Analysis

(1) The pricing of electricity should always be given considerable attention no matter what type of generating fuel is used, regardless of the utility firm's operating environment. The situation confronting JPS dictates that an even greater than normal attention be given to the pricing structure of electricity. The size of JPS oil expenditures alone, if viewed considering the constant OPEC pressure for price increases, would focus attention on pricing structures which are more closely related to marginal costs than the current pricing structure.

(2) Various tariff options, based on marginal cost pricing principles, have been presented for each rate category in the JPS system. These options demonstrate immediate or interim steps that can be taken to gradually approach marginal cost pricing so that the implementation rate of tariff

changes can be completely controlled. The effects of each step in tariff development, and the associated customer bill impacts are indicated.

(3) The marginal cost pricing principles shown below were used to develop the tariffs for each customer category:

1. Total revenue requirements will not be changed.
2. Total revenue allocations between customer categories will not be altered.
3. Declining block pricing will be eliminated.
4. Ratchet provisions will be eliminated.
5. Expander tariffs will be eliminated.
6. Flat (both all-energy and two-part) demand and energy tariffs will be considered.
7. When metering and customer acceptance seems reasonable, time of use pricing will be considered.
8. The very progressive (from an efficiency stand point) fuel adjustment clause will be continued.
9. The innovative Cost of Service adjustment will be retained.
10. Continuing the residential customer flat rate with the first 10 kWh included free will be presented.

(4) The overall conclusion is that JPS and public officials should review these options and develop strategy compatible with economic goals and plans, social considerations and other factors. From this an implementation plan should be established to sequence rate tariff changes consistent with Jamaican needs and plans.

1.6 SUMMARY OF MAJOR RECOMMENDATIONS

1.6.1 General

It is recommended that the Government of Jamaica take immediate action to accomplish the following:

(1) Continue to utilize the approach of this energy assessment and to assess the potential of other promising energy areas that are not presently being considered (see energy areas referenced in Para. 1.1.2).

(2) Establish an Energy Conservation Project Office with the responsibility for developing an overall energy conservation program strategy and plan. Utilize seconded personnel to provide technical assistance as necessary.

(3) Identify the specialized personnel resource requirements of the MMNR Energy Division to implement the projects that are approved by the GOJ.

(4) Prepare an Infrastructure Plan and necessary implementing Agreements to initiate required actions.

(5) Develop and Implement a Training Program and Training Assistance Plan for all approved projects.

1.6.2 Economic Assessment

The main recommendation of the Economic Assessment is that the Combined Energy Program is a sensible way for Jamaica to direct its efforts in the energy sector over the next five years and that it should be accepted (See Table 2-1, Section 2.0). The recommendations of the special studies that have been incorporated into this program have been shown to produce benefits well in excess of their costs. The costs themselves have been found to be modest; and the government should be able to find the necessary funding.

It is recommended that immediate action be emphasized to implement the Combined Energy Program. The Government of Jamaica should consider the program without delay and move quickly on the recommendations it accepts. Financing should be sought as soon as possible.

The full results of the Economic Assessment are contained in Volume II, Chapter 2.

1.6.3 Solar Energy - Commercial and Industrial

It is recommended that a solar water heating program be developed that will be implemented over a three year period. The elements of the program include:

(1) Establish 10 solar radiation stations

(2) Establish a solar collector certification program;

(3) Eliminate the 37.5% water tank tax

(4) Establish consumer information office;

(5) Establish training programs for engineers and installers;

(6) Initiate solar hot water feasibility studies in selected building sectors;

(7) Investigate export potential of solar hardware;

(8) Support JPS residential solar demonstration program;

(9) Establish solar tax incentives; and

(10) Initiate solar hot water demonstration projects at hospitals.

Specific recommendations for the three year program are further addressed in Section 3.0. The full results of this study are contained in Volume III, Chapter 3.

1.6.4 Solar Energy - Agricultural

It is recommended that a solar agricultural drying program begin immediately and be implemented over a five year period. The main elements of the program include:

(1) Develop solar-heated air collectors;
(2) Establish R&D programs for drying agricultural products;
(3) Design and construct solar collector systems;
(4) Provide comprehensive training for the recommended solar agricultural program; and
(5) Develop community drying systems.

Specific recommendations for the five year program are further addressed in Section 4.0. The full results of this study are contained in Volume III, Chapter 4.

1.6.5 Biogas Applications

It is recommended that a biogas applications program be implemented over a five year period. Major elements of the program include:

(1) Implement the Option A program which consists of 2700 family size units and 41 medium size units immediately;
(2) Begin a detailed marketing study to assess commercialization potential;
(3) Examine feasibility of large scale demonstration unit for electric generation;
(4) Explore international funding options for an expanded program; and
(5) Begin a comprehensive training and public awareness program.

Specific recommendations for the five year program are further discussed in Section 5.0. The full results of this study are contained in Volume III, Chapter 5.

1.6.6 Energy Conversion from Waste

It is recommended that the following programs be pursued:

(1) Conduct a detailed study on waste collection problems in Kingston. Evaluate other alternatives for energy recovery; and

(2) Establish an Alternative Energies Laboratory at the University of the West Indies - Mona Campus.

The above recommendations are further discussed in Section 6.0. The full results of this study are contained in Volume III, Chapter 6.

1.6.7 Coal Prefeasibility Study

It is recommended that the following actions be taken:

(1) Government of Jamaica and Jamaica Public Service Company obtain funds to upgrade existing oil-fired electric power plant units;
(2) Conduct exploratory negotiations on the use of a joint port facility for a coal-fired power plant at Port Esquivel or Cuckold Point respectively;

(3) Authorize a coal supply and shipping study if adequate cost benefits are realized from recommendation #2
(4) Monitor coal-oil mixture development progress; and
(5) Monitor coal gasification technology progress.

Specific recommendations are further discussed in Section 7.0. The full results of this study are contained in Volume IV, Chapter 7.

1.6.8 Electric Utility Rate Analysis

As requested by JPS, specific recommendations as to which type of tariff should be adopted are not presented in this report. JPS shall review and analyze the various options and make their own recommendations to the Ministry of Public Utilities.

All findings of this study are presented in Section 8.0. The full results are contained in Volume V, Chapter 8.

EXECUTIVE SUMMARY OF SPECIALIZED STUDIES

2.0 ECONOMIC ASSESSMENT

3.0 SOLAR ENERGY - COMMERCIAL AND INDUSTRIAL

4.0 SOLAR ENERGY - AGRICULTURAL

5.0 BIOGAS APPLICATIONS

6.0 ENERGY CONVERSION FROM WASTE

7.0 COAL PREFEASIBILITY STUDY

8.0 ELECTRIC UTILITY RATE ANALYSIS

2.0 ECONOMIC ASSESSMENT

2.1 EXECUTIVE SUMMARY

2.1.1 Introduction

The purpose of the Preliminary Energy Sector Assessments of Jamaica was to assist the Government of Jamaica (GOJ) in identifying and developing viable alternative energy options for implementation. Any recommended options are to complement the goals of the Five Year Development Plan (1978-1983). A U.S. Energy Team, sponsored by the United States Agency for International Development (USAID) was engaged to support the GOJ, Ministry of Mining and Natural Resources (MMNR) Energy Division by conducting specialized studies in the following areas:

Solar Energy - Commercial and Industrial
Solar Energy - Agricultural
Biogas Applications
Energy Conversion from Waste
Coal Prefeasibility Study
Electric Utility Rate Analysis

All of these studies have been completed and each offers specific recommendations for integration into a "Combined Energy Program". Before action can be taken, however, the MMNR must determine which of these recommendations are compatible with the Five Year Development Plan and its Energy Sector Plan. Additionally, an examination must be made of their relative priorities for future implementation, and if adopted, their effect on the national economy. This chapter, Economic Assessment, serves to address these matters.

2.1.2 Terms of Reference

The purpose of the assessment was to review the specialized studies that have been completed as part of the Preliminary Energy Assessments of Jamaica, and to integrate them into a Combined Energy Program. The intention of this combined program is to further the objectives of the Five Year Development Plan (1978-1983) and its Energy Sector Plan, and to supplement other existing and planned energy efforts in the country.

2.1.3 Background Information

There have been several limitations on this study. First, the time allocated to this task has been sufficient to carry out only a rather basic analysis. A complete, quantitative economic assessment requires the type

of detailed data that were in the process of being assembled by the MMNR during the period of this study. A knowledge of the complete structure of energy use and of the intersectorial energy flows in the economy, as well as an easy-to-use computer program to analyze recommended policy measures are definitely needed. It will take at least a year to complete them. Finally, the specialized studies discussed below are only preliminary assessments. Consequently, the economic inputs they have provided to this report are tentative.

2.1.4 Study Method

The analytical approach taken in this Economic Assessment was to independently review each specialized study. The recommendations of each were then considered relative to the Five Year Development Plan (1978-1983), and its Energy Sector Plan. Next, the effects of these recommendations on Jamaica's energy situation and economy were analyzed.

Once all six sets of recommendations were treated in this fashion, they were reviewed for their compatibility with each other. Where conflicts occurred, they were either modified, or one recommendation was eliminated. In all cases, the changes made were approved by the energy team members who prepared the original recommendations.

A final, comprehensive set of integrated recommendations was chosen for inclusion in the Combined Energy Program. The effects of the entire package on Jamaica's energy situation and on its economy were reviewed. The modifications of the Energy Sector Plan required to accommodate these recommendations were considered, and conclusions were drawn.

2.1.5 Findings

2.1.5.1 The Combined Energy Program

The findings were tabulated as the Combined Energy Program Summary (Table 2-1). Recommendations were grouped into highest, higher, and high priority categories. The program's initial and operating costs were calculated. It should be noted that the program is conceived as an initial effort that will encourage larger, more comprehensive efforts in the future. This program includes only the specialized studies mentioned above and does not consider other key studies such as wind, mini-hydro, and energy conservation which are being conducted by other agencies for the Government of Jamaica.

TABLE 2-1 (Page 1 of 4)

COMBINED FIVE YEAR ENERGY PROGRAM SUMMARY

Priority	Recommendation	Initial Cost	Operating Cost *	Total Cost
HIGHEST				
		(1979 US$)		
o Solar				
Industrial				
-	Climatic Stations (5)	75,000	50,000	
-	Solar Collector testing program	50,000	20,000	
-	Eliminate solar water heater tax	-	-	
-	Training course for Installers	75,000	-	
-	Industrial and commercial feasibility studies	150,000	-	
-	Hospital feasibility studies	50,000	-	
-	Hospital demonstration project (costs included in total hospital program)	-	-	
-	Technical support to J.P.S. solar demonstration (residential)	25,000	100,000	
Agricultural				
-	Air-type solar collector development	440,000	-	
-	Sun drying extension program	12,000	48,000	
-	Product drying R&D	395,000	-	
o Biogas				
-	Five year demonstration and commercialization program	1,457,143	98,285	
o Coal				
-	Negotiations with aluminum companies	-	-	
o Electric Utility				
-	None	-	-	
o Energy Conversion from Waste				
-	None	-	-	
SUBTOTAL		2,729,143	316,285	3,045,428

* For detailed breakdown of proposed program costs by technology, time schedule and origin or currency see Table 2-17 Chapter 2

TABLE 2-1
(continued)
COMBINED FIVE YEAR ENERGY PROGRAM SUMMARY

Priority	Recommendation	Initial Cost	Operating Cost	Total Cost
HIGHER		(1979 US$)		
o Solar				
Industrial				
-	Climatic stations (2)	30,000	20,000	
-	Investigate solar exports	10,000	-	
-	Tax incentives for commerce and industry	5,000	-	
-	Tax incentives for new housing	5,000	-	
-	Consumer energy office	25,000	80,000	
-	Total hospital program design	74,000	-	
Agricultural				
-	Grain dryers	120,542	2,358	
-	Cassava, Brewer's grain and tumeric dryers	400,280	7,720	
o Biogas				
-	None	-	-	
o Coal				
-	Coal plant feasibility estimate and coal contract study	200,000	-	
-	Monitor COM study	(2,000)*		
o Electric Utility				
-	None		-	
o Energy Conversion from Waste				
-	Alternative Energies Laboratory	80,000	102,500**	
SUBTOTAL		949,822	212,578	1,162,400

*Amounts in parenthesis are not included in sub-totals, nor totals

TABLE 2-1
(continued)
COMBINED FIVE YEAR ENERGY PROGRAM SUMMARY

Priority	Recommendation	Initial Cost	Operating Cost	Total Cost
HIGH		(1979 US$)		
o Solar				
Industrial				
-	Climatic Stations (3)	45,000	30,000	
-	Course for architects and engineers	37,000	-	
-	Installation of solar hot water systems for Jamaica's hospitals	1,500,000	-	
Agricultural				
-	Coffee dryers	236,705	4,295	
-	Cocoa dryers	165,050	2,950	
o Biogas				
-	None	-	-	
o Coal				
-	None	-	-	
o Electric Utility				
-	None	-	-	
o Energy Conversion from waste				
-	None	-	-	
SUBTOTAL		1,983,755	37,245	2,021,000

TABLE 2-1
(continued)

Priority	Total Cost*
Highest	$ 3,045,428
Higher	1,162,400
High	2,021,000
GRAND TOTAL OF PROGRAM	$ 6,228,828

*Excluding figures in parenthesis presented in previous pages of this table.

2.1.5.2 Effects of the Combined Energy Program On Jamaica's Energy Situation

A number of the recommendations of the Combined Energy Program will appear to have very little direct, immediate effect on Jamaica's energy situation. Nevertheless, they will create a sound base for the steady diversification of the nation's energy sources in the coming decade. In order for Jamaica's large potential resources of solar energy and biogas to be developed, and more effective use of coal to be realized, these first steps must be taken.

Almost 4.2% of Jamaica's energy imports can be replaced by solar water heating systems (3.5%) and biogas systems (0.7%) if exploited in accordance with the study recommendations. If the net fuel savings of a coal-fired electrical generating plant are included, the potential savings increase to 7.3% of energy imports. If the new electrical utility tariff structure that Jamaica Public Service Company adopts results in even a 1% savings in fuel, the potential savings of the Combined Energy Program amount to 8.3%. Using the 1978 figure of 8,887,200 barrels (net) f.o.e. (non-bauxite energy consumption) for Jamaica's consumption of imported fuel, 737,637 barrels f.o.e. could be saved annually.

Immediate effects will, of course, be much lower. None of the specialists on the U.S. Energy Team feels all of this potential will be captured within the next few years. Nonetheless, if by 1985 thirty percent of hotels (3155 barrels f.o.e.), all hospitals (13,700 barrels), and 4000 additional residences (21,200 barrels) use solar hot water; if enough commercial and industrial systems use solar hot water to save 15% of fuel imports; if 2,741 biogas plants are built (10,702 barrels); if 40 solar air-type dryers are built (130,704 gallons of #2 diesel); if a 65 MW coal-fired electrical generation plant is in operation (3.1% savings in fuel imports); and if the JPS tariff structure allows for a fuel savings of 0.2% of energy imports, the net import bill for energy will be reduced 4.4% annually, or by 389,582 barrels f.o.e.

Of course, this figure merely represents a beginning; it reflects only specific specialized study recommendations in selected energy sectors. It also assumes no technological change. For instance, by 1985 other forms of solar energy besides solar water heating systems and crop dryers may be feasible. Also, other non-energy developments might make additional projects possible. For example, if an efficient waste collection program were undertaken in Kingston, it is believed that a project to convert this waste to energy would become both technically and economically feasible.

In any case, an enormous amount of experience will have been gained by the Jamaican people in implementing alternative energy technology programs. With completed programs, finished studies, and an established technical capability, Jamaica will be in a position to obtain far greater gains over the following five years.

If the Combined Energy Program outlined here is adopted, by 1985 Jamaica quite possibly could have a well-functioning and professionally operated solar collector testing and certification service. Many plumbers could be trained to install solar water heating systems, and all its hospitals and government-owned (as well as numerous privately-owned) hotels converted to solar hot water. A reasonable number of new and old residences could be installing solar water heaters each year. Further, there should be a growing and increasingly export-oriented solar collector manufacturing industry; an increasing use of solar hot water in commerce and industry; an energy-informed public; an excellent meteorological data base; and energy-sensitive architects and engineers. Twenty-seven hundred household-size and 41 institutional-size biogas plants should also be in place and the country will have the capacity to install many thousands more. There could be an efficient and modern coal-fired electrical generating plant; a sensible electrical tariff structure that helps conserve energy; 40 solar air-type agricultural dryers in place; plus well-functioning R&D programs in air-type solar collector technology, agricultural product drying and other alternative energy technologies.

These are preliminary but important gains that would provide a foundation for Jamaica's energy development. In the absence of this or a similar energy program, few advances could be made.

2.1.5.3 Effects of the Combined Energy Program on Jamaica's Economy

Perhaps the most surprising aspect of the Combined Energy Program is the modest cost for all these improvements in Jamaica's energy situation. The total costs (capital costs plus initial operating costs) of the entire program (Table 2-1) are only U.S. $6,228,828. If only the Bustamante Hospital, rather than all hospitals in the country, were converted to solar water heating during the program, total costs would be reduced to U.S. $4,644,828. Even if the price of oil rises at 8% per year, in 1985 the estimated 4.4% savings in energy imports would be U.S. $4,644,828. (discounted) annually.

2.1.6 Conclusions and Recommendations

The main conclusion of the Economic Assessment is that the Combined Energy Program is a sensible way for Jamaica to direct its efforts in the energy sector over the next five years, and it should be accepted. The recommendations of the specialized studies that have been incorporated into this program have been shown to produce real benefits. The costs themselves have been found to be modest and the government should be able to find the necessary funding.

The need for immediate action should be emphasized. The GOJ should consider this program without delay and begin implementing the recommendations it accepts. Financing should be sought as soon as possible. With so many recommendations for so many agencies, there may be a problem coordinating the Combined Energy Program, and coordinating this program with other ongoing and planned programs under the Energy Sector Plan. Consequently, to ensure that Jamaica's efforts in the energy sector progress as smoothly as possible, it would be useful to form an Interagency Energy Coordinating Committee. Meeting perhaps monthly, with the nation's Energy Director as Chairman, this group could help resolve any conflicts among participating agencies in the energy effort and provide a forum for the interchange of useful information.

Finally, it is recommended that the Energy Sector Plan be modified, based on consideration of the Economic Assessment Final Report when the government reaches its decision regarding the Combined Energy Program.

