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BOTSWANA RENEWABLE ENERGY TECHNOLOGY PROJECT:

FINAL REPORT

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ACRONYMS

ACDO	Assistant Community Development Officer
AID	U. S. Agency for International Development
ARD	Associates in Rural Development, Inc.
BEDU	Botswana Enterprise Development Unit
BHC	Botswana Housing Corporation
BREAC	Botswana Renewable Energy Activities Committee
BRET	Botswana Renewable Energy Technology project
BRI	Brace Research Institute
BTC	Botswana Technology Centre
DDC	District Development Committee
DET	District Extension Team
DPS	Deputy Permanent Secretary
DWA	Department of Water Affairs
FWE	Family Welfare Educator
GOB	Government of Botswana
IDM	Institute of Development Management
MFDP	Ministry of Finance and Development Planning
MLGL	Ministry of Local Government and Lands
MMRWA	Ministry of Mineral Resources and Water Affairs
NDP-5	Fifth National Development Plan
NGO	nongovernmental organization
ODA	British Overseas Development Administration
PCV	Peace Corps volunteer
PfP	Partnership for Productivity
PEC	Project Executive Committee
PHU	percentage of heat utilized
PP	project paper
PV	photovoltaic
RECC	Rural Extension Coordinating Committee
RET	renewable energy technology
RHC	retained heat cooker
RIIC	Rural Industries Innovation Centre
RIO	Rural Industrial Officer
RWL	resting water level
S&CD	Social and Community Development Officers
SDA	Seventh Day Adventists
SIDA	Swedish International Development Agency
TESIE	technical, economic, sociocultural, institutional or energy (assessment model)
USDA	U. S. Department of Agriculture
VDC	Village Development Committee
VET	Village Extension Team
VHC	Village Health Committee
VTF	Village Training Facility
WTGS	Windmill Technology Group Serowe
YWCA	Young Women's Christian Association

PREFACE

The Botswana Renewable Energy Technology (BRET) project (number 633-0209) was approved by the U. S. Agency for International Development (AID) in September, 1980. Associates in Rural Development, Inc. (ARD) was selected and contracted in August, 1981 to provide technical assistance and project management. In November, 1981, the project coordinator arrived in Botswana with ARD's vice-president, Dr. James Nolfi, to begin ARD's project operations under the contract. AID funding for the BRET project, which included ARD's technical assistance component, was completed on September 26, 1985.

The first-year annual report for the BRET project was published in January, 1983. The second-year annual report covered the progress of project operations from January 1 through December 31, 1983. The third-year annual report details project activities from January 1 through December 31, 1984. This final report discusses all of the activities undertaken during the life of the BRET project, through the end of the contract on September 26, 1985.

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I. EXECUTIVE SUMMARY

The Botswana Renewable Energy Technology (BRET) project of the Ministry of Mineral Resources and Water Affairs (MMRWA) was intended to introduce renewable energy technologies (RETs) in Botswana. Associates in Rural Development, Inc. (ARD), under contract to the U. S. Agency for International Development (AID), provided technical assistance to the project for its first four years. This report covers project activities and accomplishments during those four years of support and involvement by AID and ARD.

The BRET project carried out research and development, dissemination and demonstration efforts for a variety of technologies and energy-use strategies (see Section III). ARD employed a successful "needs-driven" approach to technology selection, development and innovation (Appendix A provides a description of that approach). This technology development model can be used for most technology development or adaptation, especially in rural settings, and has proven very responsive in dealing with what is necessarily an iterative process.

As a pilot effort, the purpose of the BRET project was to determine the most attractive and potentially successful technologies and approaches for renewable energy utilization in Botswana. In accomplishing this objective, the project constantly evaluated its experiences in light of technical and economic findings related to the energy needs and market realities in Botswana. The approaches used by BRET staff, as well as specific project outputs, were continually reviewed and revised to make the project as effective as possible (see Section II). Over 60 reports and analyses of research and development work were published by the project (see Appendix C for a complete list of BRET project reports). Together, these provide a comprehensive description of the data base, BRET project experiences, analysis and future directions for the use of renewable energy in Botswana.

Despite the problems that face any pilot project working in a new area (and also addressing new concerns in many instances), the BRET project made major impacts in almost all of its areas of concentration. Much more data is now available on energy consumption, needs and renewable energy resources in Botswana, and collection systems are in place to gather additional data on an ongoing basis. Some technologies developed by the project are currently at the point of extensive field and commercial testing, such that they could have a substantial impact on future energy use (e.g., field testing of water pumping technologies). Other devices are ready for extensive market testing and commercial production--wood stoves and commercial solar water heaters. Finally, still other RETs have been successfully demonstrated and

enough training provided to bring them into widespread acceptance and use (e.g., energy-efficient building design). Also of great importance, the BRET project provided the opportunity for many individuals to gain experience and training in a variety of technical and administrative situations that will be vital to the successful adoption of sound RETs.

In carrying out its work on the BRET project, ARD's contract with AID included the provision of all equipment (purchased in the United States) as well as technical assistance. Further equipment and resources were made available by AID through the project and the government of Botswana (GOB). ARD provided 87 person-months of long-term technical assistance and 74 person-months of short-term technical assistance in Botswana. Although ARD's contract only called for approximately 50 months of short-term assistance, through careful, conscientious utilization of its resources and personnel, ARD was able to provide about an extra 24 months of assistance at no additional cost to the project.

Highlights of BRET project activities and accomplishments, discussed in Section III after the revised log frame outputs in Section II, include the following.

Energy Needs Assessments

Project work began with the selection of two pilot villages--Ditshegwane in the Kweneng District and Shoshong in the Central District--for experimental work on domestic RETs based on an energy needs assessment. To carry out the domestic energy needs assessment, an energy use and attitude sample survey was conducted during 1982 in these two villages and in an additional three towns and three major villages during 1983. It was found that energy (i.e., the availability and conservation of firewood) for cooking, lighting and space heating was the major domestic energy need in Botswana. (Section III.A contains a more detailed description of the energy needs assessments conducted by the BRET project.)

National Energy Assessments

To address the need for better and more extensive wind data, the BRET project led an effort to set up a national wind assessment program. Twenty anemometers were installed, and initial steps in data collection and computerized analysis were taken (see Section III.B.1).

To augment the limited solar data currently available in Botswana, the BRET project purchased three state-of-the-art solar radiation monitoring stations and provided training in their

setup and operation. These stations are designed for simple, durable operation in harsh climates (see Section III.B.2).

Water Pumping

The BRET project funded research and development work on two windmills of different design, an animal-drawn pump and a human traction pump. In sum, the project purchased and/or installed 50 water pumping systems for field and comparison testing. Due to a lack of appropriate equipment on the market, ARD developed and had manufactured an original water pumping monitoring system. This program is certainly the most comprehensive pump comparison program in Africa. It includes a field comparison of:

- 11 windmills,
- nine solar pumps (three to be installed during the extension of the BRET pumping program),
- one bio-gas pump,
- two animal-drawn pumps,
- three human traction pumps,
- 24 hand pumps, and
- five diesel and two ac-grid electric submersible pumps that were already in operation.

Pumping installations were used as demonstration sites and tours conducted for over 300 district and central government officials. Training and orientation sessions were held on the monitoring equipment and pump comparison methodology, as well. (See Section III.C for a complete discussion of the BRET project's pumping program.)

Photovoltaic Electrification

The BRET project purchased 13 and installed 10 photovoltaic (PV) systems at:

- three health clinics for lights and refrigeration;
- four elementary school rooms;
- three street lights for demonstration purposes; and
- three health posts, where refrigeration systems will be installed.

(See Section III.D for a description of BRET project efforts in the area of PV electrification.)

Commercial Solar Water Heaters

The BRET project undertook the following activities with regard to this technology:

- it funded development work on low-cost solar water heating units that could be commercially manufactured by a private entrepreneur;
- supported research and development efforts carried out at RIIC; and
- assisted the University of Botswana (UB) with the acquisition of monitoring equipment for a testing program of domestic solar water heating systems.

(Section III.E provides a more complete discussion of the project's work on commercial solar water heaters.)

Passive Solar Building Design, Construction and Promotion

The BRET project carried out a number of passive solar design, building and training activities, which are discussed in Section III.F. The project designed and constructed 11 passive solar buildings in five locations, including:

- a high-cost solar house in Gaborone;
- two offices and three rondavels as part of the project's two pilot village training facilities (VTFs);
- four SHHA houses in Gaborone, Lobatse and Francistown;
- an international award-winning solar office building for the Botswana Technology Centre (BTC) in Gaborone, three houses for RIIC and a SHHA office in Kasane, which has been designed, but not yet built;
- the use of a Cinva-Ram block machine in the construction of the first five buildings in Botswana using such materials; and
- four buildings of standard construction at RIIC.

In addition, the project completed design analyses and computer simulations for comparisons of building components and designs for standard and passive solar construction for a number of buildings, before reporting back to the involved ministries and departments (e.g., the Department of Works, Ministry of Local Government and Lands' Architect and Housing Office, and Botswana Housing Corporation).

The BRET project conducted 30 demonstration tours of six different buildings. It developed two comprehensive passive solar design workbooks, one for concepts and guidelines and the other for detailed calculations (PASSIVE SOLAR DESIGN WORKBOOK, Blair Hamilton, Beth Sachs and David Norris, ARD, Burlington, Vermont, March, 1984 and draft of 1985 BRET WORKSHOP ON BUILDING ENERGY DESIGN--WORKBOOK MATERIALS, Scott Matthews and Philip Niles, ARD, Burlington, Vermont, May, 1985). The project developed, distributed and trained designers in the use of methods for hand-calculator and computer spread-sheets to analyze the thermal performance of buildings (BRET THERMAL PERFORMANCE ANALYSIS METHOD--DOCUMENTATION FOR WORK-SHEET, VERSION 1.0, Scott Matthews and Philip Niles, May, 1985). This building analysis technique is an original development of the BRET project. Finally, the project conducted four training programs in passive solar design for architects, engineers and town council technicians.

Rural Development RETs

Technology selection, research and development work, as well as analysis, field testing and pilot dissemination, were carried out for earthen stoves, portable sheet metal stoves, retained heat cookers, improved building designs and simple solar water heaters. Several other devices were considered by the BRET project, but given a low priority, or found not feasible, based on an initial review and preliminary research. These specific findings were as follows.

First, after two years of intensive research and development, including both laboratory and field studies, it was concluded that high-mass earthen stoves were inappropriate for Botswana.

Second, after intensive laboratory development and testing of three prototype sheet metal stoves, one was selected. The project then developed two models and two sizes of this stove, which is capable of saving up to 50 percent of the fuelwood used for cooking. Tinsmiths and a commercial company were trained to produce the stove and 3,000 were made, with 1,500 sold or disseminated by the end of the pilot project as part of trial marketing efforts and studies. Also, a variety of promotional materials, including booklets, posters, radio spots, etc., were

developed for the BRET metal stove. This technology has the potential to be extremely successful, and a full market development and testing program should be completed.

Third, the BRET project concluded that the retained heat cooker ("Wonder-Box") was an appropriate technology (laboratory studies have indicated a fuel savings of 50 percent) after two years of field study on its use in villages. The project produced a retained heat cooker cookbook and trained 150 women to make the device at a variety of workshops.

Fourth, the project developed and field-tested six simple batch solar water heater prototypes. The field testing and analysis indicated that an inexpensive system which is attractive to consumers will be very difficult for prospective owners to produce themselves.

Awareness and Outreach

A comprehensive awareness and educational program was carried out in the project's two pilot villages (see Section III.I for a full description of these activities). The results of this work will be extremely helpful to further energy (or related development) efforts in Botswana. The BRET project created and shared information and materials for its educational and promotional efforts with other organizations and institutions to further the spread of RETs. This was particularly the case during district-level efforts undertaken in the latter part of the project. The project conducted initial trials for radio spots, displays at agricultural shows and training various multiplier groups to develop a broad-based approach to a complete, national awareness program. Important lessons have been learned from these activities that should aid government efforts to carry out similar programs.

Training

Training was a major element of the BRET project's strategy. Its purpose was to develop those skills needed for technical management of specific RETs, extension and dissemination as well as to increase villagers' capacity to manage, produce and maintain RETs. Training was provided for BRET staff members, RET users and producers, and multiplier groups. The issues of concern were different for each group, but as a whole, represented the scope and complexity of skills development for continued renewable energy activities.

The BRET project conducted more than 35 identified training sessions involving 1,505 contact-days with 575 trainees (which does not include numerous hours of one-on-one training).

Trainees included villagers, artisans, council technicians, extension workers, engineers and architects. (See Section III.J for specific information on these training activities.) In addition to training actually delivered during the life of the project, an analysis of training and institutional needs was conducted and written up in a separate BRET project report.