2.1.7 Complete Study Report

The Economic Assessment section of the study report is separately contained in Volume II, Chapter 2 - ESI Report No. EA 80-0101-2.

3.0 SOLAR ENERGY - COMMERCIAL AND INDUSTRIAL

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 provide 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 liquefied 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 widespread 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 Chapter 3, approximately 189,842 barrels of fuel oil equivalency (f.o.e.) per year could be replaced through solar water installations.

3.1.6 Conclusions and Recommendations

Based on the extensive solar heating feasibility studies (Section 3.1.8.3) and total energy sector analysis (Section 3.1.8.5), 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, effective solar cooling requires higher performance collectors which are not manufactured at this time in Jamaica. Further, solar cooling during the near-term is not economically justifiable based on the solar cooling feasibility studies conducted (Section 3.1.8.4).

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 ongoing 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, scientific and demonstration 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; and

(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 3-1).

TABLE 3-1

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	37,000	37,000	-	-	-	-	-
- 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	$787,000	$750,000	$72,000	-	-	$75,000

3.1.7 Complete Study Report

The Solar Energy - Commercial and Industrial section of the final report is separately contained in Volume III, Chapter 3 - ESI Report No. EA 80-0101-3a.

To assist those readers of this Executive Summary who may desire additional information, selected data have been extracted from the main report and are included in Section 3.1.8 as supplementary information.

3.1.8 Supplementary Information

3.1.8.1 Potential Solar Water Heating Sites

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

(2) Institutional Applications

- Bustamante Hospital for Children
- Cornwall Regional Hospital

(3) Industrial Applications

- Desnoes and Geddes Bottling Company

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

3.1.8.2 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:

* One U.S. dollar is equivalent to $1.75 Jamaican dollars

(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.

3.1.8.3 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. Summary of the feasibility study results is shown in Table 3-2. 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, of Chapter 3.

3.1.8.4 Solar Cooling Feasibility Studies

The following three solar cooling feasibility studies were completed using the criteria established in Section 3.7.8.1 of Chapter 3:

FIGURE 3-1

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

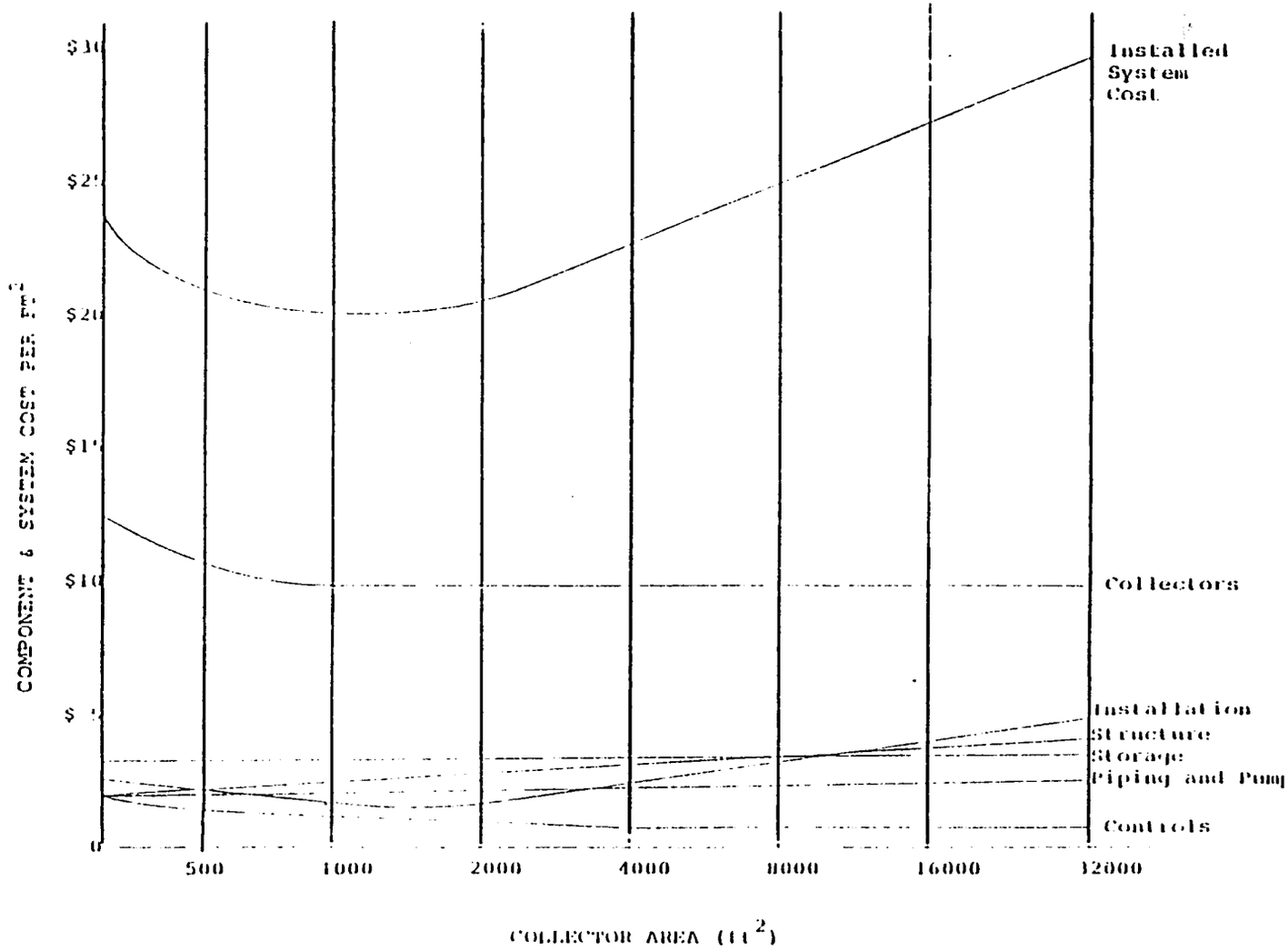
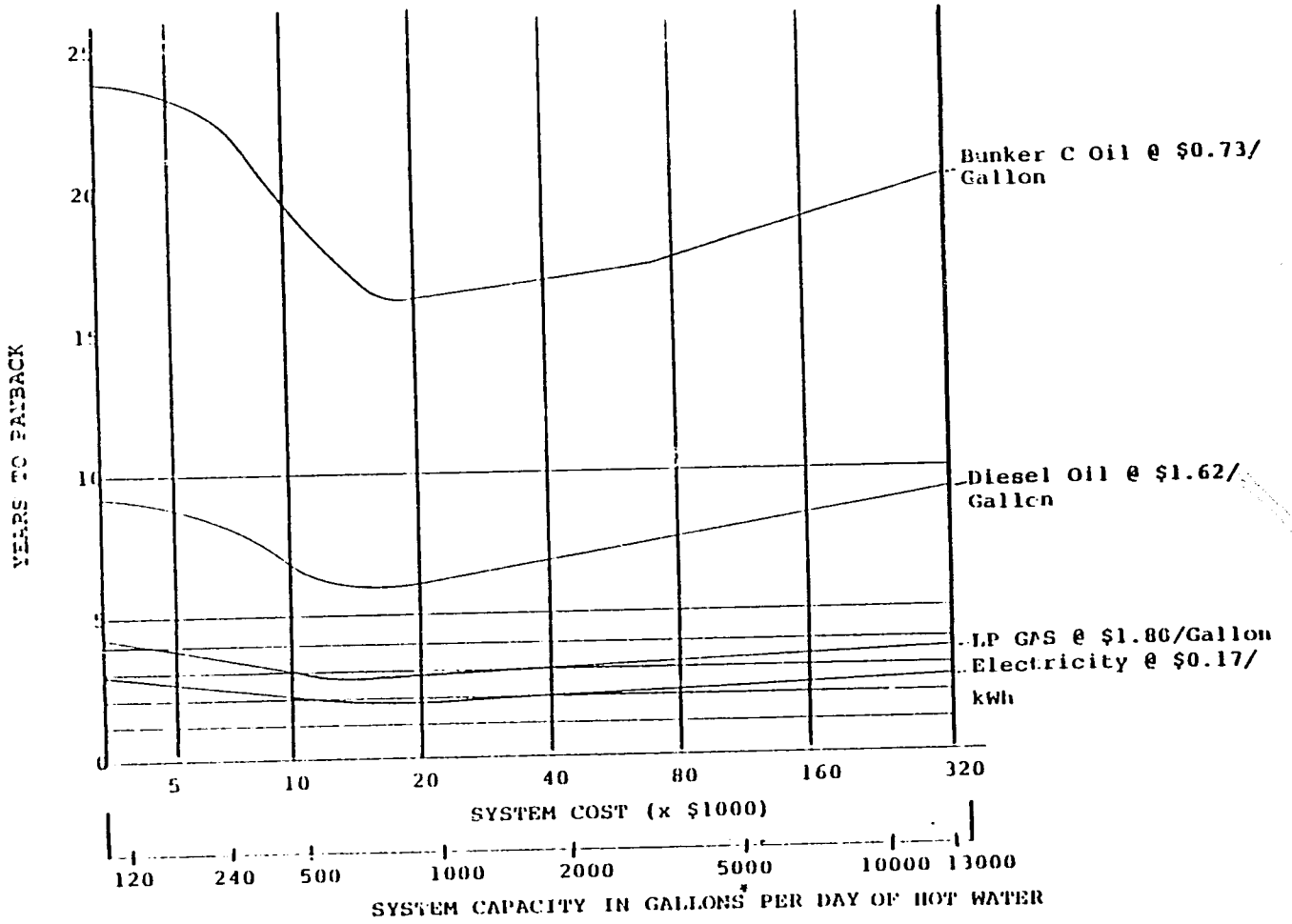


FIGURE 3-2

SOLAR WATER HEATING SYSTEM PAYBACK SYSTEM (J. $)



* Imperial Gallons

TABLE 3-2

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

(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 3-3. 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, of Chapter 3.

3.1.8.5 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:

(1) Residential
(2) Institutional (hospital)
(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 3-4.

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, of Chapter 3.

TABLE 3-3

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

TABLE 3-4

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

4.0 SOLAR ENERGY - AGRICULTURAL

4.1 EXECUTIVE SUMMARY

4.1.1 Introduction

As the world supply of fossil fuel decreases, most countries are in the process of re-evaluating their energy use patterns and developing various conservation techniques. Additionally, many of the developing nations are exploring renewable energy sources in an attempt to reduce the costs and requirements for imported petroleum. In Jamaica, where average daily solar radiation is very favorable, the collection of heat with flat plate collectors offers great potential for the drying of agricultural products.

The need for drying agricultural products exists on large and small farms and in commercial-sized operations. Agricultural produce drying provides quality export products, and is beneficial for preserving food for use between harvests. Sun drying is effective in small batches and for the initial step in commercial operations. For commercial drying to low moisture contents, however, the quantity of solar energy per unit area is not sufficient to provide the needed rate of drying. The collection of solar heat over larger areas than the barbeque (a horizontal surface used for sun drying of products) must be accomplished to gain higher temperatures and larger quantities of heat for commercial applications. A new technology needs to be introduced to use the abundant sunshine for forced-air drying of certain agricultural products. Currently, no forced-air drying is used and no air-type solar collectors are manufactured or used in Jamaica.

4.1.2 Terms of Reference

As defined by the contract Terms of Reference, the purpose of this section of the energy study is to assess the potential of using solar energy in Jamaica for drying agricultural products and to identify the technical and economic feasibility of implementing near-term solar energy projects. The following products were included in the assessment: corn, peas, beans, peanuts, onions, pepper, coffee, cocoa, tumeric, cassava, timber and fish.

4.1.3 Background Information

The need for drying agricultural products was recognized in the original Terms of Reference prepared by

the Ministry of Mining and Natural Resources. The task was to match the needs for drying in Jamaica to the technical potential of collecting solar energy. Collector design, development and manufacture is essential if solar agricultural drying is to be used for preserving food and providing a constant food supply during the months between harvests.

4.1.4 Study Method

Numerous personnel interviews and site visits were conducted during the study in Jamaica. These visits provided direct information on product drying needs and current energy usage. As a result of the data obtained, the following drying methods demonstrate the greatest potential for use in the Jamaican environment:

(1) drying in the sun using open barbeques;
(2) drying in transparent buildings (with or without attached collectors) for small operations;
(3) new drying systems using solar air heaters with forced-air drying;
(4) preheating air for existing commercial fossil fueled dryers; and
(5) fish drying via chemical dehydration with solar regeneration of the chemical.

4.1.5 Findings

4.1.5.1 Solar Radiation Data

A two to three year record of hemispherical solar radiation is available only for Kingston. A method of computing solar radiation from climatic data agreed with the measured hemispherical radiation with a mean difference of only 4 percent. Solar radiation and climatic data are needed at more stations over a longer period of time if solar energy systems are to be designed efficiently and with minimum risk of failure.

4.1.5.2 Solar Air Heaters

In order to utilize solar-heated air for drying agricultural products and heating water, air-type solar collectors which are suitable for construction and use in Jamaica must be developed.

4.1.5.3 Drying Research and Development

To maximize product quality, a research and development project is needed to study drying methods peculiar to Jamaica in order to establish the best configuration for product exposure to the heated air and to determine

optimum drying rates and temperatures. This R&D effort should include a literature study, visits to other countries, engineering design and economic analysis, construction and operation of prototypes and laboratory-scale drying experimentation.

4.1.5.4 Sun Drying

Sun drying of agricultural products in small quantitites and the initial commercial drying of large quantities are well developed and energy efficient. The study found that sun drying very high moisture products to a medium or low moisture content was efficient and profitable and should be encouraged.

A thorough study of small (100 to 500 lbs/batch) drying systems should be made using an engineering/economic approach as part of a research and development project to maximize the use of sun drying in Jamaica.

4.1.5.5 Solar-Heated Air Drying

Solar-heated forced-air drying of agricultural products needs to be developed in Jamaica. Whenever sufficient quantities of legumes or grains are assembled, solar-heated air dryers should be considered to ensure preservation.

Designs of several 140°-170°F solar air heaters examined in this study are highly efficient.

4.1.5.6 Solar Preheaters

Commercial plants which dry cocoa, coffee, cassava, brewer's grain, tumeric and lumber have large buildings with sloping roofs, which are considered excellent locations for solar air-type collectors for use as air preheaters.

4.1.6 Conclusions and Recommendations

Jamaica has an ideal climate for utilizing solar energy for drying agricultural products. The primary needs are to develop and construct solar collectors, and train engineers in solar system design and installation. Solar preheating of air for commercial dryers, however, will not be feasible until collectors are developed which are suitable for, and durable in, the environment of Jamaica. Also, solar drying R&D is necessary to optimize solar drying technology that is peculiar to the Jamaican climate. Little of such required R&D has been accomplished in the U.S. or other countries as of this time.

The following specific recommendations address the current needs:

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

(2) Begin immediate development of solar-heated air collectors using materials which are suitable to tropical climates;

(3) Establish research and development programs for drying of agricultural products with the aim to develop technically sound methods of solar-heated air drying;

(4) Encourage sun drying of agricultural products, particularly those of high moisture content; conduct research and development to determine most cost effective drying methods;

(5) Design and construct solar collector systems for use as preheaters in commercial drying facilities;

(6) Provide the necessary training for the research, development, design, construction and operation of solar air heaters and forced-air dryers for the climate of Jamaica;

(7) Begin program to develop and construct solar-heated air drying systems for community use when sufficient quantities of products are ready for drying from one or more farms.

4.1.6.1 Recommended Program for Drying Foods and Agricultural Products

A solar agricultural drying program should begin immediately with:

(1) research and development of solar-heated air drying;

(2) the development of air-type solar collectors.

These two projects should each be funded for five years at approximately U.S. $90,000 per year with an additional first year expenditure of U.S. $30,000 for materials and supplies. During the first year, one grain drying unit should be designed and constructed. During the second year, four more grain-type dryers should be constructed. Design should also commence on air-type solar collectors for preheating commercial dryers.

The recommended program schedule and associated cost are shown in Table 4-1. The program includes the R&D development and design of solar air heaters, and construction of various projects. The first year's program consists of collector development, product drying R&D and the construction of the first two ton capacity grain dryer; the rest of the recommended program is allocated over the remaining four year period.

The data used to illustrate the technical and economic feasibility of solar-heated air dryers for specific use is shown in Table 4-2. The results show that solar energy would provide essentially all of the necessary heat for the small grain dryers as well as supplement fossil fuel for the commercial dryers. An exception might be the tumeric dryer and the lumber kiln. In these two cases, the R&D program and engineering development should be utilized to assess the best method of drying various products before proceeding to production design. The lumber dryer was eliminated from the program because of the long pay back period.

The need for establishing solar-heated grain dryers is great enough that one such dryer is to be built as a part of the development program. After it is checked for performance and after smaller collector units have been instrumented and tested, larger unit design should proceed in the second year of the program.

It is believed that the costs assumed for collector construction are reasonable for contract work. In the detailed design, particularly after sufficient development, lower cost materials might be selected to achieve cost reduction. As development and construction proceed and more experience is gained, it may be feasible to reconsider the development of a lumber dryer.

4.1.6.2 Consumer and Economic Benefits

The development of food and agricultural product drying technology should benefit everyone in Jamaica by providing a better supply of food products throughout the year. A wide fluctuation in the price of a product is an indicator that more of that product should be preserved for use after the peak harvest season. The drying of products with solar energy, either directly in the sun or by using air from solar collectors, is a relatively simple technology in Jamaica. The collectors will operate at a relatively high efficiency due to high temperatures during the day and high solar radiation, particularly near the coast. Maximum use should be made of these factors.

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TABLE 4-1

RECOMMENDED PROGRAM SCHEDULE AND COSTS FOR SOLAR-HEATED AIR DRYING (US $)

PROJECT	1980	1981	1982	1983	1984
Climatic Data	See Solar Industrial and Commercial Report				
Collector Development	$120,000	$ 90,000	$ 90,000	$ 90,000	$ 50,000
Encourage Sun Drying	12,000	12,000	12,000	12,000	12,000
Product Drying R&D	120,000	90,000	75,000	60,000	50,000
Grain and Legume (2000)* Dryers	8,900	18,000	57,000	19,000	
Cassava		(16,000)	154,090		
Brewer's Grain			(16,000)	158,000	
Tumeric			(6,000)	58,000	
Coffee		(8,000)	33,000	100,000	100,000
Cocoa			(8,000)	30,000	130,000
TOTAL	$260,900	$254,000	$451,000	$527,000	$142,000

*Parentheses indicate initial design cost; planning for additional units is included with construction cost.

TABLE 4-2

DATA USED IN ASSESSMENT OF SOLAR-HEATED AIR DRYING

Project	Dryer Units	Total Collector Construction Area Sq. Ft.	Energy Production Btu Per Year	No 2 Diesel Equivalent US Gallons	Saving Per Year US Dollars	Payback Period In Years	Total Capital Thousands US Dollars
2 Ton Grain Dryer	13	9,100	0.8×10^9	8,840	8,224	1	125
Brewer's Grain Dryer	1	16,500	2.8×10^9	30,700	28,600	6.2	158
Coffee Dryers	14	24,000	2.45×10^9	26,900	25,000	11.6	230
Cocoa Dryers	10	18,000	1.84×10^9	20,190	18,780	11.3	173
Cassava Dryer	1	16,000	3.2×10^9	35,100	32,700	5.2	154
Tumeric Dryer	1	6,000	0.82×10^9	8,970	8,300	8.2	58
Lumber Dryer	1	8,000	0.68×10^9	7,470	6,950	19	98

4.1.7 Complete Study Report

The Solar Energy - Agricultural section of the final report is separately contained in Volume IIIb, Chapter 4 - ESI Report No. EA 80-0101-3b.

To assist those readers of this Executive Summary who may desire additional information, selected background information has been extracted from the main report and has been included in Section 4.1.8 as supplementary information.

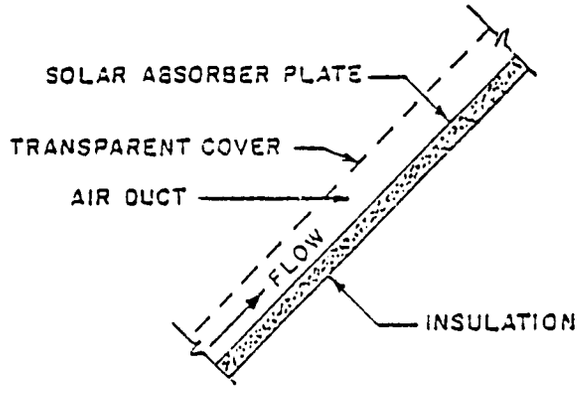
4.1.8 Supplementary Information

4.1.8.1 Solar Energy Use In Drying Agricultural Products

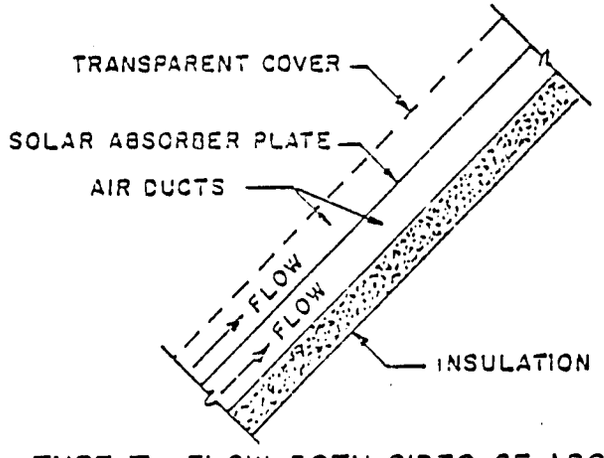
In many of the solar applications in agriculture, direct use of solar energy already plays an important role. Nevertheless, a significant amount of fossil fuel presently goes into the low temperature heating and drying operations just because of the traditional convenience and dependability of fuel-fired operations. With increasing costs and unavailability of various fossil fuels, the need to focus on energy conservation for agricultural applications becomes important. When preservation of food and agricultural products are jointly considered with energy conservation, then the need to examine alternative methods of crop drying by solar energy becomes an economic necessity.

4.1.8.2 Types of Collectors for Crop Drying

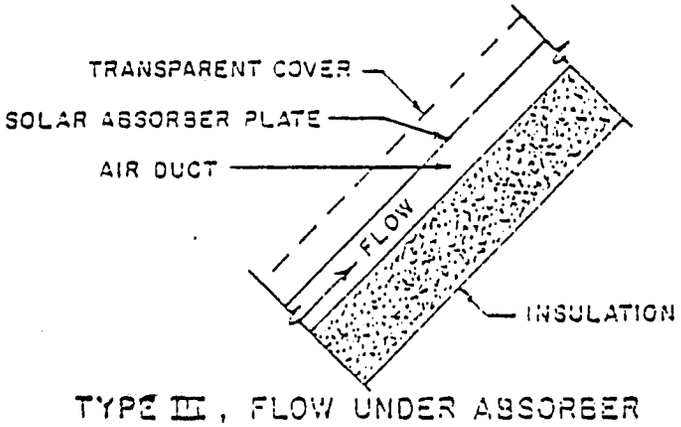
In drying crops with solar energy, it is important to remember several important characteristics. First, solar energy is diffuse and large collector areas are generally required. Unlike domestic solar water heating systems where solar collector areas are small, collector areas required for agricultural drying range in size from 400 ft^2 to 20,000 ft^2 or more. Therefore, cost becomes a significant factor. Also, while liquid solar collectors are more appropriate for water heating, air-type solar collectors are generally more suitable to crop drying applications. A feature of air-type solar collectors for agricultural drying is that they can, because of design simplicity, be constructed more cheaply and be assembled at the construction site. There are three basic air-type solar collectors (referred to as "solar air heaters" in this report). Figure 4-1 illustrates the three types. The dashed line represents one or more transparent covers. Type I utilizes flow over the absorber. Type II utilizes flow on both sides of the absorber and Type III, flow under the absorber. Such collectors must be carefully designed and sized to obtain maximum heat transfer characteristics. In fact, the heat transfer characteristics are more critical for solar air heaters than liquid collectors.



TYPE I, FLOW OVER ABSORBER



TYPE II, FLOW BOTH SIDES OF ABSORBER



TYPE III, FLOW UNDER ABSORBER

Figure 4-1 AIR - TYPE COLLECTORS

4.1.8.3 Status of Air-Collector Development

Technically, the design and development of solar air heaters are in their infancy. Much is yet to be learned about their performance, characteristics, heat transfer, and the longevity of materials used with a wide range of temperatures and humidities.

4.1.8.4 Methods of Solar Drying

There are a number of applications in which solar energy can be applied for use in crop drying. Each application has its own peculiar characteristics, advantages and disadvantages, and they must be understood when trying to achieve cost effective drying results. The features of various solar energy drying techniques are outlined below.

4.1.8.4.1 Sun Drying by the Barbeque Method: This method involves the drying of agricultural products on an open surface exposed to direct sunlight. The features of this method are:

- -- Most energy efficient method; little use of energy;
- -- Optimum method for initial drying of products down to 20% moisture content (M.C.);
- -- Requires a long time and large areas for drying to preservation ranges of 10-15% moisture content; and
- -- Exposed drying surfaces susceptible to unexpected rain or showers.

4.1.8.4.2 Sun Drying in Transparent Buildings: This method involves enclosing the ceiling and walls of a drying chamber with a transparent cover. Free or forced convection is used to direct the air inside the building to dry products spread out inside the building. The main features of this method are:

- -- Products protected from rains and showers;
- -- Requires drying of larger quantities to justify use;
- -- Rate of drying and energy efficiency are reduced as compared to the barbeque method, probably due to reduced air flow rate and solar heat; and
- -- Improved drying should be achieved by blowing hot air down through products.

4.1.8.4.3 Solar-Heated Forced-Air Drying: This method involves the use of a fan to force solar-heated air through a bin of the product being dried. The features of this method are:

-- Highly effective for drying products to low moisture content;
-- Promotes crop preservation for use between harvests;
-- Simple low cost technology;
-- Improved drying performance as compared to sun drying; and
-- Nominal to insignificant use of electric energy for fans.

4.1.8.4.4 Preheating of Air for Commercial Dryers

This method involves the use of solar air heaters to preheat air which is then ducted to rotary drum, cyclone, vertical or tunnel dryers for drying products in large quantities at commercial drying facilities. The features of this method are:

-- Collectors can be mounted on new or existing roofs;
-- Simple low cost collector technology;
-- Requires large roof or other area for collectors;
-- Absorbers may be mass produced and assembled during roof construction; and
-- Collector design may be adaptable for use in liquid collectors also.

5.0 BIOGAS APPLICATIONS

5.1 EXECUTIVE SUMMARY

5.1.1 Introduction

Biogas, a high grade fuel similar to butane, is a mixture of methane and carbon dioxide which burns with an invisible to blue flame and is useful for cooking and other purposes. It is produced simply by anaerobic digestion of organic matter. Agricultural crops can be used as feedstock, but a common practice is to digest manure from animals such as cattle, pigs and chickens. In producing biogas, the slurry retains its original fertilizer components and therefore, biogas is an energy dividend which can be obtained merely by operating the digesters.

5.1.2 Terms of Reference

The objectives of the biogas study were to assess the feasibility of biogas generation and prepare recommendations for projects that might be undertaken. Included were energy and economic evaluations, as well as a review of low cost facility designs which would be most suitable for conditions in Jamaica.

This biogas study was initiated in August 1979. After a planning period and development of a questionnaire, site visits were made to selected farms and institutions in all parishes of the country where biogas could be generated. Based upon these studies and discussions with representatives of institutions and agencies which would be involved, a recommended program in biogas was prepared for presentation to the Government of Jamaica and to the Final Report Conference held November 13-14, 1979 in Kingston, Jamaica.

5.1.3 Background Information

Jamaica has many characteristics which could lead to successful development of biogas as an alternate energy source. Much of the economy is agricultural in nature and therefore large amounts of biomass materials are available. In rural areas where biogas plants could be built there are often shortages of butane and kerosene, so the plants would be located in areas of greatest need. The ambient temperature is sufficiently high throughout the year in Jamaica that auxiliary heating of digesters is not necessary. This obviates the need for costly equipment which is required in colder climates, where biogas is economically justified even when such heating adds significantly to construction and operating costs. Finally, biogas plants are cost effective in Jamaica, where all oil and gas must be imported.

Cooking is often done with butane or kerosene in Jamaica. Generally, 100 cu ft of gas per day is sufficient to supply the cooking needs of a family of six. Approximately 2.7 lbs of butane or 1/3 gallon of kerosene can be replaced by 100 cu ft of biogas.

A brief review of biogas progress in countries which have major programs, such as India, Korea, the Philippines, Taiwan, China and the United States, indicates that Jamaica should be able to institute a successful biogas program with little initial research and development effort.

5.1.4 Study Method

In order to obtain input from those already involved in developing this energy source, a Biogas Working Group was formed with representation from appropriate agencies and institutions. Meetings were held with this group and with private individuals. Visits were made to sites where biogas plants are now operating, and surveys were made of 75 farms, communities and schools throughout Jamaica to evaluate the potential for a program of biogas works (see Appendix E, Chapter 5 for survey results). Certain farms were selected based on livestock figures provided by the regional offices of the Ministry of Agriculture. although this survey should not be considered a full market analysis, the preliminary results indicate that the potential for a viable biogas program exists. Upon completion of the surveys, the data were evaluated, economic and energy analyses were made, and a recommended five year biogas program was developed.

5.1.5 Findings

The surveys showed that farmers and managers of institutions were quite receptive to the concept of biogas. In some cases their knowledge of the subject was fairly good, and many expressed an interest in installing their own biogas plants.

The Scientific Research Council (SRC) has been conducting research and development on design of family size biogas plants for the past five years. They are presently concentrating on developing lower cost designs. A basic design has now been developed and perfected through the testing and demonstration program and will enhance the potential for success.

The economic potential for biogas use is excellent in Jamaica. Because of the high price of imported fuel, the

cost of butane or kerosene for cooking purposes averages from J. $100 to J. $250 per year per family. The present biogas plant design would have a construction cost of about J. $1,000 per family size unit, and a Chinese design being studied by the SRC may reduce this to as low as J. $300. Using the two designs for a national program of implementation could result in an estimated average cost of J. $500 per family size unit. The pay back period could be as low as one and one half years but would probably average in the range of two to four years on the basis of energy alone. This does not include the fertilizer and other values of the digested residue.

The Ministry of Agriculture is interested in assisting in a national program of biogas energy throughout the rural areas of Jamaica. Personnel from this Ministry could play an important role in the program because of their knowledge of the agricultural sector and their normal day-to-day contacts at the local level.

A biogas program would be compatible with the objectives of the Energy Sector Plan, Section 4.3-B.v. The suggested biogas program would help divert the present energy supply mix away from imported petroleum, develop an economically feasible non-conventional energy form adapted to local needs, accelerate the development of an indigenous biomass energy source, and contribute to Jamaica's energy self-sufficiency through the development of a non-conventional energy source. Moreover, it would reduce the cost of energy to low income groups by replacing purchased butane, kerosene and other fuel with essentially free energy from renewable feedstock.

5.1.6 Conclusions and Recommendations

Based on climate, rural population, animal numbers, Jamaica's dependence on expensive foreign oil and the enthusiasm shown in many sectors, it is concluded that a national biogas program would be successful. To ensure this success the experts on the study team formulated a group of recommendations:

(1) Select for large scale implementation one of the SRC family of small and medium size biogas plant designs;

(2) Postpone program to install a biogas plant at UWI-Mona Campus;

(3) Implement the Option A (Section 5.1.8.1 A and Table 5-5) five year biogas program immediately;

(4) Begin a detailed marketing study to assess the commercialization potential;

(5) Conduct feasibility study for a large scale biogas unit for electricity generation;

(6) Re-assess the feasibility of Option B, the accelerated program (Section 5.1.8.1 B and Table 5-6) after the detailed marketing study;

(7) Explore the interest of government, international and private institutions in funding Option C (Section 5.1.8.1 C and Table 5-7);

(8) Establish a Jamaican Government biogas program organization; and

(9) Begin a comprehensive training and public awareness program.

5.1.6.1 Recommended Biogas Applications Program Based on the recommendations cited above, a Biogas applications program has been defined that could be implemented over a five year time frame.

5.1.6.1.1 Organizational Infrastructure: The proposed organization for carrying out the biogas program is shown in Figure 5-1. The role of the Energy Division of the Ministry of Mining and Natural Resources would be primarily planning, funding, policy decisions, and monitoring the work of the interacting groups in the biogas program. The role of SRC would be primarily R&D in the development of low cost design, as well as training development. Training assistance may also be desirable from academic institutions and the Ministry of Agriculture. SRC would be called upon as experts to assist in technical matters of the biogas program, and MMNR would then proceed with managing the overall construction and implementation program.

Local contact with farmers could best be carried out by the Ministry of Agriculture personnel, who have more than 400 extension agents located throughout the rural area. The Ministry of Agriculture is most aware of the energy needs of farmers and is keenly interested in assisting the rural population by providing biogas information and advice to them.

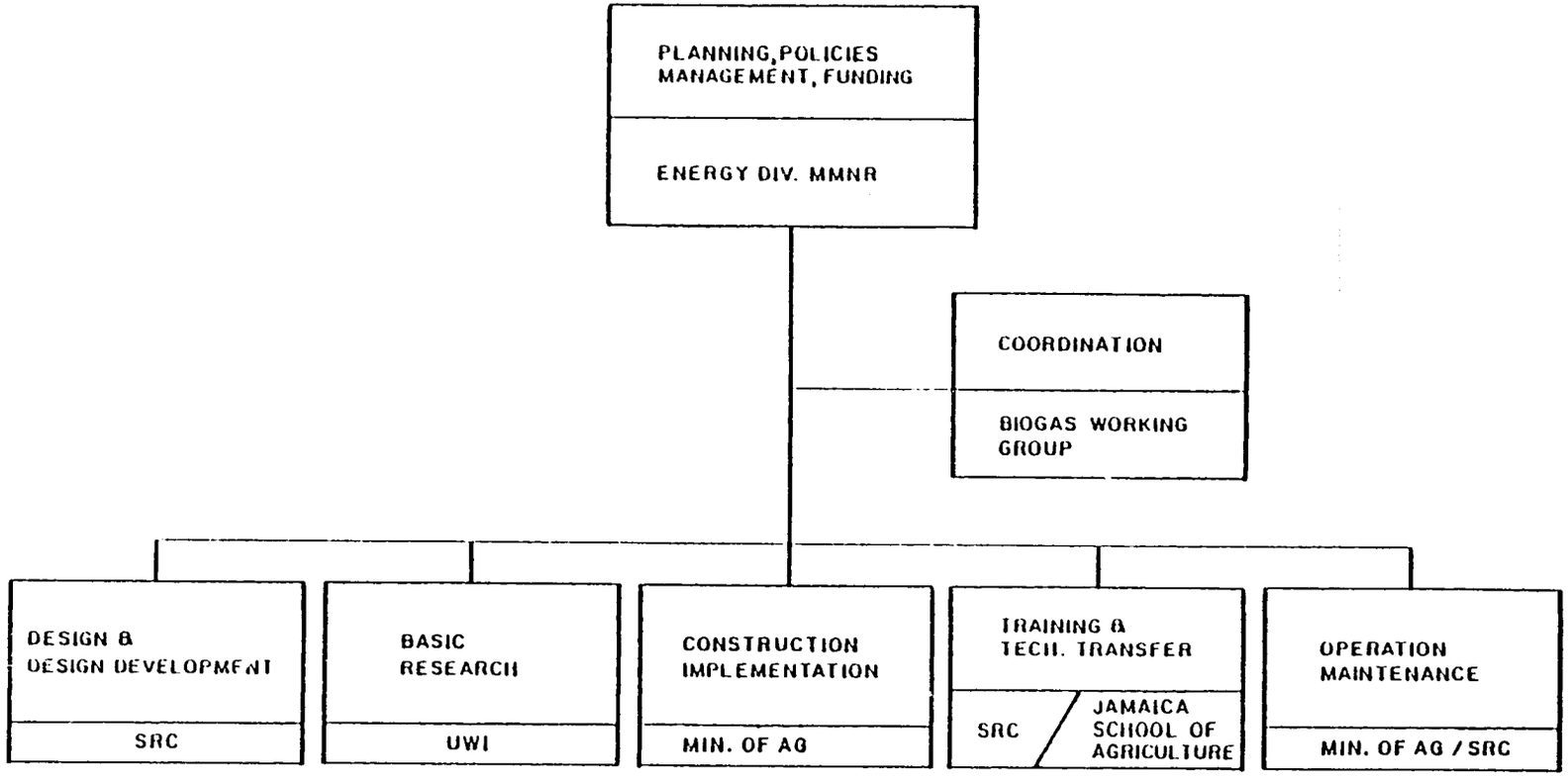


FIG. 5-1 BIOGAS PROGRAM ORGANIZATION

5.1.6.1.2 Construction and Implementation Program: The construction and implementation program should be carried out by a combined effort of private industry and government. It would perhaps be appropriate to call in general contractors and consultants from the private sector to work with government officials so that all could be involved in a program to achieve highest quality of workmanship at least cost. Replication of constructed plants by the same team should be encouraged, in order to apply experience in initial plants to the construction of follow-on units.