Developing GOB and Batswana Capabilities

Throughout the BRET project, this issue was addressed by providing training to project staff both on the job and at local, third-country and U. S. seminars, workshops and courses; planning project activities to link BRET staff and GOB institutions which have or might take on RET activities in the long run; and building the BRET project's experience into the newly formed MMRWA Energy Unit. In the course of these activities:

- eight people received a total of 36 months of training in the United States, which they found extremely helpful in their jobs and increased their capability to assist with BRET activities in general; and

- 18 BRET staff received a total of approximately 135 months of on-the-job training during the project's life.

Details on these activities can be found in Section III.K.

Key Lessons from the BRET Project's Experience

Several key conclusions or lessons can be drawn from the experiences of this pilot project. A number of new and important developments that came out of the BRET project were unforeseen. The electronic monitoring equipment designed and developed for the comparative pumping program is a state-of-the-art system that did not exist anywhere prior to the project. Similarly, the new spread-sheet method for determining the thermal performance of buildings was developed for the project. In addition, the solar design workbooks for southern Africa prepared during the project are an important step forward in providing such materials that are specifically intended for the climate in Botswana.

It is important to note that the duration of the pilot project was too short. It was simply not possible to develop all of the promising technologies identified to the final stages of technology transfer, or a point where their production could be self-sustaining by the private sector or a government organization, in a time frame of less than 10 years. Substantial progress was made with several technologies, and some are very

close to self-sustained production and having a major impact on energy consumption in Botswana. However, the development of trained personnel, completing the research and development on technologies that require more time, and the resolution of marketing issues will require additional work by the BRET project and other organizations in the near future.

Finally, the steps necessary to develop RETs to the point of successful widespread use requires effort and a project carried out by the government. Adequate skills, information and funds do not exist in the private sector to achieve such success without a program like the BRET project. It is clear that in certain areas, more must continue to be done by the GOB, while some other functions and technologies can be successfully transferred and gradually taken over completely by the private sector.

II. INTRODUCTION AND PROJECT OVERVIEW

The Botswana Renewable Energy Technology (BRET) project was designed as a pilot project by the Government of Botswana's (GOB) Ministry of Mineral Resources and Water Affairs (MMRWA) and the U. S. Agency for International Development (AID). The project paper was completed in September, 1980. In August, 1981, Associates in Rural Development, Inc. (ARD) signed a contract to provide technical assistance and project management, which began in October, 1981 and ended in September, 1985.

The project was designed to further the energy policy goals of Botswana's Fifth National Development Plan (NDP-5). As defined in the project paper, the purposes of the BRET project were to:

- introduce village renewable energy technologies (RETs) that can be easily reproduced and are inexpensive and;
- research, develop and put into use RETs which can reduce Botswana's dependence on vulnerable supplies of increasingly expensive fossil fuels.

To fulfill these purposes, a series of project outputs was defined, and the following development and dissemination process was used to attain those outputs for each technology:

- needs and resource assessments,
- technology identification, matching and selection,
- prototype development and testing,
- comprehensive field testing and pilot education, and
- widespread dissemination or transfer to the public domain.

At each stage, data were collected and analyses made of the technical, economic, sociocultural, institutional and energy issues related to each technology. This information enabled decisions about whether to continue with the next step in the process, make adaptations or abandon that particular technology. An important underlying approach used throughout the development and dissemination process was community and entrepreneur involvement. Moreover, it is important to realize that this is essentially a "needs-driven" approach to technology selection and innovation. A detailed description of the BRET project's research, development and dissemination process, and technology assessment model can be found in Appendix A.

The project first carried out a village energy use and sociological needs assessment to help prioritize energy-related needs and determine the technologies that would be most likely to decrease the growing demand for fuelwood through increased availability of rural domestic RETs and heightened awareness of the need for conservation. The RETs selected were intended to focus on more efficient use of or substitute fuels for wood, and have the capability to be fabricated from cheap, abundant, locally available resources to save on both labor and money.

To minimize Botswana's dependence on imported petrolem-based fuels, the project paper specified that the BRET project should work on a number of institutional RETs. Thus, the technologies that the project concentrated on fell into two general categories:

- domestic RETs, such as cooking devices and stoves, small batch solar water heaters, thatch insulation, evaporative coolers, and improved housing designs for rural villages; and

- institutional technologies, such as various types of water pumping systems, photovoltaic-powered lighting and refrigeration, and energy-efficient designs for office buildings and houses in towns.

The work of the BRET project began with the selection of two pilot villages for research on domestic RETs--Ditshegwane in the Kweneng District, with a population of 820 according to the 1981 census, and Shoshong (population of 4,600) in the Central District. To perform the domestic needs assessment, an energy use and attitude survey was conducted during 1982 in these two pilot villages, and in an additional three towns and three major villages during 1984. It was found that the availability and conservation of firewood for cooking, lighting and heating was the major domestic energy need in Botswana.

The project paper suggested a number of RETs for consideration, but portable sheet metal stoves, earthen stoves, retained heat cookers, small solar batch water heaters and desalination systems were selected for development. Evaporative coolers, thatch insulation and pedal-powered sorghum de-hullers were also investigated, but early research indicated that they should be accorded a lower priority. Earthen stoves and simple, 15-liter solar water heaters progressed through the prototype development and testing stage before work on them was suspended because of problems with cost, durability and construction. As of the end of the pilot project, both sheet metal stoves and retained heat cookers had been found to be effective and economical, and are ready for widespread dissemination. The BRET project also supported solar desalination work carried out by the Rural Industries Innovation Centre (RIIC) in Kanye, as well as

the development of two commercial batch solar water heaters by an entrepreneur in Gaborone.

With regard to community or "institutional" RETs, as they were referred to in the project paper, both the BRET project and other studies determined that the following energy-related needs were of high priority:

- water pumping systems,
- lighting and vaccine refrigeration for health clinics in rural areas, and
- the thermal comfort of buildings in summer and winter.

The project paper outlined research, development and field testing of hand, solar and wind pumps (including both standard and advanced windmills). During the course of the project, the pumping program was expanded, in cooperation with RIIC, to include human and animal traction and biogas pumps. Also, due to the clear need for better water pumping information, a comparative pumping assessment was added to BRET project activities. At the end of the pilot project, 45 pumps had been installed and are at the operation/maintenance stage of the development process. They include a monitoring and data collection system for the pump comparison effort.

Photovoltaic electrification systems were installed, along with accompanying monitoring equipment, at three rural health centers for lights and refrigeration, and four elementary schoolrooms for lighting.

In addition, because both wind and solar resource data for Botswana are sparse, a program for wind and solar radiation data collection and assessment was developed.

The BRET project carried out a variety of activities related to energy efficiency in building design and increasing the thermal comfort of buildings. Research, development, construction and monitoring were completed on eight houses and three small office buildings. A number of training activities were undertaken, and two solar design workbooks and a thermal performance analysis procedure were also developed. In addition to consultations with various officials, the project influenced the design of four government projects and buildings for three para-statal organizations.

The mid-term AID project evaluation was conducted in December, 1983. The resulting report recommended:

- expanding the pump research and development program to include a comprehensive field-test comparison of all of the RET pumps with standard diesel and AC-grid pumps;

- taking the passive solar design component of the project beyond construction into a broad training and design consultation effort; and

- intensifying the project's general extension efforts and expanding the portable BRET stove program.

In connection with all of the activities mentioned here, extensive training programs were conducted for BRET staff as well as a large number of extension workers, technicians, engineers and architects working for various government and para-statal agencies, and rural people in the districts where the project was active.

ARD fielded two long-term staff and numerous short-term consultants. During the project's first year, most of the 15 Batswana counterparts and administrative personnel were hired. Five Peace Corps volunteers (PCVs) worked with the BRET project in 1982 and 1983, while two served during the third year.

This report is organized according to the outputs and magnitude of outputs in the project paper's logical framework (log frame), which were revised based on the recommendations from the mid-term project evaluation. The log frame enables decision-makers to identify project purposes and goals to plan for project inputs and outputs. It has been used widely by AID missions to assist in project planning, provide measures for project evaluations and state assumptions about causal linkages.

The original log frame that appeared in the project paper has been reproduced in Appendix B. The outputs and magnitude of outputs from the revised log frame are shown on the last five pages of this section. They provide both a brief overview of project activities as well as a guide to this report. Each output is covered in a separate section, and most encompass a number of magnitude of outputs (or sub-outputs) that are discussed under subheadings within each major section. For instance, two different energy surveys were conducted, one in the two pilot villages and the other in six major villages and towns, and the output for research and development on water pumping specifies work on seven different RET pumping systems. Thus, each survey and pumping system is described in a separate subsection. In addition, <u>each major section is organized into three standard subsections</u>:

- developmental history, which is generally a chronology of activities that details the actual

course of events during the project's technology development and dissemination process;

- results and conclusions; and
- recommendations, some of which are rather general and others, more specific.

As part of the project, separate reports on each of the technologies mentioned in this section were prepared. A complete list of BRET project reports is given in Appendix C.

Outputs	Magnitude of Outputs Necessary and Sufficient to Achieve Purpose
1.0 Energy needs data collection and analysis for use in technology selection and development.	1.1 Survey in two pilot villages. 1.2 Survey in three large villages and three urban areas.
2.0 National energy assessment studies: The definition of precise outputs utilizing at least five per-months of short-term consultancies will be made during PEC meetings.	2.1 Wind studies in conjunction with Meteorological Services. 2.2 Solar radiation studies with Meteorological Services. 2.3 A woodlot/on-farm/multi-use forestry study, subject to REDSO review. 2.4 Others as determined by BRET and MMRWA with PEC.
3.0 Research, development and field testing of water pumping systems.	3.1 Develop a comprehensive report on each pumping system, which will include a comparison between systems. 3.2 As necessary, design, select, purchase, install, test and monitor the following: 3.2.1 Eight standard farm-type windmills. 3.2.2 Eight high-performance windmills. 3.2.3 Five PV systems. 3.2.4 Fifteen hand pumps. 3.2.5 Eight human traction pumps, including improvements, plans and manufacture. 3.3 Fund development and monitoring of two RIIC animal traction pumps. 3.4 Fund comprehensive evaluation report of RIIC biogas-powered pumps. 3.5 Comprehensive study of total costs and performance of diesel grid electrical pumping.

4.0 Research and development of small-scale photovoltaic electrification.

4.1 The design, installation, field testing, monitoring of and comprehensive report on small-scale PV electrification at the following:

4.1.1 Six health clinics/posts.

4.1.2 Three street lights with MMRWA/DEE.

4.1.3 Four schoolrooms with MLGL.

4.1.4 Respond to other PV demonstration possibilities presented by other GOB ministries and departments.

5.0 Research and development of solar heaters for urban households and rural institutional use.

5.1 Fund R&D work with local entrepreneur for developing low and medium costs units.

5.2 Test the first units produced.

5.3 Test commercial units imported to Botswana.

5.4 Testing and evaluation of existing units installed on BHC houses.

5.5 Final report on these technologies with implementation and policy guidance for GOB.

5.6 Develop, test and field test simple batch low-cost systems for rural institutional use.

6.0 Urban and rural passive solar buildings designed, constructed, monitored and evaluated.

6.1 Two urban model buildings, one house, one small office.

6.2 Two low-cost cement block model structures similar to SHHA-size in test villages.

6.3 Two improved rondavels in pilot villages.

6.4 In addition, four conventional houses at the RIIC headquarters in Kanye.

6.5 Field testing of stabilized earth block.

7.0 Design, monitoring, analysis, reporting and promotion of passive solar houses and office buildings.

7.1 Individual passive solar building innovations will be analyzed to calculate respective contributions to energy savings, overall performance and cost increases.

7.2 Work with ministries and departments and parastatals with building programs.

7.3 Conduct periodic tours of solar buildings.

7.4 Conduct training workshops for rural and urban housing.

8.0 Design, testing and pilot diffusion of rural domestic technologies, including earthen stoves, portable sheet metal stoves, retained heat cookers, small batch solar water heaters, and earthen bread stoves.

Preparation of reports to GOB on each technology outlining the state of the technology, cost factors, potential and effective demand, institutional and skills constraints to diffusion, and BRET's guidance to GOB for possible widespread activities in the future. The report should also identify role of local entrepreneurs, distributors, credit facilitie and other village characteristics drawn from Output and Output 9 as follows:

8.1 Earthen stoves.

8.2 Portable sheet metal stoves.

8.3 Retained heat cookers.

8.4 Small batch solar water heaters.

8.5 Earthen bread ovens.

9.0 Institutional assessment and guide of the two pilot villages and districts.

9.1 Factors or individuals that may be promoters or constraints to widespread diffusion.

9.2 Identification of all extension personnel, GOB interactions, entrepreneurs, including shop owners, teachers, and others who impact on RET dissemination.