5.1.6.1.3 Funding: Funding requirements for the Five Year Program, Options A through C, are shown in Tables 5-1, 5-2, and 5-3 respectively, and are summarized in Table 5-4. It is recommended that funds be provided either to the Energy Division of the Ministry of Mining and Natural Resources or to an agency designated by this Division, from which they would then be allocated to those organizations who participate in the program.

5.1.6.1.4 Training: It is envisioned that a substantial training program will be necessary in order to achieve the effects desired from the biogas program. This training would best be carried out by SRC, possibly in conjunction with academic institutions and the Ministry of Agriculture.

5.1.6.1.5 Public Education: Since a family size biogas unit can be constructed quite simply, there is a great opportunity for enterprising and energy-conscious homeowners to build their own units separate from the government program. In many cases, local cast-off containers and materials are available, and use of the farmer's own labor could result in an extremely low cost facility.

5.1.7 Complete Study Report

The Biogas Applications section of the final report is separately contained in Volume III c, Chapter 5 - ESI Report No. EA 80-0101-3c.

To assist those readers of the Executive Summary who may desire additional information on the National Program options, such information is included in Section 5.1.8 as supplementary information.

TABLE 5-1

PROPOSED FIVE-YEAR FUNDING OF BIOGAS PROGRAM
OPTION A

	J $
YEAR 1	
Management	10,000
R & D	30,000
Construction	61,000
Operation and Maintenance	7,000
Foreign Consultancy	6,000
Training - 24 man months at $1,000	24,000
1 Vehicle	20,000
YEAR 2	
Management	10,000
R & D	30,000
Construction	61,000
Operation and Maintenance	15,000
Foreign Consultancy	10,000
Training - 36 man months at $1,000	36,000
YEAR 3	
Management	13,000
R & D	60,000
Construction	160,000
Operation and Maintenance	30,000
Foreign Consultancy	10,000
Training - 36 man months at $1,000	36,000
1 Vehicle	20,000
YEAR 4	
Management	13,000
R & D	60,000
Construction	320,000
Operation and Maintenance	45,000
Foreign Consultancy	10,000
Training - 36 man months at $1,000	36,000
YEAR 5	
Management	36,000
R & D	40,000
Construction	1,240,000
Operation and Maintenance	75,000
Foreign Consultancy	10,000
Training - 48 man months at $1,000	48,000
1 Vehicle	30,000
5 YEAR TOTAL	J. $2,722,000

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TABLE 5-2

FIVE YEAR FUNDING OF BIOGAS PROGRAM
OPTION B

	Jamaican $
Year 1	
Management	10,000
R&D	100,000
Construction	61,000
Operations & Maintenance	7,000
Foreign Consultancy	6,000
Training -	
24 man months at $1,000	24,000
1 Vehicle	20,000
Year 2	
Management	10,000
R&D	120,000
Construction	122,000
Operations & Maintenance	14,000
Foreign Consultancy	10,000
Training -	
36 man months at $1,000	36,000
1 Vehicle	20,000
Year 3	
Management	18,000
R&D	100,000
Construction	320,000
Operations & Maintenance	45,000
Foreign Consultancy	10,000
Training -	
48 man months at $1,000	48,000
1 Vehicle	20,000
Year 4	
Management	20,000
R&D	80,000
Construction	740,000
Operations & Maintenance	75,000
Foreign Consultancy	15,000
Training -	
60 man months at $1,000	60,000
1 Vehicle	20,000
Year 5	
Management	35,000
R&D	80,000
Construction	5,500,000
Operations & Maintenance	300,000
Foreign Consultancy	15,000
Training -	
150 man months at $1,000	150,000
2 Vehicles	60,000
5 YEAR TOTAL	$8,171,000

TOTAL NO. OF UNITS -

11,550 FAMILY SIZE
79 MEDIUM SIZE

TABLE 5-3.

FIVE YEAR FUNDING OF BIOGAS PROGRAM

OPTION C

	J $
YEAR 1	
Management	10,000
R&D	30,000
Construction	61,000
Operation & Maintenance	7,000
Foreign Consultancy	6,000
Training - 24 man months at $1,000	24,000
1 Vehicle	20,000
YEAR 2	
Management	10,000
R&D	100,000
Construction	140,000
Operation & Maintenance	13,000
Foreign Consultancy	6,000
Training - 36 man months at $1,000	36,000
YEAR 3	
Management	13,000
R&D	30,000
Construction	360,000
Operation & Maintenance	30,000
Foreign Consultancy	10,000
Training - 48 man months at $1,000	48,000
1 Vehicle	20,000
YEAR 4	
Management	13,000
R&D	50,000
Construction	680,000
Operation & Maintenance	40,000
Training - 48 man months at $1,000	48,000
Foreign Consultancy	10,000
1 Vehicle	20,000
YEAR 5	
Management	36,000
R&D	60,000
Construction	1,200,000
Operation & Maintenance	100,000
Foreign Consultancy	10,000
Training - 150 man months at $1,000	150,000
2 Vehicles	60,000
5 YEAR TOTAL	$4,176,000

Total No. of Units - 1,700 Family Size
153 Medium Size

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TABLE 5-4

SUMMARY OF FIVE YEAR PROGRAM OPTIONS

ENERGY PRODUCED, AND COSTS

OPTION	NO. OF UNITS FAMILY	NO. OF UNITS MEDIUM	EQUIV. OIL (BBLS/YR)	EQUIV. BUTANE (1000 LB/YR)	EQUIV. KEROSENE (1000 GAL/YR)	COSTS J$
A (recommended)	2,700	41	10,700	3,450	490	2,722,000
B	11,450	79	39,600	12,800	1,830	8,271,000
C	2,700	153	17,515	5,650	808	4,376,000

5.1.8 Supplementary Information

5.1.8.1 National Program Options

It is the purpose of this Section to develop a national biogas plan with three program options for funding by one or several lending agencies or donors. The proposal is based upon discussions with the Biogas Working Group, but the concepts are primarily those of this study effort. It would be anticipated that modification would occur with additonal review and study in preparation of documentation to funding agencies for program support.

It is necessary, during the first two years of any option considered, that a full market study and analysis be undertaken. The survey would provide the baseline information necessary to assess full market potential and provide a systematic mechanism for program implementation. The potential for biogas unit installation could approach 20,000 household units in the rural sector. This is an estimated figure only, which represents 10% of the rural population or 5% of the total population of Jamaica.

(A) Option A - Baseline Five Year Plan

A basic five year plan of demonstrating and commercializing biogas plants on a country-wide basis is proposed. The first two years would be demonstration, or more correctly "popularization"; commercialization would be carried out during the last three years of the five year plan. During the five years there would be ongoing functions of research and development, demonstration, commercialization, and training. It is emphasized that research and development, which is primarily the evaluation of alternate designs in order to develop modifications and allow use of materials which are suitable for Jamaica, should be done concurrently with the implementation plan in order not to lose time. It should also be understood that although this study and report focus on smaller biogas units designed to provide methane for use in cooking, a large scale demonstration unit for electricity generation should not be ignored. A further consideration is to explore the feasibility of such a unit for technology gains and possible use in Jamaica and other Caribbean countries.

The baseline five year program consists of family and medium size plant construction as per the schedule shown in Table 5-5. Three or more household size plants would be built in each region (Cornwall, Middlesex, and Surrey) per year of a two year demonstration period. Commercialization would then proceed over the next three years, with a total of 2700 family size units and 41 medium size units having been constructed at the end of five years.

TABLE 5-5

ENERGY DERIVED FROM PROPOSED BIOGAS PROGRAM - OPTION A

YEAR	BIOGAS UNITS	Btu/YR (Million)[1]	EQUIVALENT OIL (Barrels) at 6 MM Btu/Bbl	EQUIVALENT[2] BUTANE/YEAR (1000 lb)	EQUIVALENT KEROSENE/YR[3] (1000 Imp. Gal.)
1	50 household	912	152	49	7
	3 medium	1,095	182	59	8
	TOTAL	2,007	334	108	15
2	100 household	1,824	304	98	14
	6 medium	2,190	364	118	17
	TOTAL	4,014	668	216	31
3	300 household	5,472	912	294	42
	11 medium	4,015	669	217	31
	TOTAL	9,487	1,581	511	73
4	700 household	12,768	2,128	686	98
	21 medium	7,665	1,278	414	59
	TOTAL	20,433	3,406	1,100	157
5	2700 household	49,248	8,208	2,645	378
	41 medium	14,965	2,494	809	116
	TOTAL	64,213	10,702	3,454	494

Calculations based on equivalent Btu values, and the following data:

1. 100 cu. ft. of biogas has energy content of 50,000 Btu.
   Household unit yield of 100 cu. ft./day.
   Medium unit yield of 2,000 cu. ft./day.
   All units operating 365 days/year.

2. 1,000 lb. of butane has energy content of 10.6×10^6 Btu.

3. 1,000 Imperial Gallon of kerosene has energy content of 130×10^6 Btu.

(B) Option B - Accelerated Program

Option B would begin implementation of a biogas program at the same rate as the baseline program during the first year, but would accelerate much more rapidly thereafter. At the end of five years under Option B, there would be 11,450 family size and 79 medium size plants constructed. The five year construction schedule and the equivalent energy produced on an annual basis is shown in Table 5-6.

(C) Option C - Expanded Medium Size Plants Program

In Option C the same number of family size units would be constructed, as in the baseline program, with the distinguishing feature being construction of more medium size plants. The five year program would thus consist of 2700 family size and 153 medium size plants, as shown in Table 5-7. Energy produced on a year-by-year basis is also shown in Table 5-7.

An attractive feature of Option C is that the additional medium size facilities could be selected for funding by a particular government or international agency which might be different from that which funds the baseline program.

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TABLE 5-6

ENERGY* DERIVED FROM BIOGAS PROGRAM OPTION B

YEAR	BIOGAS UNITS	Btu/YR. (Million)	EQUIVALENT OIL (Barrels) AT 6 MM Btu/BBL	EQUIVALENT BUTANE/YR. (1000 LB.)	EQUIVALENT KEROSENE/YR. (1000 IMP. GAL.)
1	50 Household	912	152	49	7
	3 Medium	1,095	182	59	8
		2,007	334	108	15
2	150 Household	2,736	456	147	21
	9 Medium	3,285	547	176	25
		6,021	1,003	323	46
3	450 Household	8,208	1,368	441	63
	19 Medium	6,935	1,155	373	53
		15,143	2,523	814	116
4	1,550 Household	28,288	4,715	1,520	53
	39 Medium	14,235	2,372	765	109
		42,523	7,087	2,285	162
5	11,450 Household	208,960	34,827	11,234	1,607
	79 Medium	28,835	4,806	1,550	222
	TOTAL	237,795	39,633	12,784	1,829

*CALCULATIONS BASED ON EQUIVALENT Btu VALUES AS PER TABLE 5-5.

TABLE 5-7

ENERGY* DERIVED FROM BIOGAS PROGRAM OPTION C

YEAR	BIOGAS UNITS	BTU/YR. (Million)	EQUIVALENT OIL (Barrels) AT 6 MM BTU/BBL	EQUIVALENT BUTANE/YR. (1000 LB.)	EQUIVALENT KEROSENT/YR. (1000 IMP. GAL.)
1	50 Household	912	152	49	7
	3 Medium	1,095	182	59	8
		2,007	334	108	15
2	100 Household	1,824	304	98	14
	130 Medium	4,745	790	255	36
		6,569	1,094	353	50
3	300 Household	5,472	912	294	42
	33 Medium	12,045	2,000	648	92
		17,517	2,912	942	134
4					
	700 Household	12,768	2,128	686	98
	73 Medium	26,675	4,440	1,432	205
		39,413	6,568	2,118	403
5	2,700 Household	49,248	8,208	2,645	378
	153 Medium	55,845	9,307	3,002	430
	TOTAL	105,093	17,515	5,647	808

*CALCULATIONS BASED ON EQUIVALENT BTU VALUES AS PER TABLE 5-5

6.0 ENERGY CONVERSION FROM WASTE

6.1 EXECUTIVE SUMMARY

6.1.1 Introduction

The economic recovery of energy and materials from urban wastes has been of interest to public works officials for many years. In general, the recovery of resources from urban wastes has not been successful. The value of recovered resources has not been sufficient to offset the added costs of recovery efforts.

Increases in the price of fuels in recent years have led to renewed interest in energy recovery from urban wastes. Several research and demonstration projects are underway in the United States and other countries to evaluate the potential of energy recovery from solid wastes.

This report will center on the application of various approaches to energy recovery from urban wastes in Jamaica and how such approaches might best be demonstrated.

6.1.2 Terms of Reference

The principal thrust of this study was to assess the feasibility of a prototype demonstration unit for energy recovery from the solid wastes generated on the Mona Campus of the University of the West Indies (UWI), Kingston, Jamaica. Discussions with various Jamaican officials led to an expansion of the scope of the study to include an analysis of the potential for energy recovery from urban wastes in Jamaica with the Kingston area serving as a case study.

6.1.3 Background Information

6.1.3.1 Urban Solid Wastes as a Fuel

The use of urban solid wastes as a fuel will not solve the energy problems of any country. In the United States, for example, the recovery of the heat value in all of the 200 million tons of urban solid wastes generated annually would provide only two to three percent of the 75 quadrillion (75 x 1015) Btu of total annual energy consumption.

Energy consumption on a per capita basis in Jamaica is about 13 percent of what it is in the United States. Data indicates

that the per capita generation of urban wastes is also lower in Jamaica. Based on the Kingston urban area, indications are that the energy available in urban solid wastes in Jamaica, as a percentage of total energy consumption, may be in about the same range (two to three percent) as in the United States.

The point is, the energy available in urban wastes is really quite small, regardless of the location. Nevertheless, most countries can ill afford to ignore any material that may help to reduce petroleum consumption.

6.1.3.2 Recovery Alternatives

Alternatives for the recovery of fuels or energy from urban solid wastes may be classified as thermal, biological, or mechanical. Specific types of systems that have been applied to energy recovery from urban wastes are:

(1) Waterwall Combustion
(2) Refuse Derived Fuel (RDF)
(3) Pyrolysis
(4) Anaerobic Biological Conversion (Biogas)
(5) Landfill with Gas Recovery

The only system in the above list that is beyond the experimental stage is waterwall combustion. All the other alternatives will work, but have not been proven on a wide scale.

6.1.3.2.1: Waterwall combustion involves the burning of refuse as received without prior separation of non-combustibles. Heat recovery and steam generation are the principal end products. The steam may be used for some nearby industrial need or for the generation of electricity.

6.1.3.2.2: The Refuse Derived Fuel (RDF) systems are highly mechanized, involving shredders, separators, classifiers, and other maintenance-intensive components which separate and process the combustibles (the fuel) and the non-combustibles (metals, glass, etc.). An advantage of the RDF approach is that the fuel produced may be transported for use at a distant site. The RDF is often mixed with another fuel such as coal, for burning in industrial boilers.

6.1.3.2.3: Pyrolysis involves the heating of organic matter in an atmosphere devoid of, or deficient in, oxygen. The goal is the destructive distillation of the

complex organics and the production of gaseous, liquid or solid fuels. Several systems have been under development and demonstration in the United States and elsewhere. It can be concluded that pyrolysis is a process that is well understood, but the technology has not been well demonstrated for application to complex mixtures of materials such as urban refuse.

6.1.3.2.4: The anaerobic biological (biogas) process for the conversion of organic matter to methane and carbon dioxide is another alternative for the recovery of energy from wastes. The process has been applied for over 60 years in the stabilization of sludges in waste-water treatment. The process is well understood, but has not been widely applied to urban solid wastes. A demonstration project requiring 50 to 100 tons per day is underway at Pompano Beach, Florida.

6.1.3.2.5: Another approach that is being evaluated for energy recovery from urban solid wastes is the recovery of combustible gases from sanitary landfills. As a practical matter, attempts to recover methane from landfills may only complicate an otherwise simple method of refuse disposal.

6.1.4 Study Method

An important element of the urban wastes study was discussions with various individuals in the national and local governments of Jamaica and the University of the West Indies, Mona Campus. Tours of various facilities in the Kingston urban area, including the UWI campus, that could have potential for or be involved in energy recovery from urban wastes were conducted. To gain a better feeling for the urban wastes situation in other cities of Jamaica, a 600 mile auto tour of the island was conducted. Also, several reports dealing with the energy situation in Jamaica and with urban solid wastes were reviewed.

6.1.5 Findings

6.1.5.1 Urban Solid Wastes - Kingston

One element of this study was the evaluation of energy recovery from urban wastes using the Kingston area as a case study. From a review of previous reports, discussions with individuals, and personal observations it was apparent that there is a problem with refuse

collection in the Kingston urban area. A 1979 report on solid wastes management in the Kingston Metropolitan Region (KMR) by consultants to the National Planning Agency (NPA) indicated that about 1000 tons per day (TPD) of urban solid wastes are generated in the KMR. Of the 700 tons generated daily in the Kingston and Saint Andrew Corporation (KSAC), the consultants estimated that only about 130 TPD of refuse is actually collected and transported to disposal sites. Although some individuals mentioned in discussions that the 130 TPD figure appeared low, there is a serious problem in the reliable collection of refuse in the Kingston area.

The consultants to the NPA estimated that the capital and annual operation and maintenance (O&M) costs required to implement a new solid wastes collection system in the KSAC and St. Catherine and St. Thomas areas would be U.S. $12 million and $8 million, respectively.

Capital costs estimation for a waterwall incinerator with steam generation capabilities would be U.S. $40 million for a 1000 TPD facility. Operation and maintenance costs would likely average about U.S. $10 per ton of refuse processed. Annual costs for such a facility to handle the 1000 TPD of urban solid wastes generated in the KMR are estimated as follows:

Annual Capital Costs (U.S. $40 million, 20 yr, 8%)	$4,074,000
Annual Operation and Maintenance (U.S. $10 per ton of wastes)	3,650,000
TOTAL ANNUAL COSTS	U.S. $7,724,000

The annual costs for new equipment and operational costs to bring the refuse collection system to the required level of efficiency, as proposed by the consultants to the NPA, are:

Annual Capital Costs (U.S. $12 million, 10 yr, 8%)	$1,788,000
Annual Operation and Maintenance	8,000,000
TOTAL ANNUAL COSTS	U.S. $9,788,000

The annual cost of a waterwall combustion system, including O&M, is about equal to the value of the energy in the urban solid wastes generated in the KMR. If the solid wastes were

being collected in an efficient and reliable manner, it would be feasible from an energy and economic standpoint to proceed with a more detailed study and plans for a waterwall incineration/steam generation facility in Kingston.

6.1.5.2 University of the West Indies - Mona Campus Demonstration

Another part of this study was a feasibility assessment of an energy recovery demonstration at the Mona Campus of the University of the West Indies. About 1000 pounds per day of refuse is generated by the University and hauled for burning in incinerators at the site of the University's waste-water treatment plant.

The only energy recovery alternative that was considered to be reasonable for a field-scale demonstration was the anaerobic digestion (biogas) approach. Calculations indicate that a biogas reactor with a volume of 864 cubic feet would be required to produce 360 cubic feet of gas per day from a daily feed of 90 pounds (dry weight) of organic refuse. This would be sufficient gas production to serve as fuel for a one-horsepower internal combustion engine operating 24 hours per day.

6.1.6 Conclusions and Recommendations

(1) Based on the analysis of the potential for energy recovery from urban solid wastes in the Kingston Urban Region, it is concluded that the only technical alternative worthy of consideration is waterwall incineration with steam generation. Based solely on the value of the refuse as a fuel (U.S. $7.4 million per year) versus the cost of recovery by waterwall incineration (U.S. $7.7 million per year), it appears feasible to proceed with energy recovery in Kingston. This cannot be done, however, since the urban solid wastes are not being collected. It is recommended that a detailed study be made of the urban solid wastes collection problem in Kingston and that a detailed evaluation of alternatives for energy recovery be considered. It is estimated that this study would cost approximately U.S. $150,000.

(2) The results of this study indicate that the University of the West Indies should not proceed with a field-scale anaerobic digestion demonstration unit. It is recommended that the University center its energy interests on the establishment of a properly equipped laboratory to be devoted to the research and demonstration of energy alternatives. Establishment of such a laboratory would cost an estimated U.S. $182,500.

6.1.6.1 Recommended Energy Conversion from Waste Program

Based on the recommendations cited above only two programs were defined as follows:

(1) A detailed study on waste collection problems in Kingston and an evaluation of the alternatives for energy recovery; and

(2) The establishment of an Alternative Energies Laboratory at the University of the West Indies - Mona Campus.

(A) University of the West Indies - Mona Campus Laboratory

A better use of the available resources would be the development of a laboratory that could be devoted to research and development on a number of energy conversion alternatives, not just a single technology as would be the case in a field demonstration. This laboratory might be called an "Alternative Energies Laboratory".

It is estimated that the energy laboratory could be established and operated at a cost of U.S. $182,500 over the next three years. Details on this estimate, developed in consultation with Professor Lalor of the University, are as follows:

- Renovation of 1000 sq ft of space @ $40/sq ft	U.S. $ 40,000
- Salaries: One research fellow, 3 years @ $17,000/year, average	51,000
- One technician, 3 years @ $5,500/year, average	16,500
- Furnishings and Equipment	40,000
- Travel and living expenses for visiting professors to U.S. over 3 years	25,000
- Conference travel, publications, etc.	10,000
TOTAL	U.S. $182,500

Education is an essential ingredient in developing and demonstrating the new technologies involved in energy alternatives. It is not very effective for a teacher to read about a particular technology and then to attempt to pass on the concepts to others. The teacher, especially at a university level, must be involved in a "hands on" way with what is being taught. Laboratory research provides this kind of experience and, in addition, usually results in the generation of new knowledge.

The proposed laboratory at UWI-Mona might concentrate on alternative fuels production, primarily biomass conversion to methane (biogas) and other fermentations, such as alcohol production. The concentration in the fermentations area seems appropriate for UWI-Mona since a very capable faculty in the areas of chemistry, microbiology and physics is located there.

It is felt to be of importance for the faculty members who are to begin working in the alternative energies area to spend some time in existing research laboratories in the United States to get first-hand experience before beginning their own work. For this reason, travel funds for visiting professors are recommended.

An important use of the laboratory, of course, is education and training of students, not just research and development. The laboratory should be an extremely valuable asset for this purpose in Jamaica.

6.1.7 Complete Study Report

The Energy Conversion from Waste section of the final report is separately contained in Volume IIId, Chapter 6 - ESI Report No. EA 80-0101-3d.

7.0 COAL PREFEASIBILITY STUDY

7.1 EXECUTIVE SUMMARY

7.1.1 Introduction

The objective of this study was to determine if the use of coal for power and steam production appears sufficiently attractive, both technically and economically, to justify a full scale feasibility study. Jamaica is completely dependent upon foreign fuel oil and is concerned about possible disruption of supply. Equally important is the continually escalating cost of oil and the adverse effects of such escalations on the Jamaican economy. These considerations make the use of an alternative fuel, such as coal, desirable.

7.1.2 Terms of Reference

The study will assess the technical, economic and environmental feasibility of diversification from oil-fired electric power generation units to coal. The possibility of retrofitting existing units to burn 3 percent sulfur coal or a coal-oil mixture will be investigated. Since the benefits to be accrued exist for both the alumina companies and the Jamaica Public Service Company (JPS), all plant sites and harbors will be considered in the analysis of coal transportation, coal handling and storage facilities, and the infrastructure required to support coal operations. Price projections for coal and the potential for obtaining long-term coal supply contracts will be addressed.

7.1.3 Background Information

Early in the study, through discussions with key representatives from Jamaica Public Service and the alumina companies, the original Terms of Reference were expanded to provide a more detailed study of alternative methods of power generation. The following generation schemes were analyzed: coal-oil; combined-cycle gas turbine; diesel; oil; and coal gasification.

7.1.4 Study Method

7.1.4.1 Personnel Interviewed

Discussions were held with officials and employees of the public electric utility, government sector and with several major energy users in Jamaica. Power generation sites and potential coal off-loading and power plant sites were also visited.

Rough estimates of station capital costs were made for each of the different types of generating schemes considered. Levelized fuel cost savings were calculated over the 25 year life for each type of station and compared with generation by existing units. In addition, sensitivity calculations were made for various oil price escalation rates. These calculations considered fuel cost only, as differences in operation and maintenance costs between the schemes were relatively small. However, separate calculations were made to show the relative cost per kWh for each generating scheme. These were calculated for 1979 and levelized from 1985 for comparison and included capital, fuel, operating, and maintenance costs.

Estimated prices for coal and shipping were obtained from at least three sources.

Existing reports were also reviewed for background information.

7.1.5 Findings

7.1.5.1 Retrofit Capability of Existing Boilers

Existing steam and electrical generating capacity of JPS and the alumina companies, except Alcoa, were reviewed. It appears that none of the boilers are suitable for burning coal directly. They may be capable of burning a coal-oil mixture or a medium-Btu coal-gas when and if these processes are proven feasible.

7.1.5.2 Long-Term Coal Contract

The possibility of obtaining a long-term coal contract at this time is good for there is an oversupply of coal. The 1979 estimated coal price in Jamaica selected for the study was U.S. $47 per ton or U.S. $2.10 per million Btu, and is based on verbal conversations with three suppliers. This is J. $82.25 or J. $3.68, respectively. This price escalated to 1985, the study date, is J. $133 per ton and U.S. $76 per ton.

Later it was learned that a new mine is scheduled for opening in Columbia in 1985. Discussions indicate this future supplier may be able to deliver coal at U.S. $30-35 per ton at the dock in Jamaica on the basis of current prices. It is expected that inflation will continue at 7 percent per year through 1985, and coal is to exceed this by 1 or 2 percent. Thus, the 1985 price would be about J. $98.00 per ton or U.S. $56.00.

7.1.5.3 Transportation of Coal to Jamaica

Reynolds has indicated interest in the transport of coal in their bauxite ships on the backhaul. All others, including Jamaica Merchant Marine, indicate their schedules are too tight to transport coal.

7.1.5.4 Economic Analysis of Alternative Generation

The economic evaluation of alternative generating schemes on the JPS system included the following:

(1) Coal/Oil-Fired Unit
(2) Combined-Cycle Gas Turbine (Heavy Oil)
(3) Low Speed Diesel (Heavy Oil)
(4) Oil-Fired Unit

The above evaluation indicated that coal-fired units produce a net savings only slightly greater than that of the combined-cycle gas turbine. However, the combined cycle gas turbine saving is not subject to the same risk as the coal-fired plant capital cost estimate. For example, if new port and unloading facilities are required for the coal-fired station, it is doubtful it could be justified at a less than 12 percent oil escalation rate. A decision to build a new port for a coal-fired station could only be made after a detailed site survey, port study, and full feasibility analysis.

Several ports were surveyed for feasibility as sites for adjacent coal-fired plants. A brief summary of findings is given below:

Old Harbour Station

(1) Undeveloped harbor, large amount of dredging required.
(2) Considerable space for possible plant siting.
(3) Very close to Old Harbour station and 138 KV system.

Montego Bay

(1) Distant from major electrical users, increased line losses.

Port Esquivel

(1) Most attractive -- joint use of harbor with Alcan.
(2) Sufficient land available for plant siting.
(3) Close to Kingston and Old Harbour 138 KV transmission lines.

New South Manchester

(1) Could be used jointly to accommodate alumina and coal shipment.
(2) Possible new harbor.
(3) Distant from existing transmission lines causing considerable line loss.

An option less dependent upon high fuel oil price escalation rates might be the use of an existing port, either at Port Esquivel or the proposed South Manchester port.

Based on the previous findings, an economic analysis was conducted for various generation schemes using coal. The net cost savings and power generation costs levelized from 1985 are as follows:

System	Savings x 10^6 ($J.)	Power Generation Cost ($J./kWh)
Existing Oil-fired	Base	-
New Coal-Fired	182.8	.205
New Combined-Cycle	175.1	.214
New Low-Speed Diesel	140.3	.221
New Oil-Fired Unit	18.9	.261

7.1.5.5 Potential Problems

Potential problem areas for the various generation schemes include:

(1) capital expenditures
(2) maintenance
(3) ash disposal
(4) operator training
(5) reliable future fuel cost estimates
(6) pollution

7.1.6 Conclusions and Recommendations

7.1.6.1 Conclusions

The following conclusions have been reached:

(1) JPS installed system capacity is approximately 455 MW which is greatly in excess of the present 210 MW peak demand. Thus, a new unit is not needed to meet the expected system load at the present time. However, unit outages cause frequent rolling blackouts. A major program is needed to improve unit availability, particularly of the newer, more efficient units. If the four newest

units, having a total capacity of 250 MW, could have improved availability and operate at a high capacity factor, there would be a large fuel savings without any capital expenditure.

(2) Existing boilers for JPS or the alumina companies can not be retrofitted to burn coal directly. In the future they may be able to burn a coal-oil mixture or a coal gasification product.

(3) The possibility of obtaining a favorable long-term coal contract is very good at the present time. However, a detailed coal contract study is required to determine the actual price of delivered coal to Jamaica.

(4) The transportation of coal from the U.S. Gulf coast in bauxite ships on the backhaul is a distinct possibility. There is a good possibility coal can also be transported by non-U.S. ships at a cost approximating that of the bauxite ships.

(5) The installation of a coal-fired unit may seem attractive at a conservative differential oil-coal escalation rate of only 1 percent if joint use of harbor facilities and site can be achieved at Port Esquivel, or at the new proposed JBM South Manchester site at Cuckold Point. This can only be determined after detailed discussions with Alcan and JBM, preparing more detailed cost estimates and obtaining acccurate coal study prices.

(6) The decision to build a coal-fired unit at this time with new harbor and extensive coal unloading and storage facilities would be a judgment decision, as a large differential coal-oil escalation rate of 3 to 4 percent would probably be required to justify the construction. This would also assume that the large differential escalation rate would continue for 25 years.

(7) The use of a combined-cycle gas turbine does not obviate the eventual use of coal. If one of the low-Btu coal gasification processes proves commercially feasible, it can supply coal gas to the gas turbines and capitalize on the benefits of a very low station heat rate of approximately 8,750 Btu/kWh as compared with about 10,500 Btu/kWh for a coal-fired unit.

7.1.6.2 Recommendations

The following recommendations are made:

(1) JPS and the Jamaican government should obtain sufficient foreign exchange to implement a program to maintain and upgrade existing power plant units to realize the potential fuel savings available from the newest, most efficient units. Such a program, if not already accomplished should be initiated immediately with all of the specific upgrading requirements identified.

(2) Exploratory negotiations should be started immediately with Alcan and JBM regarding the joint use of their harbor facilities and site at Port Esquivel and Cuckold Point, respectively. If these negotiations prove positive, it is recommended that a more detailed cost estimate for installing a coal-fired unit on one of these sites be prepared and compared with the expected cost benefit for burning coal.

(3) If an adequate cost benefit is shown, it is recommended that a coal supply and shipping study be authorized to confirm the delivered price of coal to Jamaica. This will provide the necessary back-up to more accurately determine the expected cost savings for burning coal and will provide the basis for future coal contract negotiations.

(4) A pre-investment feasibility study is not recommended at this time; however, in about 2 1/2 to 3 years, if the JPS availability improvement program shows continual success, coal-oil mixture (COM) firing in oil-fired boilers is proven feasible, and oil prices continue to increase by 1 to 2 percent more than coal, it is recommended that a full-scale feasibility and site selection study be authorized. (Note: Recommendation (2) should not be delayed awaiting this full-scale study as the task will provide JPS with planning information and permit them to move quickly with a primary coal-fired installation on an existing port site if COM is not feasible.)

(5) Technology advances in coal gasification and COM firing should be monitored closely, and as systems are proven feasible they should be examined for applicability in Jamaica.

7.1.7 Complete Study Report

The Coal Prefeasibility Study section of the final report is separately contained in Volume IV, Chapter 7 - ESI Report No. EA 30-0101-4.

To assist those readers of this Executive Summary who may desire additional information, selected data have been extracted from the main report and have been included in Section 7.1.8 as supplementary information.

7.1.8 Supplementary Information

This Section provides background information on coal-fired and combined cycle systems, along with an introduction to two potential alternative generation schemes: coal-oil mixture firing, and coal gasification. It also provides study information on: JPS fuel oil consumption; availability of existing oil-fired units; load growth and systems expansion; and cost data applicable to a new 65 MW power station.

7.1.8.1 Electric Power Generation Systems

Electric power can be generated using a variety of energy sources, principally, coal, oil, gas, nuclear, and hydropower. About 76 percent of the electricity in the United States is produced in conventional power generation systems using coal, oil, or gas -- 74 percent in steam turbines and 2 percent in gas turbines or diesel engines. (Gas turbines and diesel engines often are used for standby power generation during periods of peak loading on the utilities grid or during unscheduled outages.) By comparison, about 97 percent of the electric generation capacity of Jamaica Public Service is in conventional power generation systems using oil or gas -- 74 percent in steam turbines, 19 percent in gas turbines and 4 percent in diesel engines.

7.1.8.2 Coal-Fired Unit

The efficient combustion of coal for industrial purposes requires a system that differs with the rank or type of coal, the required firing rate (load capacity) and the time-profile and quality of the steam load.

The three conventional methods for firing coal in a steam boiler are stoker, pulverized-coal, and cyclone-firing. Stoker systems are limited in size to boilers that can produce about 400,000 lb/hour of steam. For boilers with large capacities, other firing methods are more economical. The primary advantage of stoker systems is their versatility; they have a wide operating range and burn all types or ranks of coal.

7.1.8.3 Combined-Cycle Systems

Combined-cycle systems are comprised of two or more different thermodynamic cycles connected in a way to gain maximum efficiency from the primary heat source. In most cases, both cycles are used for the same purpose -- usually to generate electricity. Such systems using coal or coal-derived fuels offer significant improvements over conventional systems for electric power generation in terms of increased efficiency, potentially lower cost, and reduced environmental impact. The major combined-cycle options currently under development include: open-cycle gas turbines; closed cycle turbines; fuel cells; and magnetohydrodynamics. Advances in combined-cycle power plants focus on high-temperature gas turbines combined with steam systems.

7.1.8.4 Coal-Oil Mixture Firing

There are a number of programs currently underway which seek to demonstrate the feasibility of using coal-oil mixture (COM) as a replacement boiler fuel for oil. There is general agreement that the lower the ash content, the greater the probability that such fuels will be a viable substitute for oil.

7.1.8.5 Coal Gasification

There are several commercially proven coal gasification processes. The two most important are the Lurgi pressurized process (based on 40 years of continuous development) with 14 commercial plants comprising 65 gasifiers around the world, and the Koppers-Totzek process with 16 plants in Europe (the first in Finland, in 1952) and Asia, comprising 48 gasifiers in operation or under construction.

Many coal gasification processes are being investigated and some may prove to be a viable alternative to burning oil in Jamaica. It will take approximately two or three years to prove the feasibility of one of these processes. At that time, a study in greater depth can be made as to the feasibility of installing a gasification plant to supply medium-Btu gas to existing boilers in Jamaica.

7.1.8.6 Fuel and Energy Consumption

Fuel oil consumption and energy generation is summarized in Table 7-1 for the Jamaica Public Service Company, Ltd. and the bauxite/alumina industry, as these are the two areas of the economy under review in this study.

7.1.8.7 Availability of Existing JPS Units

Although an operational review of existing JPS units was not a part of this study, the following was evident and is pertinent to the installation of new generating equipment.