10.0 Village awareness and outreach campaign.

10.1 Awareness in two pilot villages and some experience into the two districts.

10.2 Develop outreach-extension strategies for each technology system and the two test village/districts.

10.3 The following kinds of demonstration units will be installed:

10.3.1 Earthen stoves.

10.3.2 Sheet metal portable stoves.

10.3.3 Retained heat cookers (RHC).

10.3.4 Simple solar water heaters.

10.3.5 Earthen bread baking ovens.

10.3.6 PV electrification.

10.3.7 Wind data collection.

10.3.8 Passive solar housing design.

10.3.9 RE pumping systems.

11.0 Village RET and institutional RET training.

11.1 Training needs and skills assessment: Make an assessment of skills for staff of BRET relevant to GOB offices, the two demonstration districts, other group entrepreneurs and in the two test villages necessary for project implementation.

11.2 Based on this assessment and PEC review, specific training outputs will be determined for relevant groups, including:

- Department of Water Affairs and Council Water Technicians in regions where water pump systems are installed for testing;
- GOB extension workers in the two villages and demonstration districts;

- Entrepreneurs in the production of solar hot water and metal stoves;

- MMRWA, MOH, MLGL and Electrical Brigade(s) on PV electrical generation, installation and maintenance at health centers, schools, etc.

12.0 Batswana and GOB capacity to manage on-going extension, training and research after the RET project.

12.1 Six counterpart and four facilitators will be trained to implement the project after the USAID project ends.

III. ACTIVITIES AND ACCOMPLISHMENTS

A. Energy Needs Assessments

Two types of energy needs assessment were defined as project outputs. The first was to be carried out in the two pilot villages, as the first step in the technology development process; the second, to be carried out in towns and major villages. The village energy surveys were conducted in Ditshegwane and Shoshong in 1982, with supplementary fuel measurements taken in 1983. The survey of towns and major villages was conducted during the first half of 1984.

1. Village Energy Survey

Developmental History

The National Development Plan and PP provided preliminary guidance for this work, and interviews with community leaders conducted during the village selection process supplied additional information in this regard.

The village needs and resource assessment involved several stages:

- structured survey work was conducted, including interviews, observations and a review of existing reports;
- organized discussion groups were conducted in the pilot villages to share and verify the conclusions of the survey work as well as mutually define the energy end-uses of greatest concern to villagers;
- careful fuel measurements were made during two seasons in a limited, but representative, sample of households;
- there was ongoing participation of BRET village facilitators in VDC meetings; and
- an analysis of village responses to awareness activities and demonstrations occurred throughout the life of the project.

Surveys and a survey process were designed and implemented to:

- introduce the BRET project to the pilot villages, and initiate discussions with villagers about their energy needs;

- gather detailed data on village energy use; and

- collect information to assist the project in identifying and prioritizing primary energy needs, matching RETs to village needs and resources, assessing the social and economic feasibility of proposed technologies as well as the social, cultural and economic details of present energy end-uses, and developing dissemination strategies.

Of course, this last objective requires an ongoing process, and subsequent sections of this report provide a more comprehensive analysis of the information gathered in the two villages over the course of the project.

The surveys in the two villages were completed in 1982 and are discussed in detail in a BRET project report (BOTSWANA VILLAGE ENERGY SURVEY REPORT, Judith Oki, ARD, Burlington, Vermont, September, 1983). In both villages, survey findings were shared with the VDC to let them know the results and also verify that the conclusions were consistent with their perceptions. In each case, the VDC felt the results were accurate.

The supplementary fuel measurements were taken during the winter of 1983 and summer of 1984. Although the data and preliminary report were available within the BRET project immediately for technology development and dissemination, the final report has just been produced as an addendum to the original survey.

The rest of this subsection presents a summary of the survey findings and the relationship of those findings to the initial selection of village-level RETs.

Results and Conclusions

The BRET project's village energy survey produced the following major results:

- virtually all households rely on firewood for domestic activities, with cooking as the predominant end-use;

- additional household activities that use firewood include heating water for bathing and washing dishes and clothes, space heating and lighting;

- although villagers reported that drought was the most serious problem they faced, they are also aware of the increasing time and money required to gather or buy firewood;

- of the 150 households in the Ditshegwane sample (all occupied households at the time of the survey), only civil servants and trading store employees had regular cash incomes--in Shoshong, just 10 percent of the 165 households surveyed had regular incomes;

- annual per capita consumption of fuelwood in Shoshong is 357.98 kg and in Ditshegwane 602.84 kg--as might be expected, the per household average in winter is almost twice that of summer; and

- where it was possible to distinguish economic level, the rate of consumption of the two major fuels, wood and paraffin, is higher among households in the higher economic level--winter consumption of fuelwood in high-income households is almost double that of low-income households.

The survey provided the BRET project with important information for determining priority energy needs, criteria and design parameters for technologies that would be responsive to local needs and practices. Based on the survey results, the project decided to focus on inexpensive cooking technologies and proceeded to examine a number of potential technologies in terms of their suitability for this particular situation. Secondary technologies/strategies that were considered included energy-efficient building design, thatch insulation and simple batch solar water heaters. Over time, the focus of project activity became cooking devices, with some work on simple solar water heaters. The experiences with those technologies are found in subsequent sections of the report.

A more in-depth review of the survey data provided necessary information for beginning to work on cooking devices. The survey results indicated that 80 percent of the households in Shoshong use three-legged, cast-iron pots ranging from size one to three. In Ditshegwane, a single food, maize or sorghum porridge, is cooked once a day. About 26 percent of the time in Shoshong and less frequently in Ditshegwane, meat and/or vegetables are cooked to accompany the porridge, which requires two cooking pots. The average cooking time for porridge is about 45 minutes--it demands constant stirring over high heat to avoid sticking, burning or an uneven, lumpy texture. Meat is generally boiled for 20 to 45 minutes or longer, depending on the type and tenderness of the meat. Vegetables are also cooked for a relatively long time until they are soft, sometimes with oil added--for example, cabbage is generally cooked for about 45 minutes. Samp, whole

kernels of a hardy maize, is cooked two to four times a month, and requires five to six hours of cooking time. The cooking fire is also used to simultaneously heat water.

The three cooking devices selected for development by the BRET project were earthen stoves, portable sheet metal stoves and retained heat cookers. The earthen stove was an appropriate response for low-income households. A portable stove responded to the annual movement between village, agricultural lands and cattle post. Retained heat cookers seemed well suited to traditional foods, although modifications would have to be made to accommodate the three-legged pots. Limited consideration was given to simple solar water heaters to complement the work on cooking devices and potentially replace another function of the open fire.

The surveys provided information to guide the project, a baseline of village socioeconomic data to help assess project success and an entry into the two pilot villages.

Recommendations

First, the relatively homogeneous character of domestic activities in rural Botswana lends itself to more in-depth study of activities in a smaller sample. A smaller sample with more in-depth observation would yield equally useful, if not more useful, results with less staff time involved in implementation and data analysis.

Second, while needs assessment is a necessary starting point for technology development, the survey approach might also be used to select villages for concentrated RET dissemination efforts. The selected villages would be those where energy needs were perceived as a fairly high priority, where the majority of the population was in a low-middle to upper-middle income grouping, and where the population was at least 4,600. This last criterion would not require a survey.

2. Urban Domestic Energy Use and Attitude Survey

Developmental History

MMRWA's Energy Unit undertook two complementary studies to assist in the development of its energy master plan--a survey of domestic energy use towns and major villages to be done by the BRET project; and a rural energy study to be funded by the British Overseas Development Administration (ODA). This section of the report describes the BRET project's study, which is called "urban" because both the towns and major villages in Botswana

have urban characteristics in terms of population, economy and services.

In 1983, terms of reference were prepared and an ARD consultant selected for the urban domestic energy use and attitude survey. The survey was designed to determine:

- household demographic characteristics, infrastructure and economy;
- energy equivalents per household per year from basic energy sources;
- fuel sources by amount and tasks; and
- attitudes towards energy requirements and fuel use.

Gaborone, Lobatse and Selebi-Phikwe were the selected towns and Molepolole, Palapye and Serowe, the major villages. The study was undertaken in a total of 576 households, 128 in Gaborone, 64 in Palapye and 96 in each of the other four centers.

The research was conducted by an ARD consultant, Dr. John Gay, with the assistance of a full-time field supervisor and 18 enumerators. Fuel measurements were taken over a three-day period in each of three seasons (hot summer, autumnal transition and cold winter). Each day questions were asked concerning demographic characteristics, material possessions, attitudes and other topics required by the terms of reference.

The households sampled in each community were intended to be roughly proportional to the population size, but to ensure good representation of the diverse households in each community, a slightly larger proportion was chosen in the smaller centers. The sample is comparable to the household sample of the 1981 National Census, with the exception that this survey included more households in the upper end of the income scale. This was a conscious decision made to adequately capture the diversity of energy use and demand across all income sectors of the economy.

The households were stratified according to reported monthly income and total value of energy-using household devices. This resulted in five strata, with each household being assigned to one. The total value of energy using devices was intended to be an indicator of wealth, not reflected by monthly income, e.g., remittances, cattle, etc.

The survey collected an enormous amount of demographic, infrastructure, attitude and energy data. They have been coded and entered into the mainframe computer in the GOB Computer Bureau and are accessible for further analysis to people familiar

with the SPSS-X (Statistical Package for the Social Sciences) program.

Results and Conclusions

An analysis of the survey data across five income strata in the sample demonstrated that as income increases, Batswana households consume more aggregate energy per capita on a daily basis. This increase has two characteristics of importance to the BRET project:

- there is a shift to higher value (i.e., more expensive and nonrenewable) energy sources as well as an increase in the gross consumption of a range of energy sources; and

- the increase in available disposable income manifests itself in the consumption of a wider range of energy-using household appliances and systems.

Among the sample households, those using wood as their principal cooking fuel ranged from a surprising 24 percent in Gaborone to 86 percent in Palapye, with the mean percentage of households across the six communities being 56 percent. Gas ranks second as a principal cooking fuel with numbers ranging from 50 percent in Gaborone to 13 percent in Palapye, and a mean of 39 percent. Wood is the only principal cooking fuel used by all groups, varying from 83 percent of the lowest strata to 23 percent of the highest. Cooking and heating water account for over 70 percent of household energy use.

The lowest and highest income groups indicate the most resistance to new technologies. The lowest group is reluctant not only to adopt new technologies but also to change patterns of fuel acquisition. While this is an obvious constraint for the BRET project, almost 80 percent of the population is outside the income extremes and has indicated interest in and the ability to change. This represents the largest area of opportunity for BRET project dissemination efforts.

Two perceptions emerged regarding the energy supply situation. The first is that people do not recognize that fuels of all varieties are scarce in Botswana. The second is the belief that while regulation of tree cutting should occur, it should be the responsibility of either central government or tribal authority. The notion of individual conservation efforts was not put forth.

Finally, with respect to public awareness of RETs in general, the survey results indicate a general awareness of specific technologies, such as a solar water heater, but no

appreciation for it in terms of the energy source used and the potential for long-term savings.

Respondents were asked to indicate their willingness to purchase and/or make various RETs, at a given purchase price and given fuel savings. These data were indicative only of what people might or might not do. Generally, there was strong interest in the metal stove with an improved fuel efficiency of 10 percent and at a cost of P15. The responses were mixed regarding the retained heat cooker. More than half of the upper-strata respondents indicated a willingness to buy the device for P20 if it saved 10 percent of their fuel. For the lower-income groups, it would have to save 20 to 50 percent. The earthen stove required savings of 40 to 50 percent to be considered. Solar water heaters and PV mini-systems were interesting in upper-income groups.

These results reinforce two concepts of national economic development:

- in the process of national economic development, as family household income increases, there is an accompanying shift in consumer preference toward higher-value goods and services; and

- household investment decisions regarding the adoption of new, improved technology are strongly modified by the relationship of available disposable income and individual perceptions of the presence of risk and uncertainty.

The quantitative fuel-use aspects of the survey were the most difficult to implement and analyze. This was due partly to the structure of the survey itself as well as enumerator error and inadequate support from the electricity corporation. The second recommendation below addresses this issue.

Recommendations

First, based on the above, RET dissemination should be targeted at middle-income groups who have some disposable incomes. Attempts should also be made to encourage more efficient use of firewood among low-income, low-consumption groups, although the risk involved for them in adopting a new technology is higher. Upper-income groups, who use a wide range of imported fuels, are also less interested in change for different reasons, and technologies that substitute for purchased fuels might be of more interest to them.

Second, gathering quantitative data on such a large scale is difficult. In future work of this nature, support from the power

corporation needs to be solicited, and a larger number of professional researchers, perhaps one per site, should be hired to supervise and verify measurements.

B. National Energy Assessments

1. Wind

When planning for potential uses of renewable energy, a number of background assessments are necessary. The first and most important of these involves developing a profile of current energy sources and uses. This aspect of the BRET project's work has already been discussed in the preceding section (III.A). Other assessments of financial, economic, institutional and social factors are also necessary to assist in the definition of appropriate RETs and reasonable dissemination strategies. However, before reaching this stage, it is necessary to assess the potential renewable energy resources that are available. These assessments have been or are being performed by the BRET project and are the subject of this section of the final report.

In Botswana, the renewable energy sources with the greatest potential are wood, biomass, wind and solar energy (but not hydropower, for example). An examination of existing resource information indicated that the quality and quantity of data were inadequate in terms of both the level of analytical detail envisioned in subsequent phases of the project and forecasting the potential impact of various renewable energy strategies. For these reasons, it was necessary to develop programs for gathering data about renewable energy resources.

Wood is already a widely used renewable energy source. Due to concerns about the present use of wood energy and the longer-term implications of increased pressure on this resource, which takes time to replenish through new growth, MMRWA made arrangements with ODA to conduct a comprehensive nationwide Rural Energy Survey. This activity is complemented by the BRET surveys described in the previous section. BRET staff cooperated fully with the study by providing administrative and logistic support, acting as consultants to MMRWA on such issues as reviewing terms of reference and report drafts, serving on the reference group, and providing data and information gathered as part of the BRET project's urban domestic energy use and attitude survey.

Wind and solar energy have been largely untapped sources of energy in Botswana. It was determined by the BRET project and MMRWA that improving the quantity and quality of such data was an important objective of the project. There is clearly a need for clean water and small-scale, decentralized lighting and refrigeration for isolated health clinics and schools. Wind and solar energy appeared to have the potential to meet those needs, partly due to recent technological innovations in both areas. The technology identification and selection process was initiated in the PP, which stated that windmills, solar pumps and PV

electrification were relevant RETs to consider for inclusion in BRET project activities. At that time, only few data of uncertain reliability existed. Project activities in wind and solar resource assessment have begun to address the need for more complete data in these two areas.

Developmental History

There have been wind speed and wind run data collected at two-meter heights at various meteorological and agricultural stations. These data have been collected for agricultural purposes. Most windmills operate on 10-meter towers, and there are significant and variable differences in wind velocity at two- and 10-meter levels that cannot be predicted with any certainty. Met Services had long-range plans to install anemometers and collect 10-meter data at its 10 synoptic stations spread throughout Botswana. Even in the BRET project planning stages, MMRWA and DWA had plans to develop programs for wind assessment at 20 sites and conduct standard windmill field tests with 16 windmills. These MMRWA plans became part of the BRET program.

In the first year of the project, there were meetings among Met Services, University of Botswana Physics Department, BTC, DWA and BRET staff to determine appropriate sites, finalize plans for installation and monitoring, and develop a coordinated data analysis process for 30 anemometer sites. In 1983, a Swedish meteorologist offered assistance with the aid of a grant from the Swedish International Development Agency (SIDA). He is currently engaged in a 16-month consultancy with the BRET project to oversee wind data collection and conduct the analysis.

Most of the first year was spent arranging for the installation of the remaining equipment, repairing malfunctioning equipment, and organizing and putting in place a workable data collection and reporting system. During this period, most of the anemometer sites were visited to check their operation, meet volunteer observers, and ensure that they were well-exposed and placed in a location representative of the geographical area. Unfortunately, this work did not leave much time for more formal analysis of the wind data by the meteorologist.

However, several working papers have been written and circulated. Working Paper Number 1, "Wind Observation Sites in and around Botswana," (November, 1984) is a detailed account of sites in and near Botswana where data have been collected in the past, and much of the processed data from these sites is included. Working Paper Number 2, "Wind Statistics in Botswana: Earlier Attempts," is an analysis of several earlier attempts at documenting and defining the wind regime of Botswana. These attempts were limited by insufficient data at the 10-meter level and broad assumptions about the horizontal shear characteristics

of the wind. The BRET project's wind study overcame these two deficiencies by a wide network of anemometers located at a 10-meter recording level.

To get some idea of wind speeds for the wind pump report prepared at the end of the BRET project, some of the 1984 wind data were studied. Total yearly data from nine sites throughout the country were analyzed for monthly and annual average wind speeds. The annual average windspeed varied between 2.4 and 3.6 meters per second. The 1984 minimum monthly averages varied between 2.0 and 2.5 meters per second, from February to July. The monthly maximum ranged between 3.1 and 4.0 meters per second in September, October and November. The minimum months and monthly averages are important design considerations because they determine the minimum potential water supply that must be pumped to meet anticipated demand at that time. If the maximums matched the dry months with higher borehole water demands, the wind resource would provide an advantage for wind pumping capacity at that time of year.

Although this report marks the end of the BRET project, it was understood that the wind resource assessment was a process which required a long-term commitment, if reliable statistical data were to be ultimately available. The wind consultant has been funded through April, 1986, so that sufficient analysis of the data collected to date can be completed and the anemometers already in place can be calibrated. Unfortunately, it is anticipated that repair of faulty equipment will continue to be a major part of this project's activity. Met Services has committed a counterpart to the program, and three skill requirements have been identified as needed for successful continuation of the program. These are repair and maintenance, data collection and input to computer, and analysis and report preparation. It is hoped that the commitment of the GOB's Meteorological (Met) Services will result in an ongoing data collection and analysis program that will continue well into the future.

Results and Conclusions

First, an ambitious, comprehensive, and time- and resource-consuming wind energy assessment program has been initiated. The role of Met Services in facilitating cooperation in this program has been substantial.

Second, a sound program has been started with the involvement, support and cooperation of a number of organizations, SIDA in particular. The work completed to date would not have been possible without the active cooperation of the organizations represented on the Reference Group.

Third, the maintenance and repair of equipment will continue to be resource- and time-consuming. There are inadequate personnel to maintain the program into the future at its current level.

Fourth, three separate areas for counterpart development with different skill requirements have been identified. They include overseeing and implementing:

- repair and maintenance,
- data collection and input into a computer, and
- data analysis and report writing.

Met Services has already identified and appointed someone in the second area.

Fifth, the potential for wind pumps as part of a national pumping strategy warrants continuation of a wind assessment program for a few years into the future.

Recommendations

First, an effort should be made to begin developing recommendations and plans regarding desirable and feasible length of continuing the wind assessment program at all of the current sites--perhaps two or three years will give sufficient data and is the most realistic time frame. There should also be an assessment made as to whether the equipment should then be moved to other sites to round out the national wind regime picture. The instruments no longer needed at current or supplementary sites could also be used for special studies for necessary projects.

Second, additional resources should be provided for Met Services to carry out competent instrument maintenance and data collection and analysis, as it has been shown that separate staff skills are needed in each area.

Third, training will be a necessary part of any ongoing wind assessment program. Counterpart skills in the three areas defined above probably do not require three separate full-time people, but do require interested and competent staff to work part-time on the wind data program. They will need training.

Fourth, two Met Services technicians should receive short-term training in equipment maintenance and repair.

Fifth, consideration should be given to continued intermittent expatriate assistance beyond May, 1986 for continued

data collection and analysis. A repair component should also be considered with any additional funding and technical assistance. Additional spare parts and instruments will be needed.

Sixth, MMRWA should take the lead in facilitating cooperation between the Geological Survey, Met Services and SIDA consultant for preparation of a wind-power and water-depth map of Botswana.

2. Solar

Developmental History

MMRWA, DWA, MLGL and district councils have all been interested in exploring the possibilities of solar PV-powered pumps to meet the need for water in isolated rural areas and lower recurrent fuel and maintenance costs. Similar interest also existed in using PV power for lighting and refrigeration for certain GOB facilities in isolated locations, particularly health clinics. Solar energy applications in building have also been a long-standing interest of MMRWA, MOW, MLGL and BHC, both for water heating and, more recently, space heating and cooling of buildings. All these applications can meet the GOB-stated need to reduce dependence on imported fuels. All these applications also require solar radiation data for good application engineering.

For a number of years, Met Services had been making observations at a few locations to determine daily hours of clear sunshine and estimated amounts of cloud cover, but not measured amounts of solar radiation or energy available at different times of the year. MOA and DWA also have some limited insolation data. These observations only give daily information (not hourly) and only reveal whether it is sunny or not, rather than the actual amount of solar radiation received. These data are inadequate for solar energy application engineering purposes.

Due to the increased interest in solar energy applications in Botswana, as well as a desire to further develop the capabilities of the meteorological data program, Met Services began discussions with the BRET project and MMRWA in late 1983 regarding establishing solar data acquisition capability at several existing observation sites.

The BRET project was already interested in collecting these data for its PV and passive-solar building design work, but the only information that could be used for engineering purposes was from meteorological stations outside Botswana in Zimbabwe, Namibia and the Republic of South Africa, where solar radiation has been measured for many years. However, an analysis of

sunshine observations which had been made in Botswana, together with other climatic factors (comparative rainfall, etc.), suggested that extrapolation of data from these outside sources to particular locations in Botswana could easily lead to errors in the range of 10 to 20 percent. Such uncertainty necessarily leads to oversizing of systems and/or less than desired performance. The cost of oversizing all future solar collection applications by 10 to 20 percent would clearly be more expensive than developing more accurate data by a program of field measurement.

A second difficulty discovered by the BRET project was that the data from outside sources were not readily available in daily or hourly format and, therefore, could not be used in engineering applications, which require dynamic daily or hourly solar radiation data. For example, the computer simulation model used for most BRET building energy analysis requires an hourly weather file, which had to be synthesized at significant cost and difficulty because of the lack of measured hourly data.

In early 1984, the BRET project and Met Services agreed on a collaborative program to establish three sites for solar radiation measurement. In Gaborone, both global total solar radiation and direct normal solar radiation would be measured. In Tshame and Maun, global total solar radiation would be measured. All equipment and procedures would be to Class I standards of the World Meteorological Organization. The BRET project agreed to provide the necessary equipment and training in its operation.

ARD consultants held discussions with U. S. experts and recommended hardware to Met Services, which was agreed on and delivered to Met Services in December, 1984. Two weeks of intensive training were provided to Met Services personnel regarding the principles, operation and maintenance of the equipment. Standard data collection, handling and processing procedures were developed and documented. The first of the three systems was installed at the new international airport in Gaborone. An obscure manufacturing error in the data acquisition systems required the equipment to be returned to the manufacturer, but the problem was corrected and the units returned to Met Services in June, 1985. The system in Gaborone was checked out and operational at the end of July, 1985, and Met Services personnel were prepared to complete the other two installations on their own.

Results and Conclusions

First, a sound program for solar radiation data collection has been initiated, which will be of significant importance to future solar energy applications engineering in Botswana, as well

as a valuable contribution to the worldwide program of solar radiation measurement.

Second, the equipment selected is more complex than that used to date at most meteorological observation stations in Botswana. While the training provided with this equipment was adequate, the trainees had little background in this area. These factors will probably lead to some continued difficulties with the solar data program. However, such electronic data collection and processing is the direction that Met Services is taking with its other observations, so in the long run, the experience gained in this effort should ease the transition to more sophisticated meteorological data acquisition.

Recommendations

First, Met Services should make equipment installation in Maum and Tshame a high priority. A high level of support should be provided to observers at all these sites to overcome the difficulties of working with new and unfamiliar equipment. This can be justified not only because of the value of the information to be collected, but also for its value in establishing how more sophisticated electronic data acquisition will be used by Met Services in the future.

Second, additional resources will probably be needed by Met Services for instrument maintenance and to ensure the quality of data collection, analysis and reporting. Such a program will be only as good as the resources that permit the implementation of these essential activities. Additional donor-funded expatriate technical assistance should be considered, in consultation with Met Services.

Third, the long-range objectives of this solar radiation data acquisition effort should include the development of data files for solar engineering, which are comprised of hourly solar radiation values for each hour of the year, with concurrent temperature, wind direction and wind velocity.

3. Woodlot/On-Farm/Multi-Use Forestry Resources

Because work carried out under the ODA study was aimed at gathering information for the development of a woodlot program and the other important activities of the BRET project, MMRWA, AID and the project accorded work in this area a very low priority and did not authorize the BRET project to undertake any activities on such an energy assessment.

4. Other Assessments

No other assessments were considered as part of the BRET project.

C. Water Pumping

The BRET project conducted a comprehensive comparative testing program of a variety of water pumping systems in Botswana. The purpose of the program was to quantify as many pertinent factors as possible, which characterize various water-pumping options from technical, financial/economic, social and institutional perspectives. The goal of this study was to determine which of the wide range of available pumps were the most appropriate choices for water delivery systems under a variety of circumstances commonly encountered at small-scale, rural water supply development sites in Botswana.