TABLE 7-1

FUEL AND ENERGY CONSUMPTION
1973 1978

	1973	1974	1975	1976	1977	1978
Petroleum Consumed						
1000 Barrels						
Jamaica Public Service	2,705	2,490	2,658	2,704	2,797	2,620
Bauxite/Alumina Ind.	10,189	9,382	7,556	6,193	7,034	7,732
Other	7,341	6,594	7,279	6,651	6,030	
Total, 1000 Barrels	20,280	18,466	17,493	15,554	15,861	
Net KWh Generated						
10^6 KWh						
Jamaica Public Service						
Steam	946.1	938.1	985.0	1,100.6	1,048.3	1,119.8
Gas Turbines	96.1	75.7	126.7	61.0	167.3	72.4
Diesel	57.0	57.2	51.7	51.4	167.3	36.4
Hydro	98.4	121.8	131.2	110.4	109.1	114.7
	1,198.5	1,192.8	1,294.8	1,325.0	1,324.7	1,343.3
Bauxite/Alumina Ind.	869.4	906.8	840.7	630.2		
Other	99.2	96.6	109.4	103.0		
Grand Total	2,167.1	2,196.2	2,234.9	2,058.0		

The JPS installed system capacity is approximately 455 MW (Table 7-2) which is greatly in excess of the existing peak loads of about 210 MW. Thus, a new unit should not be justified on the basis of insufficient system capacity. Blackouts occur almost daily due to unit outages and particularly poor availability of the newest, most efficient units. Although this was not part of the study nor fully investigated, it appears there is a lack of spare parts and adequate maintenance, with very little if any preventative maintenance. Spare parts and maintenance assistance by manufacturers' representatives require foreign exchange, and this appears to be one of the major problems. The use of inefficient, old steam units and high fuel cost gas turbines consumes extensive fuel and foreign exchange. The study indicated that a new oil-fired unit with about the same heat rate as the newest, most efficient units on the JPS system would pay for itself if operated at a 65 percent capacity factor.

7.1.8.8 Load Growth and System Expansion

JPS provided the forecasted power sales for the system for 1979 through 1991 (Table 7-3).

7.1.8.9 New 65 MW Power Station

The study indicates a new coal-fired plant will return the greatest savings if it can be placed at an existing port facility with minimum additional plant cost for coal unloading facilities. The cost saving summary of the evaluation with costs levelized from 1985 is contained in Table 7-4.

TABLE 7-1

INSTALLED GENERATING UNITS AS OF OCTOBER 1979

	Year of Commissioning	Size MW
Steam		
Old Harbour 1	1968	17.0
Old Harbour 2	1970	54.0
Old Harbour 3	1972	60.0
Old Harbour 4	1973	65.0
Hunts Bay 1	1953	9.5
Hungs Bay 2	1955	9.5
Hunts Bay 3	1958	13.5
Hunts Bay 4	1960	13.5
Hunts Bay 5	1962	19.0
Hunts Bay 36	1975	65.0
Total Steam		306.0
Gas Turbines		
GT 1 Hunts Bay	1968	13.0
GT 2 Hunts Bay	1969	13.0
GT 3 Bogue	1973	20.0
GT 4 Hunts Bay	1974	20.0
GT 5 Hunts Bay	1974	20.0
Total Gas Turbines		86.0
Diesels		17.5
Hydro		15.2
Total System		454.7

Maximum continuous net rating (output to lines).

TABLE 7-3

SYSTEM LOAD FORECAST
JAMAICA PUBLIC SERVICE COMPANY, LTD.

Year	Sales MWh	16% Losses MWh	Total Generation, MWh	System, MW Ave.	System, MW Peak
1979	1,057,100	169,136	1,226,236	140	209
1980	1,051,591	168,255	1,219,846	139	208
1981	1,065,774	170,524	1,236,298	141	211
1982	1,103,637	176,582	1,280,219	146	218
1983	1,137,535	182,006	1,319,541	151	225
1984	1,167,988	186,878	1,354,866	155	231
1985	1,199,721	191,955	1,391,676	159	237
1986	1,242,013	198,722	1,440,735	164	245
1987	1,271,760	203,482	1,475,242	168	251
1988	1,205,962	192,954	1,398,916	160	238
1989	1,266,162	202,586	1,468,748	168	250
1990	1,413,135	226,102	1,639,237	187	279
1991	1,472,906	235,665	1,708,571	195	291

TABLE 7-4

CAPITALIZED FUEL COST SAVINGS

Jamaican $	Equivalent Generation By Existing Units	New Coal Fired Unit	Combined Cycle Gas Turbine	Diesel	New Oil Fired Unit
Annual Fuel Cost Savings	Base	47,107,000	32,123,000	35,702,000	19,279,000
Capitalized Fuel Savings	Base	362,358,000	247,183,000	274,647,000	147,309,000
Capital Cost 1985	Base	179,510,000	72,118,000	134,327,000	129,448,000
Net Savings	Base	182,848,000	175,065,000	140,320,000	18,861,000
Net Savings Compared to New Oil Fired		163,987,000	156,204,000	121,459,000	Base
U.S. $					
Annual Fuel Cost Savings	Base	26,918,000	18,362,000	20,402,000	11,017,000
Capitalized Fuel Savings	Base	207,062,000	141,125,000	156,941,000	84,748,000
Capital Cost 1985	Base	102,577,000	41,210,000	76,758,000	73,970,000
Net Savings	Base	104,485,000	99,915,000	80,183,000	10,778,000
Net Savings Compared to New Oil Fired		93,707,000	89,137,000	69,405,000	Base

8.0 ELECTRIC UTILITY RATE ANALYSIS

8.1 EXECUTIVE SUMMARY

8.1.1 Introduction

The structure for pricing electricity in Jamaica has evolved over a period of many years. The current pricing system contains a number of features which were instituted for very good reasons during a period of lower priced oil imports. Many circumstances have changed since these features were adopted, however, thus providing reason to question their continued use. Tremendous price increases for imported oil, reduced customer demand, high costs for any new generation and distribution equipment, and the desire to reduce foreign exchange expenditures have all been factors which precipitated this study. The foreign exchange situation has been very damaging to the Jamaican economy, especially that caused by foreign oil imports. As the disparity between goods sold abroad or foreign currency brought into Jamaica and that Jamaican currency which must be used to purchase goods abroad (such as oil) increase, the Jamaican currency loses value. The situation is self-perpetuating in that one encourages the other, consequently the cost of oil imports in real Jamaican dollars is increasing more drastically.

8.1.2 Terms of Reference

The electric utility rate analysis has as its goal a thorough examination of the tariff structure of the Jamaica Public Service Company (JPS) in order to determine whether it (a) promotes an economically efficient use of electricity in the society; (b) is consistent with basic principles of equity and fairness; and (c) provides the company (JPS) with sufficient resources to maintain an acceptable quality of service. JPS officials specifically requested that the study focus on findings and options so that JPS could examine these options and draw specific conclusions and recommendations themselves for presentation to the Ministry of Public Utilities.

8.1.3 Background Information

There has been a worldwide movement toward marginal cost pricing for electricity as a means of keeping costs as low as possible. Marginal cost pricing may be used to modify the accounting approach traditionally used to price electricity. Pricing signals to customers are important factors in reducing electricity use and imports of foreign oil. The current declining block pricing structure, based on accounting costs, does not provide adequate pricing signals to customers. Customers are given a pricing signal which, in the higher usage blocks, charges them less than

the average cost of providing the power. This signal does not provide enough conservation information, and also has the effect of reducing earnings for JPS as the customer uses increased amounts of power in the higher usage blocks. This study, using marginal cost pricing philosophy, offers options to policy makers in Jamaica for changing the JPS electricity pricing structure.

8.1.4 Study Method

During the study, the team members attempted to become knowledgeable about the social and economic goals of Jamaica, and to take them into account when picking the most likely options for analysis. With this in mind, options for JPS have been developed. However, only those in Jamaica, with the ongoing knowledge of their nation, can make the final decisions on which of these options to implement.

In performing the analysis, several assumptions were made which are important to reader understanding of the efforts:

(1) Total revenues to JPS will not be increased or decreased by the adoption of the prepared options;

(2) Customer categories continue to generate revenue in the same relationship to one another as at present;

(3) Declining block pricing should be eliminated;

(4) Ratchet and expander clauses should be eliminated;

(5) Time of use pricing will be considered if appropriate; and

(6) The fuel adjustment and cost of service clauses will be continued.

Taking into account these considerations, Jamaican decision-makers have been provided several options for electricity customers, including tariffs for immediate or phased-in adoption, which move toward marginal cost-based rates.

8.1.5 Findings

Table 8-A is a summary of existing JPS tariff structure; the discussion of this structure follows.

8.1.5.1 Residential Tariffs (Rate 10)

Residential tariffs currently appear to be structured with steeply declining blocks. The effect of declining block tariffs is to reduce the conservation signals

TABLE B-A

SUMMARY OF EXISTING ELECTRIC TARIFFS IN JAMAICA

CUSTOMER CLASS	TARIFF REFERENCE	GENERAL TARIFF DESCRIPTION	TARIFF STRUCTURE, JAN 1980 J.$	
			Customer Charge	$1.99/month
Residential (Rate 10)	B - 10	o Declining Block (cost decreases with usage) o Monthly rate adjusted for inflation o Fuel adjustment clause	Use(kWh) 10 or less Next 20 Next 70 Next 290 Next 200 Over 500	 0 10.00¢ 15.13¢ 11.01¢ 7.00¢ 6.25¢
Small Commercial (Rate 20)	B - 11	o Declining Block (cost decreases with usage) o Monthly rate adjusted for inflation o Fuel adjustment clause	Customer Charge Use(kWh) 10 or less Next 90 Next 900 Next 9,000 Next 10,000	$1.99/month 0 29.64¢ 13.51¢ 10.64¢ 8.00¢
Large Commercial (Rate 40)	B - 12	o Two-part tariff - power (kW) and energy (kWh) o Demand charge = 12 mo. ratchet* o Energy charge = Declining Block + expander** o Fuel clause o Monthly rate adjusted for inflation	Demand Charge First 100 kW demand Next 200 " " Over 300 " "	$2.15/kW/month 6.00¢/kWh 5.00¢/kWh 4.50¢/kWh
Industrial	B - 13	o Two-part tariff - power (kW) and energy (kWh) o Demand charge = 12 mo. ratchet* o Energy charge = Declining Block + expander** o Fuel clause o Monthly rate adjustment for inflation	First 100 kW demand Next 200 " " Next 200 " " Over 500 " "	6.00¢/kWh 5.00¢/kWh 4.00¢/kWh 3.50¢/kWh

* Ratchet: A disincentive charge for increased use of power. A specific billing period's maximum demand is compared to previous months' (usually 11 or 12 months) maximum demand.

** Expander: Reduction in customer's energy charge when use in kWh's increases for a fixed level of maximum power, kW.

which are given to the residential customers. However, cost of service and fuel clause adjustments levied by JPS significantly reduce the relative differentials paid for levels of consumption in the different blocks.

Several tariff options are offered based upon marginal cost pricing principles, including those which might be termed ultimate tariffs, and several which could be used in phases, including modifications to the present tariff, an inverted block tariff and a declining block tariff. Detailed comparisons are provided to illuminate the impacts of the various tariffs on customer billings.

8.1.5.2 Small Commercial Tariffs (Rate 20)

Small commercial customers are served under a tariff with declining block features similar to the residential tariff. As with the residential sector, the most accurate price signals are not being provided to the customers. Jamaican decision-makers may choose from various tariffs developed herein, including eliminating two of the blocks in the declining block structure, utilizing flat rates, or using a tariff with a slightly inverted block structure. As with the residential options provided, phasing-in alternatives are included and detailed bill analyses are provided.

8.1.5.3 Large Commercial Tariffs (Rate 40) and Industrial Tariffs (Rate 50)

Not only the amount of power, but the time during which it is used must be considered. In the JPS system there are differences in generation costs depending on the time of day. Although the differences are not large, they are large enough to warrant installation of time-of-day recording meters for the large industrial customers and modification of the electricity pricing structure to take into account the time-differentiated generation costs. If the current system was operating at design capabilities (excess generation capacity) equipment could be retired which could, at some point in the future, increase the time-of-day generation cost differential. This provides another reason to consider placing the 24 industrial customers on a time-of-day tariff. If such a tariff is adopted, it should be carefully explained to the customers before its effective date, and could be offered as an optional, rather than a mandatory, tariff. A period of time during which customers receive billing comparisons for both old and new tariffs might also be considered.

It is suggested that other features of the large customer tariffs, such as the "ratchet" and "expander" clauses, be examined. "Ratchet" clauses discourage customer growth in maximum demand, but, at the same time, encourage demand up to a level established by the customer during a previous billing period. "Expander" clauses, while encouraging customers to improve their individual load factors, do not ensure that system load is levelized.

8.1.5.4 Large Commercial Tariffs (Rate 40)

The currently offered two-part tariff is not consistent with marginal cost pricing principles. However, options are presented both to continue and to eliminate the two-part tariff. It is suggested that the "expander" clause be eliminated early in any changes to the tariff structure, with eventual elimination of the "ratchet" clause. Additional tariffs are also provided which take into consideration differences in generation costs between peak and off-peak times. For better understanding of the impact of the options presented, detailed bill comparisons are provided.

8.1.5.5 Industrial Tariffs (Rate 50)

As with the Rate 40 tariff, the elimination of the "expander" and "ratchet" clauses is suggested. Several possible options provided for consideration include two-part, one-part, flat, and time of use tariffs. As with the other rate categories, detailed bill analyses are presented to explain customer impacts.

8.1.6 Discussion of Findings

After analyzing the existing JPS tariff system, the study team then developed tariff options based on marginal costs principles. Marginal cost is simply the cost (or savings) incurred by the utility in providing more (or less) electricity. In very general terms the following statements will help explain the marginal cost principles used to develop options for JPS:

- Marginal cost of providing electricity as stated above is passed on to the consumers;
- These costs must be equitably apportioned among consumers;
- The allocation of society's scarce resources among alternative uses must be efficient;

- Resources are channeled from one use to another primarily as a response to pricing signals;

- This channeling as a response to price may be distorted by (1) absence of competition or (2) existence of societal concerns. Both exist in the pricing of electricity; and

- The primary task of regulators and decision-makers is to see that prices perform the signalling function.

Table 8-B is an overview of options which utilize marginal costs principles in electricity pricing in Jamaica. The following general conditions applied to the development of these options.

(1) Total revenue requirements will not be changed;
(2) Total revenue allocations between customer categories will not be altered;
(3) Declining block pricing will be eliminated;
(4) Ratchet provisions will be eliminated;
(5) Expander tariffs will be eliminated;
(6) Flat (both all-energy and two-part) demand and energy tariffs will be considered;
(7) When metering and customer acceptance seems reasonable, time of use pricing will be considered;
(8) The very progressive (from an efficiency standpoint) fuel adjustment clause will be continued;
(9) The innovative Cost of Service adjustment will be retained; and
(10) Continuing the residential customer flat rate with the first 10 kWh included free will be presented.

These marginal cost pricing principles were used to develop the tariffs which follow for each customer category.

8.1.7 Conclusions and Recommendations

Rather than making specific recommendations as to what type electric tariff structure JPS should adopt, this study, in response to JPS request, outlines basic tariff options and compares them to the existing tariff structures. The impacts and introduction schemes of these tariff options for various sectors of the economy are discussed. The structure of these options is too detailed for this executive summary to sufficiently discuss their meanings and impacts. Thus, the reader is referred to Section 8.7 of the study report for a review of the options for

TABLE 8-8

A SUMMARY OF OPTIONS BASED ON MARGINAL COST PRINCIPLES

CUSTOMER	TARIFF OPTION	DISCUSSION	EXAMPLE TARIFF STRUCTURE*			ILLUSTRATED TARIFFS
Residential (Rate 10)	o Flat Tariff	o The same rate regardless of usage	All Usage		11.66¢/kWh	8-19A
	o Inverted Block	o Costs increase with usage	0-10 kWh	0¢	10.60¢	8-19B
			11-100 kWh	12.19¢	10.60¢	8-20A
			over 100 kWh	12.60¢	12.60¢	8-20B
Small Commercial (Rate 20)	o Flat Tariff (Low)	o The same rate regardless of usage	All Usage	12.42¢	12.77¢/kWh	8-21A
	o Inverted Block	o Costs increase with usage	0-1000	11.274¢		8-21B
			over 1000	13.274¢		8-22
Large Commercial (Rate 40)	o Flat Tariff with Demand Charge	o The same rate regardless of usage - Two factors determine Rate: (1) Maximum power requirement (kW) above established level; (2) Total energy demand over a period of time (kWh)	2.15¢/kW/mo. + 6.11¢/kWh			8-23 8-24
	o Peak - Off-Peak with Demand Charge	o Less is charged during periods of low demand - Same two factors above (kW and kWh) determine charge	2.15¢/kW/mo. + 7.11¢ during peak or 4.11¢ during off-peak			8-25
	o Increased Revenue	o Declining Block (more usage - less cost) -- not as steep as existing blocks	First 100 hrs		6.38¢ + 2.15¢/kWh	
			Next 200 hrs		5.38¢ + 2.15¢/kWh	
			Over 300 hrs		4.59¢ + 2.15¢/kWh	
	o Flat Tariff - No Demand Charge	o Flat rate with no two-part charge as above	All Usage		6.11¢/kWh	
	o Peak - Off-Peak No Demand Charge	o Flat rate for peak time usage -- another less expensive flat rate for off peak usage	Peak Usage		7.89¢/kWh	
			Off-Peak Usage		4.89¢/kWh	

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various sectors of Jamaica. Several assumptions are made with some in the form of recommendations. These were shown previously in Section 8.1.4.

The overall conclusion is that JPS and Jamaican decision-makers should review and compare these options in light of their overall economic goals and plans. From these options, discussions should be conducted to decide which rate tariff changes would derive the most benefit for all concerned.

8.1.8 Complete Study Report

The Electric Utility Rate Analysis section of the final report is separately contained in Volume V, Chapter 8 - ESI Report No. EA 80-0101-5.

9.0 REFERENCES

1. Economic and Social Development, Country Studies Division - Jamaica; Socio-economic Report (Volume 1), Washington, D.C.; InterAmerican Development Bank, July 2, 1979.

2. National Planning Agency; Economic and Social Survey - Jamaica 1978; Kingston, Jamaica; Government of Jamaica, 1979.

3. Energy Planning and Coordination Unit, Ministry of Mining and Natural Resources in collaboration with the National Planning Agency and Ministry of Finance and Planning; Five Year Development Plan 1978-1983: Energy Sector Plan; Kingston, Jamaica; Government of Jamaica, 1978.

4. Latin American and the Caribbean Regional Office, the World Bank; Current Economic Position and Prospects of Jamaica (Report No. 2504 - JM); Washington, D.C.; The World Bank, May 2, 1979.

5. National Planning Agency, Ministry of Finance and Planning; Five Year Development Plan 1978-1983: Main Report (First Draft); Kingston, Jamaica; Government of Jamaica, March 1978.