In Botswana, surface water is scarce in most areas, so ground water must be pumped. All pumps require outlays of limited financial resources and all require varying degrees of periodic maintenance and repairs to keep them running successfully. Each type of pump has a best application, which is a function of the water demand, water source constraints such as borehole yield and water quality, the pumping head and the amount of capital available for purchasing the pump.

The types of pumps examined varied widely in terms of capacity, cost, levels of technical support skills required, and labor/capital intensity characteristics. The pump types included solar photovoltaic (PV), windmills, diesels, human traction and hand pumps, grid-electric submersibles, animal traction and bio-gas pumps. The last two types were not tested directly by the BRET project, but were subcontracted to the BTC and RIIC for development and testing. Most of the pumps tested were in the low range of system size, as that is the area in which the alternative pumping systems are most likely to be competitive with diesel pumps, which are the de facto standard in Botswana.

While a number of previous studies have examined certain types of pumps, there has been and, to a lesser extent, still remains a dearth of practical field experience with older technologies (such as windmills) as well as more recent developments (such as PV). As yet, no effort anywhere in Africa has been made to compare so many alternative systems using the same analytical methodology. While manufacturers' data on their products are useful in design estimation, they are often overly optimistic for use in detailed system design. The performance curves are normally generated under ideal operating conditions in the laboratory, pumping very clean (non-corrosive) water, and with a multitude of researchers nearby to attend to the maintenance of each component. Field-test results are crucial to the sizing and design of real systems. Information from BRET field tests will aid other system designers with future projects, as well as give some indication of what the real costs are of

pumping water with a wide range of small-scale water pumps in Botswana.

Diesel pumps are the most common water delivery system in areas which do not have access to the national electrical grid. In some countries, diesel-driven generators drive electric pumps. In Botswana, 85 percent of the boreholes used are equipped with direct, diesel-driven Mono (progressive cavity) pumps. Botswana has been fortunate in that the Department of Water Affairs (DWA) of the Ministry of Mineral Resources and Water Affairs (MMRWA) and the District Councils' maintenance units had a very successful pump maintenance program for their diesels. In large part, this is due to standardization of equipment and a commitment to training. However, DWA is increasingly concerned with the actual long-term costs of using diesel pumps, costs which in the past have not been adequately quantified.

1. Developmental History

The project paper included as part of its technical development and demonstration effort the installation of two PV pumps, two "integrated water pumping systems," and eight small wind/hand pump systems in small villages. After reviewing the current situation, ARD and BRET staff concluded that simply demonstrating several new systems was neither the most helpful nor most needed approach to using renewable energy for water pumping in Botswana. The GOB needed both an analytical method for evaluating the most attractive pumping systems as well as better field data on both diesel and alternative pumping options. Over the first year and a half of the project, ARD and BRET staff had extensive discussions with the government and other involved organizations concerning the need for a comparative pumping program. Consequently, following its midterm evaluation, the BRET project was finally able to refocus its efforts to expand on the original mandate in the project paper to develop what has since become a comprehensive comparative testing program for a wide range of water pumping systems. Over 40 pumps were eventually monitored and evaluated by the project.

The detailed results of the wind, PV, human traction, and hand pump testing are given in separate technical reports available through either ARD or the BRET project. (See WIND PUMP FIELD TESTS IN BOTSWANA--PRELIMINARY TECHNICAL AND COST COMPARISONS, Jonathan Hodgkin and Richard McGowan, March 24, 1986; SOLAR PUMP FIELD TESTS IN BOTSWANA--PRELIMINARY TECHNICAL AND COST COMPARISONS, Richard McGowan and Jonathan Hodgkin, April 7, 1986; THE THEBE PUMP--A HUMAN TRACTION PUMP FOR BOTSWANA, Jack Shields and Richard McGowan, September 26, 1985; TWO TYPES OF HAND PUMPS--RESULTS OF FIELD TESTS IN BOTSWANA, Jonathan Hodgkin and Richard McGowan, August, 1985.) Tentative conclusions for the bio-gas and animal traction testing are given in separate BTC

and RIIC reports. The results of the grid electric and diesel pump testing are included in the overall BRET comparative testing report (SOLAR PUMP FIELD TESTS IN BOTSWANA--PRELIMINARY TECHNICAL AND COST COMPARISONS, Richard McGowan and Jonathan Hodgkin, April 7, 1986).

In addition to the BRET project, several other organizations in Botswana have been involved to a lesser extent in testing several types of water pumps. BTC has tested a PV water pump, and participated in the BRET-funded development studies on bio-gas and animal-traction pumps. RIIC was also involved in the bio-gas and animal traction pump testing and has been working for several years on the development of a locally manufacturable windmill, the "Motswedi," which they also tested. The BRET project partially funded this development effort and purchased several of their machines for testing.

The Department of Water Affairs (DWA) has had an interest in an alternative to diesel pumping systems for some time, and had purchased several conventional windmills and hand pumps to be used for water supply at remote cattle posts. While DWA was not involved in the testing of the wind machines, they did make several of their machines available to the BRET project. DWA has also begun to use grid-electric submersible pumps as an alternative to their standard Mono/diesel combination. Interest in the submersibles increased after the World Bank Energy Sector Study was published, which recommended their use in some situations in Botswana. Finally, the Swedish donor agency SIDA has had an interest in hand pump use in Botswana for some time. As the District Council's Water Unit technicians were also interested in using hand pumps, the BRET project decided to include hand pumps in the testing program.

2. Results and Conclusions

The results and conclusions of the testing program thus far are given first by individual technology in the following five sections on diesel, grid-electric, wind, PV, and hand operated pumps. Advantages and disadvantages of each type of pumping system are pointed out. The comparative conclusions are then given in the last section.

The most important evaluative criterion calculated in this study was the unit cost of water delivery for each of the different types of systems. While both financial and economic analyses were performed, the emphasis was put on economic analysis because the largest purchaser of pumps in Botswana is the government, particularly, the Department of Water Affairs (DWA). However, choices of pumping systems are not often made purely on a cost basis. Water availability, long-term reliability, ease of system design and installation, spare parts

availability, and the level of technical skills required for proper operation and maintenance are equally important. To some extent, the financial/economic analysis included these variables, since the costs of factors such as reliability and necessary skills level can be to some extent quantified, and were therefore factored into the long-term recurrent cost schedules.

The general conclusions given below should be viewed only in terms of the many qualifications and explanations given in the text of the overall comparative pumping program report from which they are taken. They should be viewed as preliminary results which will be refined during the 16-month extension of the water pump testing component of the BRET project. While attempting to use actual measured data as much as possible, the analysis, by necessity, has included some assumptions on both recurrent costs, long-term technical performance and reliability issues. Sensitivity analysis on many of these assumptions has shown that among the most sensitive of these assumptions is the requirement of having pumpers at all government installations. This is especially true for solar and wind pumps, which do not require nearly as much attention during normal operation as diesel systems. The effect on costs is dramatic, and there are significant social and institutional impacts as well.

By way of explanation, the energy required to pump water is a function of both the volume of water pumped and the head (elevation plus losses) through which it is pumped. The energy costs of pumping, therefore, are best expressed in terms of both flow (in cubic meters or m3) and head (meters or m). Unit costs of water delivery are then expressed in terms of cost per volume*head product (pula/m3*m). (All costs are given in local currency, where US$0.57 = one pula = 100 thebe.) All pump performance data were extrapolated from relatively short-term (several weeks to several months) measured data to predictions of long-term performance. All costs used in the analysis reflect current commercial pricing of the equipment, and the authors' best estimates of long-term recurrent costs based on actual costs incurred as part of the testing program thus far. It should be noted that the size of the systems tested focused mainly on small-scale applications (less than 75 meters of head and outputs of less than 50 cubic meters per day) where diesel becomes an expensive option, and the alternatives are most likely to be cost-competitive.

Diesel

Diesel pumps are the de facto standard against which the other pumps must be measured, as they have been installed on approximately 85 percent of the boreholes in Botswana. While only a limited sample (five) of these pumps was tested, the unit costs increase rapidly when the output drops below 1,000

m3*m/day. This is equivalent to 20 cubic meters per day for 50 meters of head (lift) or similarly, 50 cubic meters a day at 20 meters of head (50 m3/day*20 meters = 1,000 m3*m/day). Sensitivity analysis of the cost assumptions revealed that the high unit cost at low daily output was largely a function of the fixed pumper costs, which become a much larger percentage of the unit water cost for smaller systems. This raises an interesting policy issue that surfaces in sensitivity analyses of virtually all the pumps tested--i.e., the importance of pumpers and employment generation in the rural sector.

Diesel fuel was the only energy source used for the pumps examined that will continue to be imported, as currently imported grid electric power will soon be replaced by the opening of the coal-fired Morupula Power Plant. As such, diesel is the only energy source used for pumping over which international market forces have control.

In general, water pumped from government boreholes in rural areas of Botswana is highly available compared to many other African countries. In large part, this is because DWA has standardized on the Lister-Mono pump combination to reduce spare parts inventory requirements and simplify the training of maintenance personnel. The success of this program has had a distinctly favorable impact on unit water costs. These successes should not be overlooked, nor should the infrastructural support costs for alternative pumping systems, which have yet to be put in place, be underestimated.

Diesel pumps have the lowest ratio of installed capital costs to total life-cycle costs, ranging from 10 to 15 percent, while the values for solar and wind pumps range from 50 to 80 percent. These figures are in line with the general perception of diesel and grid-electric pumps as having a low initial cost, but high recurrent costs, and the reverse for RET systems. Of course, this can be an advantage or disadvantage depending on current and expected future financial constraints.

The advantages of diesel pumps are:

- relatively low installed capital cost;
- they are the least expensive option for high-head, high-flow situations;
- the support infrastructure for equipment distribution, maintenance, repair and technical training is currently in place and fairly well developed;

- they provide on-demand water delivery (assuming adequate fuel availability and performance of proper maintenance procedures), so storage costs less;

- there is no practical size limit on equipment; and

- they can have electrical as well as mechanical output.

The disadvantages of diesel pumping systems are as follows:

- from a maintenance perspective, they are fairly complex, requiring periodic overhauls and a pump attendant during operation; skilled labor is needed for periodic overhauls, which require the engine to be temporarily replaced and taken to a central repair shop;

- they are dependent on national (often rural) transportation networks to maintain adequate fuel supply and international distribution and pricing vagaries;

- normally all costs, except local labor charges, are in foreign exchange;

- they have relatively high recurrent costs for operation, maintenance and repair;

- while larger, low-speed diesels are quite reliable, smaller engines used at low-demand sites usually run at higher RPMs, thereby requiring more frequent maintenance and replacement;

- since small (less than two kilowatts) units are not available, engines at low-demand sites often run well below their design point, dramatically reducing efficiency and increasing fuel consumption per unit water pumped; and

- they are noisy.

Grid-Electric

The testing of electric pumps was very limited. There was difficulty finding grid electric pumps that operated in the small-scale output range which was of primary interest. The two pumps which were selected and tested delivered well over 50 cubic meters per day and, as such, were outside the primary range of interest. However, the tests showed that electric pumps were surprisingly expensive to operate. This appeared to be due to

the high cost of electrical energy required to operate the pump. With electricity costs of 16.1 thebe per kilowatt-hour, the energy cost alone of pumping water is 12 thebe per cubic meter at a typical head of 100 meters. This compares with diesel energy costs for a similar system of seven thebe per cubic meter.

The main savings in operating grid-electric pumps would then come from their capability of running unattended, so that pump attendant costs would not have to be incurred. DWA currently assigns pumpers to these sites, which again raises the issue of the need for such a policy. The World Bank argues that the economic cost of electric energy that will be produced at the Morupula Power Plant will be about one third of the current tariff rate. If this is the case, the economic unit water cost will drop dramatically.

Note that while the electricity tariff mentioned above is not subsidized by the government in many areas, electricity sold by the GOB in remote areas which are on separate grids (such as Ghanzi, Maun and Tsabong) is subsidized by as much as 50 percent. Therefore, the relative costs of grid electric pumps in these areas are considerably greater.

The DWA has become more interested in grid-electric submersibles and has, therefore, begun to build the necessary support infrastructure. For replacement parts, the value of inventory with submersibles is considerably higher than for diesels, as the integral submersible units represent the cost of both motor and pump element. The range of pump sizes necessary to keep on hand, however, is unlikely to be much greater than that for diesels, as a single submersible motor can be used with several different pump elements for different head requirements.

The advantages of grid-electric submersible pumps are:

- relatively low capital equipment costs (excluding grid tie-in costs, such as long-line extensions or step-down transformers);
- they provide on-demand water delivery (assuming adequate energy availability and performance of proper maintenance procedures), so storage costs are less;
- there is no practical size limit on equipment;
- electronic controls allow for unattended operation, reducing pump attendant costs;
- they have longer maintenance intervals than most alternatives, with expected corresponding reductions in maintenance costs;

- while electricity is currently imported, when the Morupula Power Plant comes on-line, there will be no imported fuel requirements, so they will not be dependent upon vagaries of transportation networks or international petroleum products distribution irregularities; and

- quiet operation.

The disadvantages of grid-electric submersible pumps are as follows:

- normally, all equipment costs are in foreign exchange;

- relatively high recurrent fuel costs; and

- the support infrastructure (for system design, maintenance, parts distribution, training) is not yet extensive; costs of implementing this support infrastructure could be substantial.

Wind

Initial results from the first phase of the wind testing program indicate that wind pumps could be the least-cost pumping option only at sites where the design wind speed condition was at least 2.5 to 3.0 meters per second, and the average water demand was less than 10 cubic meters per day. If a wind pump can deliver this amount of water (remembering that this depends on the head as well), then it is likely to be the least-cost option compared to diesel. Not only is it technically more difficult for a wind pump to meet water requirements much greater than this (due to the size limits of currently available equipment), but the unit water cost for diesel pumps decreases with higher demand. Preliminary results indicate that all of the new design wind pumps can meet this criteria for heads of less than 35 meters and wind speeds in the range of 3.0 meters per second (or for lower wind speeds in conjunction with a lesser head).

However, due to generally low average wind speeds at most sites in Botswana, it appears that the sites where wind pumps are cost-competitive are likely to be limited in Botswana. The areas of highest wind speeds appear to be the southern and eastern regions, whereas the shallowest boreholes generally occur in the east. These areas remain to be defined more closely by the on-going wind resource survey and the DWA survey of water table depths.

The major uses of water in Botswana are for human consumption and cattle, with some irrigation but very little

industrial use outside one or two areas. The major activities of DWA are maintaining water delivery systems in the major villages and at government establishments, and building reticulation systems (many of which are now completed) for the 354 villages in the village water supply program. While most village requirements have been beyond the capacity of wind pumps, they may be applicable for some smaller villages.

Stock watering at Department of Wildlife sites and government-supported and syndicate-owned cattle posts appears to be the area where wind pumps could have the most impact. Storage considerations would not be such a problem, as cattle could be moved to a diesel-equipped borehole if necessary when the winds are calm. For syndicates or private users, however, interest charges (16 percent) on capital equipment costs may be a significant constraint.

A modest support infrastructure in both the public and private sectors currently exists in Botswana for conventional locally manufactured wind pumps, primarily for Climax products. If windmills are to be used at Department of Wildlife sites or by syndicates, then the Borehole Repair Service (BRS) of DWA also needs to be trained to maintain and repair windmills. For the imported wind pumps (Kijito and Wind Baron), parts procurement and technical support are major problems. Only if these machines are manufactured in southern Africa could substantial deployment in Botswana be justified. The RIIC and, to a lesser degree, WTGS designs are being built in Botswana, so that repair and maintenance skills reside completely in the country. Also, RIIC has trained a special windmill installation crew for installation and repair of their machines.

One interesting note is that at current costs, diesel systems are more cost effective in the output range of the Wind Baron. At outputs of less than about 500 to 1,000 m3*m, the diesel unit cost becomes very expensive, but at levels above this range, RET pumps will have a difficult time competing. Clearly, the Wind Baron's capital cost has a pronounced effect, and it is possible that local manufacture could significantly reduce its installed cost. However, resultant cost savings will have to be considerable to yield a unit cost less than a comparable diesel pump.

The advantages of wind pumps are:

- low long-term recurrent costs due to minimal maintenance requirements; maintenance intervals much longer than most alternatives;

- no imported fuel requirements, so they are not dependent upon vagaries of transportation networks or international distribution irregularities;

- mechanical controls allow for unattended operation; and

- locally manufactured units offer considerable savings in foreign exchange over most pumping methods.

The disadvantages of wind pumps are as follows:

- anticipated low wind speeds in most of Botswana will limit potential applications;

- relatively high installed capital cost;

- size limits (a rotor with a 6.4-meter diameter delivers about 0.5 kilowatts in three meters per second of wind) of the equipment currently available;

- current production models (except RIIC/WTGS) require the expenditure of foreign exchange;

- the support infrastructure for system design, maintenance, parts distribution, training is not yet extensive and costs of implementing such an infrastructure could be substantial; and

- they cannot supply water on demand and thus, require larger hydraulic storage capacity than on-demand units, such as diesel, so that energy can be accumulated during off-peak periods to satisfy peak demands.

Solar Photovoltaic

The two kinds of pumps tested were the Mono driven by surface-mounted Honeywell DC motors, and Jacuzzi DC submersibles with both pump and integral motor submersed in the borehole. While additional PV pumps are being tested in the second phase of the program, only these two systems will be dealt with here.

While the solar pumps did not deliver as much water as had been expected, given the borehole yield and head constraints, there nonetheless seems to be potential for their deployment in Botswana. Their application would focus on small-scale village drinking supply, stock watering and garden-plot irrigation. Irrigation is a somewhat marginal application, due to the large volumes of water normally required and the high heads normally encountered in boreholes in Botswana. Fields larger than about two hectares would require larger PV pumps than are currently

available. Commercial development of larger submersible PV pumps to address greater demand situations is underway.

PV is not currently a viable option for heads greater than about 50 meters and water demands of 20 cubic meters per day, or conversely, heads of 20 meters with water demands greater than 50 cubic meters per day. These limiting cases could currently be met only with Mono-coupled PV pumps in Botswana. For smaller heads and lower flows, submersibles are equally competitive. While three of the PV pumps tested lie in the cost-competitive range with diesel, the performance and cost of the remaining two were marginal. In one case, the pump was not well matched to the site. In the other, the system was an early design, purchased by the BRET project after installation to include in the testing program. The components were not well matched, and the system relied on batteries, with their associated high recurrent replacement costs. Both of these instances emphasize the importance of careful system design. Due to advances in pump controller technology, the use of batteries is not recommended except in unusual cases (some of which are being examined in the second phase of the program).

The advantages of PV pumps are as follows:

- low long-term recurrent costs due to minimal maintenance requirements; maintenance intervals much longer than alternatives;

- very high reliability of power supply components (PV modules now have 10-year performance warranties);

- they are a rapidly advancing technology with promise of continuing cost reduction (about 2,000 PV pumps in use, and module cost has dropped from P13.3/Wp to P10.5/Wp in the two years since the first BRET purchase);

- electronic controls allow for unattended operation, which can significantly reduce operation and maintenance costs;

- they require no imported fuel, so they are not dependent upon vagaries of transportation networks or international distribution irregularities;

- maximum water output is normally coincident with the driest period, since that is when solar radiation levels are normally highest;

- modular design, which can be precisely matched to site constraints; water output can be increased by

simple addition of modules without changing pump and controller (within limits); and

- quiet operation.

The disadvantages of PV pumps are:

- relatively high installed capital cost;
- size limits (2.2 kilowatts) on currently available equipment;
- most components require the expenditure of foreign exchange and conversely, generate little local employment;
- the support infrastructure for system design, maintenance, parts distribution, training is not yet in place and the costs to implement this infrastructure could be substantial; and
- they cannot supply water on demand and hence, require larger storage capacity (either electrical or hydraulic) than on-demand units, such as diesel, so that energy can be accumulated during off-peak periods to satisfy peak demands.

Hand and Human Traction Pumps

Hand and human traction pumps are the least-cost option for low-head, low-flow sites, assuming there are no labor costs for pump operation. Their practical output is limited by the amount of force which a typical pumper can apply to the pump handles. Practical upper limits of delivery appear to be about three to four cubic meters per day at heads of 30 meters for the India Mark II hand pump (which was far superior to the other model tested), and 100 meters for the Thebe human traction pump. At this extreme low end of the water demand spectrum, no other pumping options are even close to being cost-competitive with these pumps.

These pumps offer the distinct advantages of local fabrication and repair, district-level installations and maintenance, and are quite reliable pumps when proper maintenance schedules are followed. This usually means annual replacement of the cylinder leathers.

The advantages of hand and human traction pumps are:

- very low capital and long-term recurrent costs;

- they are the most cost-effective option for low-head, low-flow situations; and

- they are simple in design for ease of operation and maintenance.

The disadvantage of hand and human traction pumps is their practical limitation to low-head (less than 30 to 40 meters), low-flow (under five cubic meters per day).

Animal Traction and Bio-Gas

Animal traction and bio-gas pumps are not discussed in detail in this section because of the lack of adequate cost and performance data due to the inadequate testing performed thus far. However, several general comments do apply. First, the tests performed thus far by BTC have very limited value. As such, no reasonable conclusions can be made at this point. The most likely constraint to widespread use of these pumps in Botswana is that they require considerable participation and management on the part of the end users. It is possible that this may be achieved under certain circumstances for sufficiently motivated private user groups, but this issue has been the main impediment to testing thus far.

It is unlikely that the pumps will find application in government-operated potable water supply programs because of the very high labor charges, when employees are subject to the Industrial Class Regulations. Private owners may find sufficiently inexpensive labor to overcome this obstacle. Much more work remains to be done before these pumps can be considered serious options for small-scale pumping systems.

General Conclusions

The major conclusions reached by the comparative pump testing program are summarized here. First, diesel/Mono pump systems were clearly the most cost-effective system for moderate- to large-scale systems (i.e., water demand greater than 1,000 m3*m/day).

Second, hand-operated pumps (including both traditional hand and human-traction pumps) were clearly the most cost-effective choice for the low end of the pumping demand spectrum--water demand of less than 120 m3*m/day or the equivalent of pumping four cubic meters per day at 30 meters of head.

Third, based on testing at only two sites, grid-electric submersible pumps did not appear to be a significantly less expensive pumping option than diesel/Mono systems, as had been

widely assumed. However, this finding is based on current electricity tariffs. When the Morupula Power Plant comes on-line, reduced tariffs could change this tentative conclusion.

Fourth, the applicability of wind pumps is the most site-dependent pumping option, as it requires both a low head (less than about 50 meters) and relatively high wind speeds (an average wind speed greater than 2.5 meters per second for the worst-case design month) to be cost-competitive with a diesel system. While a wind resource study is currently underway, wind speeds in most areas of Botswana are marginal.

Fifth, solar PV pumps are not as site-dependent as wind systems because of the relatively high and uniform solar radiation levels throughout Botswana. PV pumps appear cost-competitive with diesel systems at sites where the demand for water is between 120 and 1,000 m3*m/day, and the head is limited to about 50 meters. The costs of PV equipment are by far the most volatile of any of the equipment tested, and continued price decreases will make the cost of PV pumping systems increasingly favorable, compared to diesel.