10.0 APPENDICES

APPENDIX A

TERMS

OF

REFERENCE

STATEMENT OF WORK

A. Objective

The objectives of this activity are:

1. To conduct, by a team of experts, a study to assist the Government of Jamaica (GOJ) in further program development under its Five Year National Energy Plan (1978-1983).

2. To assess the feasibility of, and/or requirements for, successful implementation of particular key projects and programs.

3. To provide the baseline information necessary to identify potential opportunities for future support in the general area of Energy.

B. Scope of Work

Task 1 - Study Integration and Project Management

The scope of the first task is to develop a detailed study plan based on the information contained in this Statement of Work. The plan will contain a detailed schedule of all study activities and manpower allocations. The plan will include a Project Management Plan, an initial identification of the outline of task reports, work flow functional diagrams, preliminary identification of study tasks, and data requirements between tasks. Also included will be a definition of criteria, assumptions and procedures to be used in the study. Although subject to later revision as information and analysis proceed, the study plan will serve as the basic management and control procedure for the remainder of the study.

Upon approval by the USAID Mission to Jamaica and the Government of Jamaica, Energy Division, Ministry of Mining and Natural Rescources, the study plan will be implemented and used to accomplish Tasks 2 through 7 specified below.

The scope of work to be implemented includes the following specific subtasks:

1. Overall management of the U.S. Study Team

2. Overall U.S. Team Coordination

3. Overall Coordination between U.S. Team and GOJ and Jamaican personnel, as well as with USAID Mission.

4. Planning and conducting periodic Study Reviews in support of GOJ.

5. Preparation, review and integration of draft and final Study Reports.

Task 2 - Economic Assessment

The Government of Jamaica Five Year Development Plan (1978-1983) Energy Sector Plan, serves as the baseline planning document establishing the requirements for the specialized studies of the energy projects defined in Tasks 3 through 7. After the specialized studies are sufficiently underway, the energy projects proposed by the individual studies will be reviewed for their general energy implication on The Five Year Development Plan. Appropriate changes to the Energy Plan will be recommended to the GOJ Energy Division, Ministry of Mining and Natural Resources.

Based upon the above work a coordinated summary report on economic aspects of energy projects, drawing broad policy implications shall be prepared.

Task 3A - Solar Energy - Commercial & Industrial

Task 3B - Solar Energy - Agricultural

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 1 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.

Task 4 - Biogas Applications

The study shall assess the feasibility of biogas generation in rural agricultural areas. Included in the assessment shall be an examination of the following: size of livestock holdings, feasibility of collecting animal wastes, the possible use of biogas to provide cooking, and lighting in rural areas that are without access to electricity.

Particular attention should be paid to medium-scale installations (approximately 100 cattle or equivalent in animal waste) and installations appropriate for agricultural research stations, agricultural schools and other schools and rural communities to be specified by the Government of Jamaica.

The study should also address the feasibility of the generation of biogas as an integral part of the sewage treatment facilities of the Jamaican campus of the University of the West Indies.

Pertinent projects already initiated by the Ministry of Mining Energy Division, the Scientific Research Council and others should be reviewed in detail. The report should include recommendations for follow-on projects that might be undertaken. In such projects, adaptive programs should be emphasized, rather than basic research.

Task 5 - Coal Prefeasibility Study

The objective of this task is to prepare a prefeasibility study on the potential of substituting imports of steam coal (particularly 3% sulphur coal) for some imported 3% sulphur #6 fuel oil. The study will include a recommendation to the GOJ as to the desirability of conducting a full pre-investment feasibility study of this subject. If the recommendation is positive, a scope of work for a full feasibility study should be prepared. Particular attention should be given to the economics of coal imports for satisfying a large part of the primary energy needs of the steam raising plants of the Jamaica Public Service Company (JPS) System. Discussions should be held with the operators of the alumina plants (Alcan, Alcoa and Alpart) in Jamaica to ascertain what studies/analyses they have performed or intend to perform regarding the use of imported coal to raise steam in

their power plants. The results of any studies performed by these companies should be commented on.

The study should also assess the technical, economic and evironmental feasibility of diversification into coal. In particular, the study should address the following:

1. The possibility and terms of obtaining long-term supply contracts for steam coal (particularly 3% sulphur coal). Price projections for such coal for up to ten years should be made.

2. Feasibility of transporting coal to Jamaica from U.S. Eastern Seaboard ports in bauxite ships returning on the backhaul, or by other appropriate modes.

3. The location of port handling facilities and storage facilities at port and plant sites. In particular, two schemes are to be assessed: unloading at Old Harbour for use at the JPS Old Harbour Plant and unloading at Montego Bay with overland rail transport to Old Harbour. The latter scheme is to be considered in relation to proposals to use port facilities in Montego Bay for trans-shipment and distribution of metallurgical coal in the Caribbean.

4. The possibility of retrofitting existing units on the JPS system to burn either steam coal or a mixture of coal and oil and the possibility of using either of these fuels in projected new plants on the JPS system.

5. The possibility of carrying out similar retrofitting in alumina plants, bearing in mind any proposals of the companies themselves, and the possibility of burning coal or coal/oil mixtures in any new alumina plants.

6. The potential environmental impact of diversification into coal and possible methods and anticipated costs of ameliorating adverse impacts.

Task 6 - Electric Utility Rate Analysis

The purpose of this study is to derive a practical tariff structure which:

1. Promotes a more economic use of electricity in the Jamaican Society.

2. Maintains the financial viability of the electric utility.

3. Optimizes the use of fuel and foreign exchange.

4. Meets any income distribution objectives (e.g., subsidizing poorer consumers) which the electricity tariff may be required to serve.

The study should include the following elements:

1. The determination of the long-run marginal cost of supply by analyzing the marginal costs of generating, transmitting and distributing electricity to consumers at different places, times and voltage levels. This will require due attention to the daily and seasonal variations in actual and, to the extent possible, in forecast demands of various consumer classes. Much of the required information may have to be specially collected, e.g., by taking substation readings, by inquiring about shift-working and seasonal work patterns and by statistical analysis of available load curves. Particular attention should be given to identification of consuming sectors responsible for unusually high demands during peak load periods.

2. An examination of the present customer classifications to determine if each class exhibits appropriate characteristics (e.g., cost/consumption). Based on this examination, a recommendation for modifications to the customer classifications would be developed.

3. An analysis of price elasticities and associated response times for each customer classification (using available historical data). This analysis would include the effect of changes in the prices of electricity, appliances and equipment on consumer demand.

4. An investigation of the social benefits to be derived from subsidizing poorer consumers and the development of a puantitative index of the benefits derived (or the identification of such an index developed in other studies).

5. A determination of the revenue requirements to maintain the financial viability of the electric utility.

6. A determination of the foreign exchange required to operate the utility.

7. A new tariff structure should be developed based on consideration of the factors outlined above, along with considerations of practicality such as metering and administration.

8. A determination should be made of the sensitivity of the foreign exchange requirement to changes in the tariff structure, in particular a structure that promotes shift to selected loads from peak to off-peak.

9. The new tariff structure should be compared with the existing tariff structure, and the implications of a change to a new tariff investigated. Of particular concern would be the effect of price elasticity (for each consumer classification), the effect on present or potential industrial growth and probable consumer reaction.

10. A formula permitting automatic adjustment of the new tariff to allow for changes in the cost of fuel should be developed.

11. Recommendations for the expedient implementation of the new tariff structure (as proposed after any required revisions) should be developed.

12. A load forecast study involving the development of a computer based model to be used by the JPS for electric load forecasting, including projections of the requirements for additional generating capicity, transmission lines and major substations and geographic distribution of the electric load.

The study should be conducted in such a way that the maximum amount of training is imparted to the Jamaican counterparts in order that they may undertake on their own future updating of the tariff structure.

Task 7 - Energy Conversion from Waste

An assessment shall be made of the feasibility of constructing a prototype unit to produce energy, fertilizer and other by-products from the waste and refuse of the Mona Campus of the UWI which has its own sewage treatment plant (50,000 gallons of water per day), refuse dumps and incinerator.

The assessment will include a determination of the amount and type of waste available on campus, a technical evaluation of alternative approaches to energy conversion from the waste, a determination of the quality of the water to be expected to be produced from the various approaches, a determination of the availibility of applying the approaches to sewage and dry refuse handling in rural and urban areas of Jamaica, a recommendation as to preferred approach and a detailed estimate of the costs of the recommended system. Personnel of the UWI should be involved in all the required activities to the maximum extent possible. The assessment will be conducted in coordination with the study of biogas described above.

APPENDIX B

PROFILES of the UNITED STATES ENERGY

TEAM MEMBERS

PROFILES OF THE UNITED STATES ENERGY TEAM MEMBERS

1. Herbert C. Yim - U.S. Energy Team Leader

- Mr. Yim was responsible for the overall organization and management of the U.S. Energy Team which conducted the "Preliminary Energy Sector Assessments of Jamaica". Under contract to the U.S. Agency for International Development, his company, Energy Systems International, was responsible for the overall integration of all study task elements. Mr. Yim was also responsible for ensuring the coordination and joint team efforts between the U.S. Team Members and their Jamaican counterparts.

- Mr. Yim is a specialist in systems engineering -- project management for major energy and space systems programs. He was selected as a President's Interchange Executive to serve in the U.S. Government for 1 1/2 years in 1975. He specialized in domestic and international planning and analysis for solar energy programs. Mr. Yim was assigned to the U.S. Energy Research and Development Administration (now the U.S. Department of Energy). He has approximately 27 years of professional experience in engineering; the last sixteen years have been in systems planning, project management and systems engineering. His specialties include:

  - Conceptual and definition phase planning for energy programs;
  - Planning, organization and implementation of national and international energy projects and programs; and
  - Multilateral and bilateral international cooperative energy projects.

- Mr. Yim's academic background includes: B.S., Mechanical Engineering, U. of California, Berkeley, Ca.; M.S., Mechanical Engineering, U. of Southern California; and Cert. Meteorology, U.S. Naval Postgraduate School.

2. Gary G. Roberts - Deputy U.S. Energy Team Leader

- Mr. Roberts shared the responsibility for the overall organization management and coordination of all of the Jamaican Energy Study Task Elements. He was instrumental in the overall planning and development of the system, which put the project on stream. He was specifically responsible for the management of the specialized studies, interface coordination with the Jamaican counterpart organizations, and the USAID Project Office.

- Mr. Roberts has a systems engineering background which includes project management, process engineering management and systems design for major hardware system programs. He is engaged in providing operational support in the area of policy and program planning for international solar cooperation and commercialization activities of the U.S. Department of Energy. His specialities include:

  - Project/systems engineering management; and
  - Systems planning.

- Mr. Roberts' academic background includes: B.S., Aerospace Engineering, U.S. Naval Academy; M.S., Systems Management, U. of Southern California.

3. David Edelman - U.S. Energy Team Member

- Dr. Edelman was responsible for the Economic Assessment of the Jamaica Energy Study. The specific study objective was to determine the general implication of the U.S. Energy Team specialized study recommendations on the Five Year Energy Sector Plan. He was responsible for integrating all of the U.S. Energy Team recommendations into a priority listing and identifying the cost/benefits of the various recommendations along with impacts on energy savings and energy policies.

- Dr. Edelman is a specialist in energy policy planning and economic analysis for a variety of international renewable energy projects and programs sponsored by the U.S. Department of Energy. He has been a consultant for various energy issues in many countries in the Middle East, Africa, Asia, South America, Central America and the Caribbean. Dr. Edelman has also served as a

Consultant to U.S. projects involving urban and regional development policy and environmental planning. His specialty is:

- Alternative energy development in developing countries.

o Dr. Edelman's academic background includes: A.B., History, U. of Rochester, New York; M.R.P., Cornell U; and Ph. D., Policy Planning and Regional Analysis, Cornell U.

4. Thomas Y. Lewis - U.S. Energy Team Member

o Mr. Lewis was responsible for the Solar Commercial-Industrial segment of the Jamaica Energy Study. The specific study objective was to assess the potential of solar energy for heating, cooling and hot water applications in Jamaica. He was responsible for making selected feasibility studies to determine the technical, economic and commercialization potential for solar water heating applications involving hospitals, hotels, and industry.

o Mr. Lewis was the lead engineer and principal designer of one hundred and twenty commercial and residential solar heating and cooling projects including active, passive, solar thermal and photovoltaic systems. He was also the lead engineer responsible for the detailed design of the domestic hot water system for the White House, Washington, D.C., and principal investigator for six industrial process solar heating projects. Mr. Lewis has approximately nine years of experience in project management and engineering and is a consultant in solar energy and conservation systems. His specialty is:

- Systems design of solar heating, cooling and hot water systems.

o Mr. Lewis' academic background includes: B.S., Mechanical Engineering, Texas A&M.

5. Blaine F. Parker - U.S. Energy Team Member

o Dr. Parker was responsible for the Solar Agricultural segment of the Jamaica Energy Study. The specific study objective was to assess the potential of solar energy for agricultural applications in Jamaica. He conducted a technical and economic assessment of near-term applications for large and

small-scale crop drying at the regional, commercial and farm level.

- Dr. Parker is a Professor of Agricultural Engineering at the University of Kentucky. He served as Chairman of the Deparment for sixteen years. His first research in solar energy was preheating ventilation air for livestock shelters in 1958. For the last five years he has devoted his time to research and design of solar collectors and solar heating systems. Dr. Parker holds several patents on solar air heaters. He is listed in Who's Who in America. His specialty is:

  - Research and design of solar collectors and solar heating systems.

- Dr. Parker's academic background includes: B.S., Agricultural Engineering, Virginia Polytechnic Institute; Ph. D., Agricultural Engineering, Michigan State U.

6. Rolf T. Skrinde - U.S. Energy Team Member

- Dr. Skrinde was responsible for the Biogas Applications segment of the Jamaica Energy Study. The specific study objective was to assess the feasibility of biogas generation in rural areas of Jamaica. The study included small and medium scale installations for farms, agricultural communities or research centers.

- Dr. Skrinde has extensive experience in international consulting in environmental engineering and renewable energy programs. He has consulted in over fifteen countries in the Middle East, North and South Asia, and Europe. Dr. Skrinde has approximately 26 years of international experience. He has served as Energy Consultant to The National Science Foundation, and the U.S. Department of Energy. He has co-authored more than 40 published technical articles and has contributed to approximately 200 consultant reports on energy and the environment. Dr. Skrinde is listed in Who's Who in America, Engineers of Distinction, and American Men and Women of Science. His specialties include:

  - Energy studies
  - Waste waters, solid waste and industrial waste treatment
  - Biomass

- Dr. Skrinde's academic background includes: B.S., Civil Engineering, Washington State U.; M.S., Sanitary Engineering, Massachusetts Institute of Technology; Ph. D., Sanitary Engineering, MIT.

7. Walter C. Williams - U.S. Energy Team Member

- Mr. Williams was responsible for the Coal Pre-feasibility Study segment of the Jamaica Energy Study. The specific objective was to assess the potential of substituting imported coal for fuel oil for use in electric power generation. The study addressed the feasibility of: retrofitting existing oil-fired units to burn coal or coal/oil mixtures, providing cost estimates for new coal burning plants, obtaining long-term coal contracts, transporting coal to Jamaica in bauxite ships on the backhaul or other modes, location of port handling facilities, and the required infrastructure to support coal handling operations in Jamaica.

- Mr. Williams has over thirty years of experience in major steam power stations. He has developed expertise in all phases of fossil-powered steam generation including turbines, generators, auxiliary equipment, fuel storage and handling, site development, construction, software support, and total plant and system design. He has conducted numerous studies for industrial corporations which required revision or expansion of their existing steam and power facilities. He prepared the standard master specifications for main turbine generators and associated subsystems. His specialties include:

  - Project engineer for 55600 MW fossil steam power stations
  - Turbine equipment specialist

- Mr. Williams' academic background include: B.S., Mechanical Engineering, Northeastern U.

8. Charles J. Cicchetti - U.S. Energy Team Member

- Dr. Cicchetti was responsible for the Electric Utility Rate Analysis segment of the Jamaica Energy Study. The specific study objective was to assess the current operation and electric utility tariff structure employed by the Jamaica Public Service Company. The study considered the entire economic considerations involved in supplying energy to Jamaica. Specifically, the study analyzed the marginal costs of generating, transmitting, and distributing electricity to all consumers, analyzed price elasticities and associated response times for each customer classification, determined revenue and foreign exchange requirements for utility operation, reviewed the current load forecasting model, and recommended a revised tariff structure for future implementation.

- Dr. Cicchetti specializes in the management of environmental economics and related energy systems and policies. He is a member of the American Economic Association and has spent over fourteen years in the economics field including professorship at the University of Wisconsin and more recently Commissioner of the Public Service Commission of Wisconsin. He is a member of numerous national energy advisory boards and co-authored over fifty publications and articles; in addition, he has made approximately thirty presentations at national and international meetings. His specialties include:

  - Environmental economics and management

  - Energy policy planning

- Dr. Cicchetti's academic background includes: B.A., Economics, Colorado College; Ph. D., Economics, Rutgers U.

9. William J. Gillen - U.S. Energy Team Member

- Mr. Gillen was one of the team members participating in the Electric Utility Rate Analysis segment of the Jamaica Energy Study. The specific study objective was to assess the current operation and electric tariff structure employed by the Jamaica Public Service Company. The study included, among other tasks, the analysis of marginal costs of generating, transmitting, and distributing electricity

to all consumers; price elasticities and associated response times for each customer classification were also investigated.

- Mr. Gillen, over the past eight years has engaged primarily in the economic analysis, planning and pricing of numerous electric utility systems. He has been an economic consultant to the U.S. and Canadian Departments of Energy, numerous federal agencies and state public service commissions. In the fields of electricity economics, public utility regulation, and public interest law he has received research grants from National Foundations and has co-authored seven publications on energy and electricity utilization. His specialties include:

  - Systems planning
  - Economic Consultant - electric utility/systems

- Mr. Gillen's academic background includes: B.A., Economics, George Washington U.; M.A., Economics, G.W. U.; J.D., U. of Wisconsin Law School.

10. <u>Rod Shaughnessy - U.S. Energy Team Member</u>

- Mr. Shaughnessy was one of the team members particip in the Electric Utility Rate Analysis of the Jamaica Energy Study. The specific study objective was to assess the current operation and electric utility tariff structure employed by the Jamaican Public Service Company. In general, the team is considering the entire economic considerations involved in supplying energy to the people of Jamaica. Specifically, Mr. Shaughnessy assessed and determined revenue and foreign exchange requirements for utility operations. In addition to other support tasks, he provided analysis inputs and recommendations for a revised tariff structure for future implementation.