3. Recommendations

The following recommendations are intended to give some specific direction to the extension of the BRET pumping program as well as public- and private-sector groups involved in water supply issues. They are to:

- continue to collect data on the pumps currently being tested, begin data acquisition for the second set of PV pumps that has been purchased, but not yet installed, and broaden the program somewhat to expand the limited data base on diesel and grid-electric submersible pumps;

- concentrate attention on any new systems tested to sites where demand is less than 1,000 m3*m/day (i.e., the range in which alternatives are potentially most cost-competitive with diesel);

- continue to collect and analyze data on solar radiation levels and wind regimes throughout Botswana and make that information available to system designers as soon as is practical;

- examine the longer term operation and maintenance costs for all of the pumps being tested more closely--these costs have involved the greatest amount of estimation and should be determined as

precisely as possible before the conclusion of the testing program;

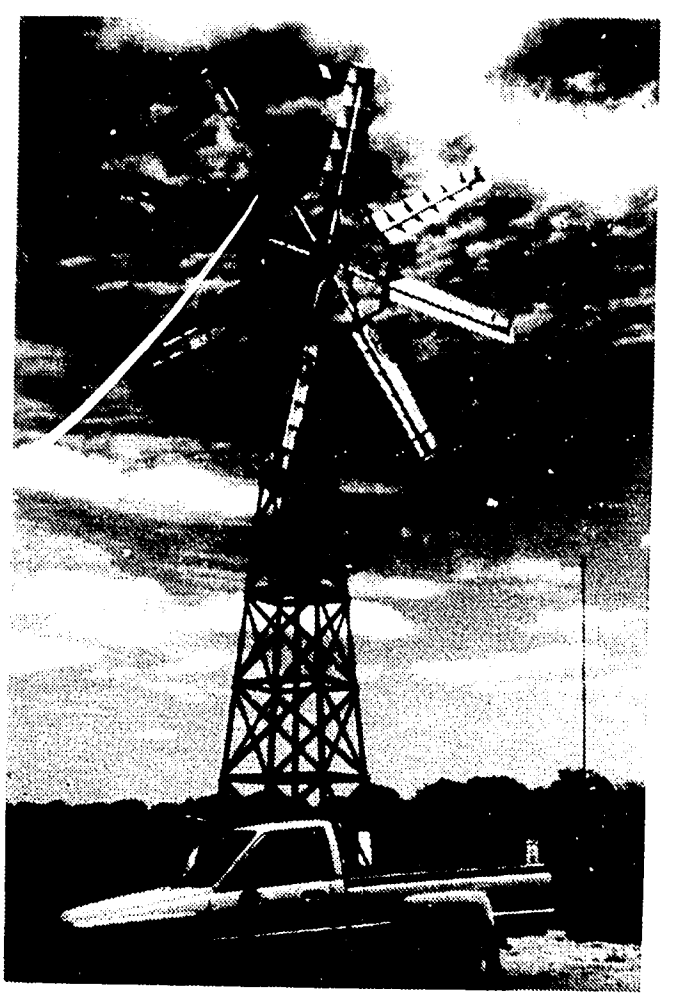
- infrastructural support requirements as well as the costs of building equipment supply, system design, and operation/maintenance networks and skills shoul be studied carefully;

- the storage sizing and cost issue for different types of pumps should be evaluated to try and determine its effect on unit water cost; and

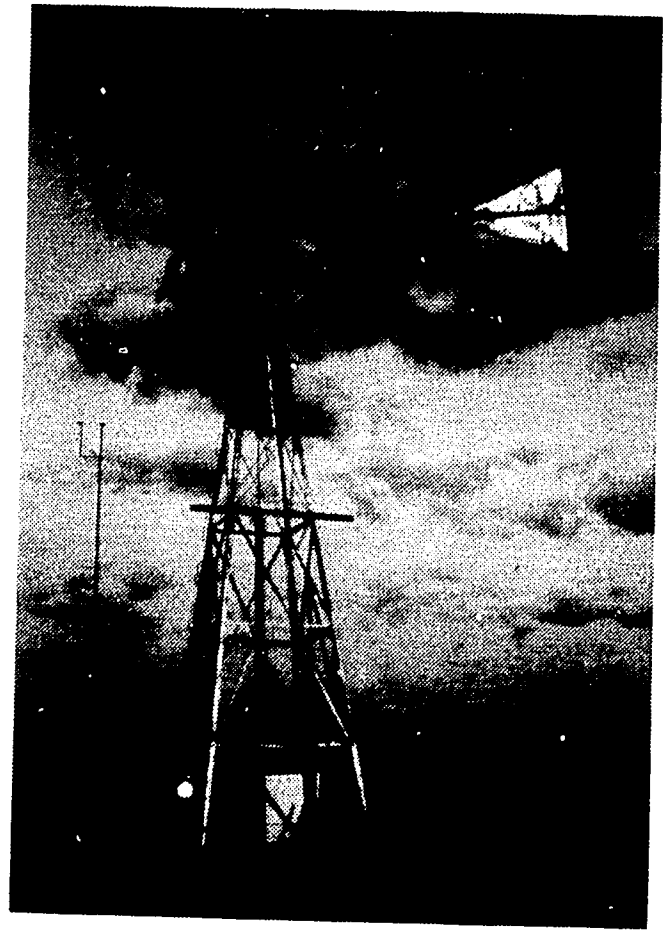
- an attempt should be made to assess the size of the market for RET pumps by a study to determine the number of existing boreholes or future sites where water demand would be less than 50 cubic meters per day at heads of less than 50 meters.

The Motswedi, developed in Botswana by RIIC.

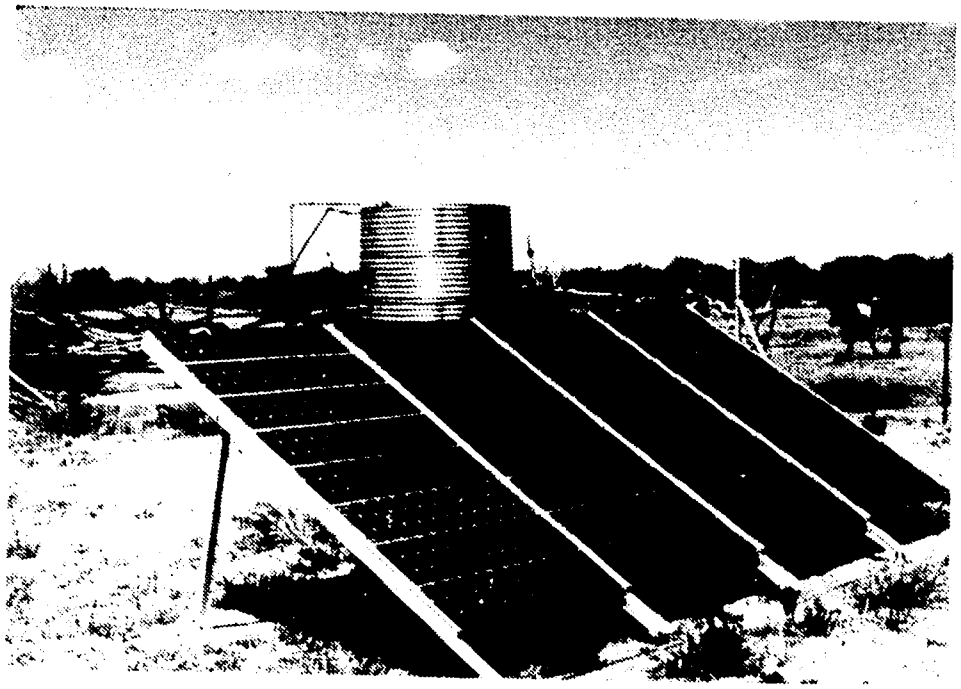
The WTGS, developed in Serowe, Botswana, by the Wind Technology Group Serowe.



The Kijito, manufactured in Kenya.

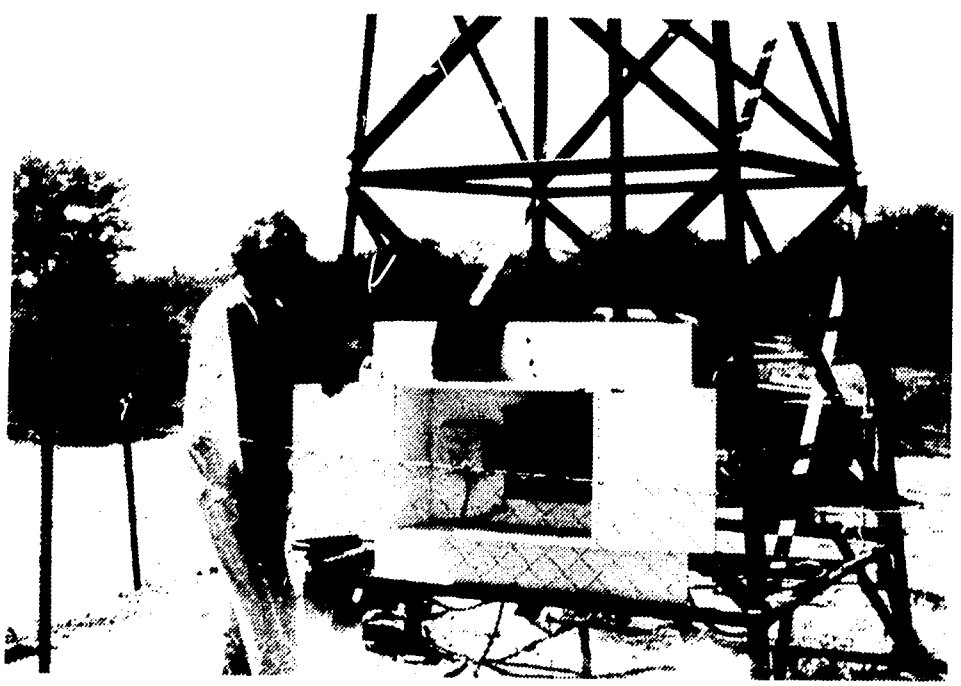


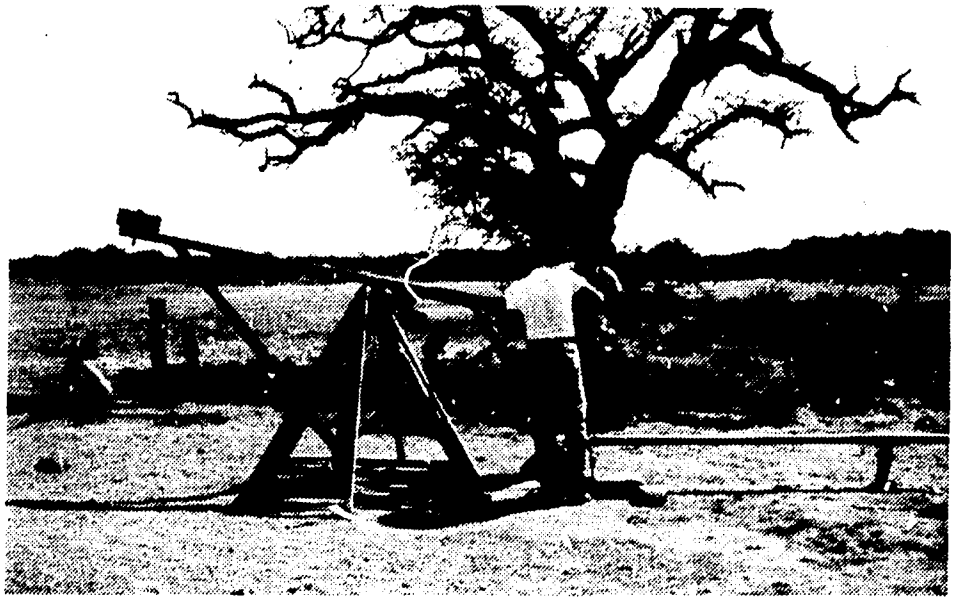
The Wind Baron, manufactured in the United States.



Above, one of five PV installations in the comparative pumping test.

Below, an ARD engineer displays monitoring equipment designed specifically for the comparative program.





BRET staff examine
human-traction
pump installation.

An ARD engineer tries
out the India Mark II,
one of two hand-pump
systems tested by BRET

D. Photovoltaic Electrification

One of the BRET project's goals was to demonstrate and evaluate the use of solar photovoltaic (PV) cells for stand-alone electricity generation at remote sites. The potential end-uses included water pumps, health clinic electrification for refrigeration and lighting, school lighting, radio communications and weather instrumentation at remote sites, although only the first two uses were identified and called for in the project paper. This section discusses the project's experiences with PV electrification of health clinics and village schools. This work involved the cooperation of MMRWA, the Ministry of Health (MOH) and Ministry of Local Government and Lands (MLGL). (For a full discussion of the project's work on photovoltaic electrification, see the BRET report titled PHOTOVOLTAIC ELECTRIFICATION OF HEALTH CLINICS AND VILLAGE SCHOOLS IN BOTSWANA, Richard McGowan and Jonathan Hodgkin, ARD, Burlington, Vermont, September 1985.)

One of the most critical needs in remote rural areas of the developing world is facilities for the storage of medical vaccines. Since health clinics in these areas seldom have access to grid (mains) electricity, until recently this need has been met by propane- or paraffin- (kerosene-) powered refrigerator/freezer (R/F) units. While the development of these units has progressed to the point where currently available units are usually quite well designed, they nonetheless have a highly variable history of reliability under harsh operating conditions in the field. They have been plagued by problems with unreliable fuel supply networks, lack of adequate local maintenance and repair capability, and high long-term operational costs due to constantly rising fuel costs.

To address the need for a cold-chain vaccine refrigerator/freezer (R/F) unit that is reliable, cost-effective, and easy to use and maintain, organizations in several countries began work on the development of a solar PV-powered R/F unit. This approach was due to the rapid decrease in the cost of PV modules during the late 1970s, which dramatically reduced overall system cost, as well as to the general perception that PV systems had the potential for extremely reliable long-term operation with minimal maintenance requirements.

Lighting in areas without grid electricity was also becoming a priority. At rural health clinics, the need for lighting is obvious. Although surgery is not normally performed, the clinics have maternity wards which require lighting for nighttime deliveries. Night emergency procedures also require adequate lighting. The conventional lighting sources have been kerosene lamps and torches.

In addition to clinic lighting, there has been increasing interest in lighting in the evenings for rural classrooms, so that teachers can prepare lessons, students can read and study, and evening classes and community activities can be held. Quantifying these benefits compared to the costs of providing lighting is admittedly difficult, and depends heavily on site-specific use patterns. Given the problems associated with the use of diesel or petrol generators (e.g., lack of fuel, heavy maintenance requirements, spare parts availability), PV modules are being examined more closely to determine their potential for powering such lighting systems.