- Mr. Shaughnessy is the Executive Assistant to the Commissioner of the Public Services Commission of Wisconsin. He has been involved in energy conservation and management at the state level and has provided consulting services to the U.S. Department of Energy and various National Laboratories and Associations involving environmental and natural resource management and utility commission regulation. He has over four years in production managment of hardware designed for energy conservation. His specialties

include:

- Energy policy plannding

o Mr. Shaughnessy's academic background includes: B.A., industrial Engineering, U. of Wisconsin.

11. Richard R. Dague - U.S. Energy Team Member

o Dr. Dague was responsible for the Energy Conversion from Waste segment of the Jamaica Energy Study. The specific study objective was to assess the feasibility of constructing a prototype biogas generation unit to produce energy and fertilizer from the waste and refuse collected at the Mona Campus, University of West Indies.

o Dr. Dague is a professor and the Director of the Environmental Engineering Area, Civil and Environmental Engineering Program of the University of Iowa. He has conducted research in a variety of areas. His principal interests are in water quality, water and waste-water treatment, residual solids management, livestock waste managment, resource recovery from solid wastes and aquatic systems modeling. He has served as a consultant to the National Science Foundation and the U.S. Department of Energy. He routinely performs as a consultant to the U.S. Army Corps of Engineers, consulting firms and industries solving special problems in water and waste-water treatment systems. Dr. Dague has over twenty years of domestic and international experience, is listed in Who's Who in Engineering, American Men and Women of Science, and and has co-authored over twenty-five publications in the water and waste-water management field. His specialties include:

- Resource recovery from solid wastes
- Water and waste-water management and control

o Dr. Dague's academic background includes: B.S., Civil Engineering, Iowa State; M.S., Sanitary Engineering, Iowa State; Ph. D., Environmental Engineering, U. of Kansas.

APPENDIX C

TRAINING SEMINAR

APPENDIX C

TRAINING SEMINAR

MINISTRY OF MINING AND NATURAL RESOURCES
P.O. BOX 495
2 ST. LUCIA AVENUE,
KINGSTON, JAMAICA.

MEMORANDUM

TO: Distribution

FROM: Henry Love

SUBJECT: SEMINAR ON BIOGAS STUDY CONDUCTED BY THE USAID ENERGY ASSESSMENT TEAM

DATE: October 18, 1979

---

1. You are cordially invited to the subject Seminar scheduled to be held at the Scientific Research Council, Conference Room, on Thursday, October 25, 1979 at 2:00 p.m.

2. The objective of the Seminar is to review and discuss the potential applications of Biogas Generation as it relates to the activities associated with the Terms of Reference described in Attachment 1. The Seminar is informal in nature and is intended to bring together the personnel from those appropriate organizations which have an interest and/or involvement in the subject area. The Seminar is expected to last for two (2) hours. Dr. Ralf Sterinde will conduct the Seminar. His background is summarized in Attachment 2.

3. For additional details concerning the Seminar, please contact Mr. Gary Roberts, at the Ministry of Mining and Natural Resources - 69170-9.

HL/js

Distribution List

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Dr. Aston Wood - 26 E. Oakridge Dr. Kgn.

Principal - Jamaica Coal of Agriculture
" - Jose Marti School

Best Available Document

Task 4 - Biogas

The study shall assess the feasibility of biogas generation in rural agricultural areas. Included in the assessment shall be an examination of the following: size of livestock holdings, feasibility of collecting animal wastes, the possible use of biogas to provide cooking, and lighting in rural areas that are without access to electricity.

Particular attention should be paid to medium-scale installations (approximately 100 cattle or equivalent in animal waste) and installations appropriate for agricultural research stations, agricultural schools and other schools and rural communities to be specified by the Government of Jamaica.

The study should also address the feasibility of the generation of biogas as an integral part of the sewage treatment facilities of the Jamaican campus of the University of the West Indies.

Pertinent projects already initiated by the Ministry of Mining and Natural Resources Energy Division, the Scientific Research Council and others should be reviewed in detail. The report should include recommendations for follow-on projects that might be undertaken. In such projects, adaptive programs should be emphasized, rather than basic research.

ROLF T. SKRINDE

U.S. ENERGY TEAM MEMBER: BIOGAS STUDY (TASK 4)

Dr. Rolf Skrinde is responsible for assessing the feasibility of biogas generation in rural agricultural areas of Jamaica. The examination shall include small- and medium-scale installations applicable to farms and agricultural communities or research centers respectively. Dr. Skrinde is recommending a Five Year Program for the use of biogas plants in Jamaica. The program, based partically on the pioneering work of the Scientific Research Council, is geared to provide household and medium size units targeted for farms and agricultural schools.

SUMMARY

Dr. Skrinde does extensive international consulting in environmental engineering and renewable energy programs. He has consulted in over fifteen countries in the Middle East, North and South Asia, and Europe. Dr. Skrinde has approximately 26 years of international experience. He has served as Energy Consultant to The National Science Foundation, and the U.S. Department of Energy. He has co-authored more than 40 published technical articles and has contributed to approximately 200 consultant reports on energy and the environment. Dr. Skrinde is listed in Who's Who in America, Engineers of Distinction and American Men and Women of Science.

SPECIALTY

Energy studies, waste waters, solid waste and industrial waste treatment, biomass.

SUBSTANTIVE POSTS

Consultant to Energy Systems International
Consultant in Fuels From Biomass to the U.S. Department of Energy

ACADEMIC

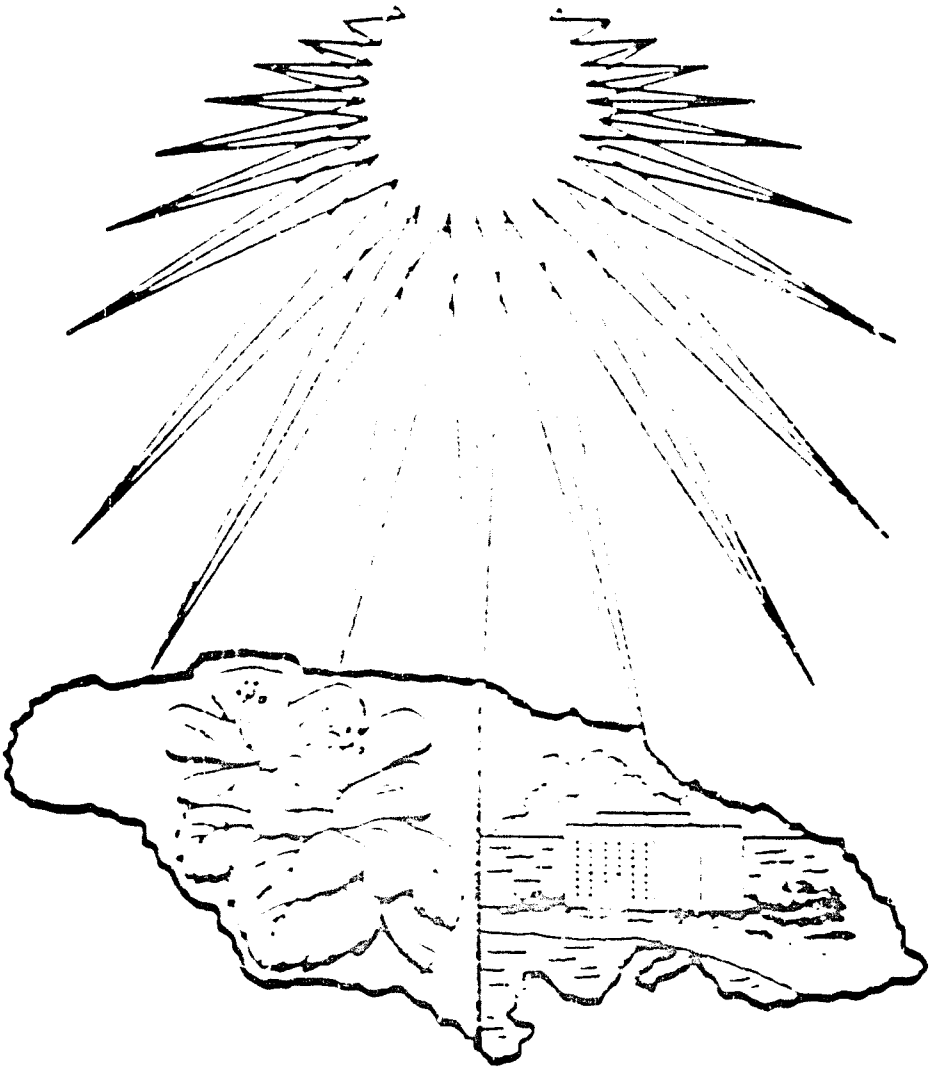
Washington State University, B.S., Civil Engineering, 1951
Massachusetts Institute of Technology, M.S. Sanitary Eng., 1952
Massachusetts Institute of Technology, Ph.D. Sanitary Eng., 1958

APPENDIX D

OVERVIEW OF

FINAL REPORT CONFERENCE

New Horizons for Energy Development in Jamaica



Government of Jamaica
&
U.S. Agency for International Development

Final Report Conference
on
Preliminary Energy Sector Assessments of Jamaica

APPENDIX C

November 13-14, 1979
Jamaica Pegasus Hotel
Kingston, Jamaica
[illegible]

MINISTRY OF MINING
P.O. BOX 495,
2 ST. LUCIA AVENUE.
KINGSTON. JAMAICA

Please Quote

Reference No.

12th November, 1979.

Dear Participant,

How we solve the problems of managing energy use and developing alternatives to imported petroleum, are more important than virtually any other issue in Jamaica today. Our performance in this area is crucial to the performance of the economy as a whole.

Since the middle of August, a team of U.S. AID experts and local counterparts from the Energy Division of the Ministry of Mining and Natural Resources have been jointly studying our energy problems. The overall purpose of the study is to help us, as it were, clear the decks for action.

Many of you will have already met members of the team in the course of their studies. Over the next two days the various specialists will be reporting their findings and preliminary recommendations.

I welcome you here, not as passive spectators, but as active participants - to discuss, to comment and to double-check. Out of this session will come the final report - our blueprint for action. Please participate fully for both days.

It is not an over-statement to state that what is at stake is the very survival of this society as a viable economic entity.

Henry Lowe,
Director, Energy Division,
Ministry of Mining

U.S. ENERGY TEAM FINAL REPORT CONFERENCE
NOVEMBER 13-14, 1979
KINGSTON, JAMAICA

PURPOSE

Provide Government of Jamaica, USAID, International Organizations, Caribbean Countries and other interested organizations with opportunity to participate in a final review of the U.S. Energy Team study.

OBJECTIVES OF CONFERENCE

1. Promote a dialogue among all organizations and entities having a hand in the decision, planning and implementation processes for an energy program in Jamaica.

2. Initiate a dialogue among all organizations and countries which can result in Jamaica becoming a future major exporter of renewable energy products and services for the Caribbean and Central/South American region.

3. Use the U.S. Energy Team study to demonstrate the readiness of the GOJ energy program and Jamaica's leadership in energy planning for future energy program activities in the Caribbean. Show GOJ/USAID team approach in study.

STRATEGY

L. Invite a broad cross-section of Jamaicans from the public and private sector to critique the study results. Have the thirteen energy team members on hand to discuss the findings and recommendations and respond to key issues and questions.

2. Invite selected Non-Jamaican individuals to participate particularly where they may be in the position of assisting the GOJ in follow-on activities.

PROGRAM

1. The first day provided an overview of the study commencing with an Executive Summary proceeding through each of the specialized studies. Both Jamaican and U.S. counterparts made joint presentations as appropriate.

2. The second day had three program segments; International cooperation discussions, study splinter group meetings and a summary discussion of splinter group findings.

3. The international cooperation discussions included participants from the following organizations:

   - World Bank
     John Callahan
     Ali Ezzati
     Robert Kanchuger

   - InterAmerican Development Bank
     Leonardo DeSilva
     Robert Garziglia
     Jose Cosio

   - Organization of American States
     E. Patrick Healy

   - United Nations Development Program
     Ahmad Zia Mian

   - Caribbean Development Bank
     Jerome O.R. Singh

   - U.S. Agency for International Development
     Jerome Bosken

GOVERNMENT OF JAMAICA AND U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

PRELIMINARY ENERGY SECTOR ASSESSMENTS OF JAMAICA

FINAL REPORT CONFERENCE

SPONSORED BY: ENERGY DIVISION, MINISTRY OF MINING AND NATURAL RESOURCES

NOVEMBER 13-14, 1979

JAMAICA PEGASUS HOTEL, KINGSTON, JAMAICA

PROGRAM AGENDA

Tuesday 13 November 1979 Montego Suite

8:00 - 8:30	Registration
8:30 - 9:30	Welcoming and Opening Remarks
9:30 - 10:15	Executive Summary of Study
10:15 - 10:30	Coffee Break
10:30 - 11:15	Economic Assessment of Study Results
11:15 - 12:15	Solar Energy
	o Solar Heating Cooling & Hot Water Applications
	o Solar Agricultural Applications
12:15 - 1:45	Lunch -No Host
1:45 - 2:30	Biogas
	o Jamaica Biogas Program
	o Biogas Program Assessment
2:30 - 3:15	Preliminary Assessment on Utilization of Coal for Electric Power Generation
3:15 - 3:30	Coffee Break
3:30 - 4:15	Electric Utility Analyses
	o Marginal Cost Analysis
	o Tariff Structuring
4:15 - 4:45	Energy Conversion From Waste
4:45 - 5:00	Summary and Concluding Remarks

Wednesday 14 November 1979 Montego Suite

8:30 - 10:15	International Cooperation Discussions
	o Government of Jamaica Programs and Plans
	o Prospective Caribbean Cooperation
	o U.S. Solar International Program Activities
	o International Institution Programs

10:15 - 10:30	Coffee Break
10:30 - 12:30	Splinter Discussion Group Meetings o Solar o Electric Utility Analysis o Waste Study o Other as Required
12:30 - 1:30	Lunch
1:30 - 3:30	Continue Splinter Discussion Group Meetings o Coal o Biogas o Economics Assessment o Other as Required
3:30 - 3:45	Coffee Break
3:45 - 5:00	Presentation of Splinter Discussion Group Findings
5:00 - 5:30	Conference Closing Remarks

* Please note: Energy films will be shown begining at 6:00 pm, Tuesday and Wednesday in the Montego Suite. Films will help aquaint attendees with subjects to be discussed.

FINAL REPORT CONFERENCE

LIST OF ATTENDEES

Roy Alexander
Min. Pub. Utilities and Transport

W. R. Ashby
M.M.N.R.

Ali Abdi
Int. Monetary Fund

Lennix Anderson
Appliance Traders Ltd.

A. E. Abrahams
Directorate of Elec. & Mechanical Services

Victor Abbot
Mona Rehab. Centre

Teddy Alexander
Ministry of Mining & Natural Resources

Winston L. Allen
Kingston College

Ngai Adu
Jamaica Public Service Co.

Winsome Archibald
Ardenne High School

Grace A. Ashley
College of Arts, Science & Technology

Hector Bernard
Gleaner

Warren Bloomfield
Harbour Cold Store

Winston Bromfield
Grace Kennedy & Co. Ltd.

Patrick J. Blair
National Hotels & Prop.

T. I. A. Barrett
Ministry of Agriculture

Sandra Bennett
Wolmer's Girls' School

Headly E. Brown
Bureau of Standards

Fitz Bartley
USAID

David Cooke
Agric. Mktg.

Peter Callen
Grace Kennedy & Co. Ltd.

Robert A. Causwell
Kingston Technical High School

R. F. Clay
Petrojam

Alvaro Casserly
Jamaica Public Service Co.

Leon Cushnie
Solar by Cushnie

Gary Chin
Meadowbrook High School

C. A. Clemeston
Ministry of Agriculture

E. R. Campbell
Cocoa Industry Board

H. G. Coore
U.W.I.

Peter Dowding
M.M.N.R.

Ambrose E. DaCosta
National Planning Agency

Winston Dunbar
Jamaica Public Service Co.

Vivianne E. DaCosta
Scientific Research Council

J. A. Davies
Texaco

LIST OF ATTENDEES (CONTD)

Jose Cosio
I.D.B.

Mr. John Callahan
World Bank

J. S. Doddamawi
Indian High Commissioner

Leonardo DaSilva
Interamerican Development Bank

W. E. Duval
R.S.A.C.

Horace Davis
Grace Kennedy

David Ebanks
R.J.R. News

George Anthoney Edwards
Mr. Earl V. Edwards Farm

Ali Ezzati
World Bank

Douglas Fletcher
National Advisory Council on
Energy Conservation

Maurice G. Fletcher
College of Arts, Science &
Technology

Valentine Fagan
Jamaica Public Service

Peter J. Francis
Agricultural Research Project

Allison Fentone
Geological Survey Div.

Richard Fletcher
Ministry of Finance

Arthur J. S. Geddes
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Hu Gentles
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Organization of American States

Marjorie Humphreys
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Meadowbrook High School

Gaven Henry
Ardenne High School

Errol A. Hanchard
The Water Commission

Carl Ingram
Jamaica Public Service Co.

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Donald Leslie
Alcan Products of Jamaica Ltd.

Veronica Lawrence
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Barrington Levy
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Hector Lawrence
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U.S.A.I.D.

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Janine Myers
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Ann Moser
M.M.N.R.

E. L. Munroe
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Lilleth E. Nelson
M.M.N.R.

Pearl C. O'Connor
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Karl Anthony Oxford
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Nelson O'Callaghan & Assoc.

Ina P. Pyne
Meteorological Services

George Phillip
Grace Kennedy

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Milton O. Rainford
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Claon Rowe
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C.A.S.T.

A. W. Sangster
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Richard Dague
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Chun Choy-Chan
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Ministry of Agriculture

Jean Shaw
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Calvin Stamp
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Brian Silvera
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Ingrid Wellington
Grace Food Processors

Hulson Walters
Forest Department

Neville Williams
Campesdown High School

Joseph E. Williams
Jamaica Constabulary Force

Lewin T. Wint
Scientific Research Council

Glynn O. Watson
Livestock Development
Ministry of Agriculture

Kenneth Wedderbuln
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R. M. Wright
Petroleum Corporation of Jamaica

O. P. Woodham
Jamaica Institution of Engineers

Monica Whute
Agency for Public Information

R. G. Wells
British High Commission

Robert Woodstock
A.R.P. Unit
Ministry of Works