Approximately 35 of the 62 secondary schools in Botswana are not connected to the national electrical grid, and hence are candidates for PV electrification (these figures are from the BRET/BTC PV workshop held in Gaborone during August, 1985). At off-grid sites where diesel generators are not being used, lighting is currently provided by white gas or paraffin lanterns, which are expensive and potentially dangerous. Another increasingly popular use of PV-generated electricity is charging small 1.5-volt, dry-cell batteries. Although this can be among the most economically favorable uses of PV, it was not specifically addressed in this program.

In early (before 1984) PV applications around the world, the direct-current (DC, the type of electricity generated by PV arrays) lighting and refrigeration equipment installed had been developed for marine and recreational vehicle use in the United States and Europe, where energy efficiency was not a great concern. The increased use of PV throughout the world has given small-appliance manufacturers incentive to develop new, more efficient DC lighting and other electrical appliances to satisfy this market. These energy-efficient appliances allow the use of fewer PV modules in the power supply, thus significantly reducing system costs. As a result, PV remote-site electrification is becoming increasingly interesting to many areas of the developing world, including Botswana. There are currently some 600 PV refrigeration units installed worldwide. Another 100 units are planned for installation in Zaire, where they will be produced through a joint venture with a local manufacturer.

A typical clinic electrified with PV has a vaccine storage unit, several lights and a power supply, consisting of the PV array, batteries and a charge controller. Usually, school PV systems simply provide a few hours of lighting a day to allow evening use of classrooms and occasionally power a small radio so that broadcasts of educational programs can be received.

Typical system configurations and costs vary, but the PV modules themselves represent the majority of the initial capital equipment cost of the system. PV modules are normally rated in terms of their peak power production capability. For instance, a

typical module might be capable of producing 40 watts of power under certain specified conditions of solar radiation intensity and ambient temperature (40 Wp, or watts peak). While PV module prices have not continued to drop as rapidly as researchers in the late 70s assumed, they have dropped from $20/Wp in the late 70s to $6/Wp currently. However, PV systems still have a considerably higher initial capital cost than fossil-fuel-based systems such as propane or kerosene. Thus, to be cost-effective, it must be shown that the reduction in long-term recurrent costs associated with using PV more than makes up for the higher initial investment in equipment.

While cost is an important consideration in the use of stand-alone PV electrification systems, the long-term reliability of the systems is of much greater importance. Reliability of operation is particularly critical in the cold chain since vaccines exposed to high ambient temperatures, even for relatively short periods, can lose their potency. Also important is user acceptance and ease of local maintenance and repair, without which no system will achieve long-term operational reliability.

Little field testing has been done on small-scale lighting systems for schools. Thus, while extensive laboratory testing of some of the currently available PV R/F units has occurred, there is still a need for comparative testing of different systems under actual field operating conditions. The interaction of lighting and refrigeration subsystems has hardly been examined at all. In particular, PV vaccine storage units are a relatively immature technology. Several new manufacturers entered the market over the life of the BRET project, and several others dropped out. The same is true for much of the 12-volt lighting equipment now coming on the market. This new equipment holds considerable promise for favorably changing the economics of PV clinic electrification, mainly due to lower equipment prices and increased energy efficiency, allowing for reduced array costs. Much of this new equipment has yet to be evaluated under actual operating conditions in developing countries. The clinic and school electrification subcomponents of the BRET project's overall PV demonstration and evaluation program were conceived to address the need for a critical analysis of these systems in small health clinics and schools in rural Botswana. This effort complements the GOB's efforts to maximize use of economically viable, indigenous energy resources and, wherever possible, to reduce dependence on imported fuels, in particular, petroleum and its derivatives.

1. Developmental History

PV Lighting in Schools

No school electrification plans were specifically mentioned in the project paper. However, as the BRET project developed and the potential for providing light at reasonable cost became better known, MLGL expressed an interest in installing PV lighting in rural schools, and the project got involved. Relatively late in the BRET project, a pilot project to install lights in one classroom in each of four schools was outlined and approved. While a detailed testing program per se was not undertaken, the intent of the activity was to gain experience from several installations and to approximately evaluate the costs and benefits of such systems.

MLGL's interest in lighting grew out of the idea that lighting in rural primary schools could serve multiple purposes, by improving the quality of life in rural areas and benefiting the rural population. First, lighting would increase the ability of schools to fulfill their responsibilities--teachers would have more time for preparing lessons and marking papers, students would have more time for studying or reading, and evening sessions could be held, particularly prior to examinations. Second, lighting would mean that community activities such as PTA meetings, Village Development Committee (VDC) meetings and other community events could take place.

Lighting was one of the first uses of PV in Botswana, and the BTC has been involved in a program to install and evaluate small-scale PV lighting systems in houses in several low-income neighborhoods of Gaborone that are not served by grid electricity. This experience convinced the BTC that PV lighting on a small scale had potential and was a technology that could be successfully disseminated. BTC committed time and effort to developing a controller that could be built in Botswana. This was part of its attempt to overcome two of the primary obstacles to successful adoption of the technology, cost and local repairability. BTC also published two documents about PV lighting, POWER FROM THE SUN--LIGHT AT NIGHT and A RELIABLE CONTROLLER FOR SMALL SOLAR POWERED LIGHTING SYSTEMS. These activities led to an increased awareness of the potential for PV lighting systems. In the private sector, PV distributors report small but steady sales of lighting systems to wealthier Batswana and expatriates. The Department of Electrical Engineering (DEE) is also interested in PV lighting systems. DEE is currently designing PV lights and contracting to have them installed at two rural branch libraries (Bobonong and Letlakeng).

The BRET pilot/demonstration program involved four rural schools and was designed to determine whether the provision of

basic PV lighting in rural schools was a cost-effective use of government funds. To answer this question, the four systems were iteratively designed based on experience with the designs used thus far. As a result, each was designed somewhat differently to reflect site-specific use patterns and availability of progressively better equipment. The four schools that currently have PV lighting systems installed are Oodi (Kgatleng District), Ditshegwane (Kweneng District), Shoshong (Central District) and Molapowabojang (Southern District). The systems were installed, in that order, between February and August, 1985.

A parallel demonstration effort to provide street lighting, suggested by MMRWA and in cooperation with DEE, was unsuccessful due to defective equipment. Three single-light streetlighting systems were purchased from ARCO Solar and installed in separate villages to provide nighttime lighting for social activities and security purposes. Within several months of installation all three units failed and were returned to the manufacturer for repair under warranty. While two of the units had been returned and reinstalled prior to the conclusion of the project, insufficient data have been collected to warrant any conclusions.

PV Clinic Electrification

The rationale for the BRET project's involvement in clinic electrification comes from the project paper, which called for installation of six PV-powered vaccine R/F units at six health posts and complete electrification (lights and R/F units) of three rural health centers. Health centers are typically larger and have more facilities than health clinics, which serve smaller populations and are primarily concerned with health education, some degree of maternity care, collecting statistics and giving immunizations. Health posts, further down the list, are not normally staffed by people trained to give injections. With the effort to upgrade all health care facilities, these descriptions are changing.

Based on a series of site visits to several clinics by ARD staff members in 1981, and discussions between BRET project staff and MMRWA officials, ARD/BRET technical staff made the decision to work with health clinics instead of health centers. A set of criteria was developed by ARD/BRET staff for choosing proper sites for the demonstration installations of these institutional-level RETs. Three sites were chosen--Lensweletau, Shoshong and Mabule, and refrigeration and lighting systems were installed at all of them.

Three of the refrigeration units purchased by the BRET project have yet to be installed in the field for several reasons. First, there was a lack of sufficient technical staff to devote enough time to the clinic and school demonstration/

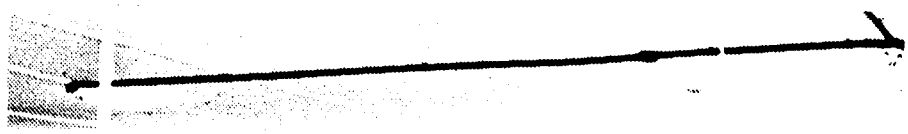
evaluation components of the overall BRET project effort in the area of photovoltaics. The comparative testing of water-pumping systems and the passive solar building design programs received primary emphasis, and thus absorbed much of the time and effort of the technical staff. Second, there were many institutional difficulties encountered, particularly in the PV refrigeration program, where one of the greatest difficulties was simply the procurement of sites. In addition, because of overlapping responsibilities of MLGL and MOH (MOH supplies medical equipment to MLGL for the health clinics), two bureaucracies (which did not necessarily have the same agendas) had to be dealt with instead of one.

Since some operational and repair problems were encountered with the first PV refrigerator installation, MLGL requested an evaluation of that unit before assigning other sites for future PV R/F unit installation. This evaluation was delayed, so further delays in assigning additional sites inevitably resulted. However, upon selection of appropriate sites, these units should be installed by DEE, which is taking responsibility for continuing the BRET project's initial PV electrification efforts.

2. Results and Conclusions

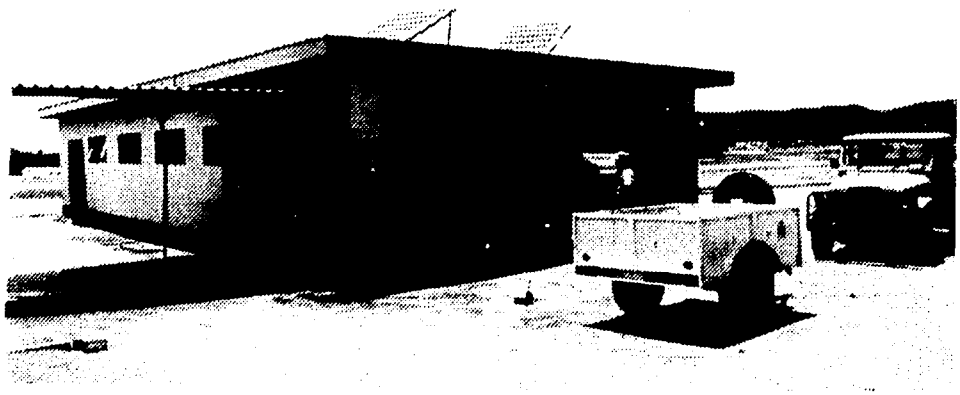
Petroleum consumption in Botswana increased an average of 3.8 percent per annum during the period between 1980 and 1984. The GOB is concerned by the increasing dependence on imported fossil fuels and would welcome alternatives to this trend (remarks by Mr. J. Diphaha, Deputy Permanent Secretary of MMRWA, at BRET/BTC PV workshop held on August 6, 1985). PV-generated electricity can be and is being used in Botswana for a wide variety of applications, including water pumping, telecommunications, health clinic electrification for lighting and vaccine storage, school lighting systems, and military applications. The high and uniform solar radiation conditions characteristically found in Botswana suggest that PV electrification in remote rural areas might well be competitive with the common alternatives of petrol or diesel-driven generators on the basis of both cost and system reliability.

Comments on specific features of the R/F units used during the BRET project with regard to specific design features are given in the PV electrification report and are not repeated here. In general, the units used by the project (with the notable exception of the first unit installed, manufactured by Western Solar Refrigeration) were quite reliable and lived up to the promises made by their manufacturers. Most of the minor problems that cropped up during the monitoring of these units were due to installation errors on the part of crews initially unfamiliar with the equipment, or users who were unfamiliar with the proper care, maintenance and limitations of the equipment. The fact



Local teachers and DEE staff examine the first school lighting installation at Oodi.

This PV array at the Shoshong clinic provides refrigeration for vaccines and lights for the maternity clinic.



A BRET facilitator and the clinic matron inspect a PV refrigerator.

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that users sometimes did not know whom to turn to for maintenance of their equipment was a significant problem. The need for more effective user/installer interaction must be emphasized.

There continues to be active interest in PV lighting in general, and PV lighting in rural schools has become a particular focus for some. Several organizations in Botswana have specific interest in the information this program can provide on the design aspects and use of PV lighting in rural schools. Among these organizations are DEE, BTC, MLGL and the Energy Section of MMRWA. Much work remains to be completed, partly because of the late start on installing the first system, and to other pressing demands on BRET staff, as well as on DEE staff, who lent valuable assistance to the program. The conclusions that can be drawn from the work to date are:

- As envisioned at the outset of the program, provision of lighting in rural classrooms results in the rooms being used for educational activities as well as community meetings, providing increased services to the rural population.

- While it is agreed that acceptable lighting levels for rural installations will be substantially less than those for grid-connected systems, a consensus needs to be reached on exactly what that level is so that PV systems can be sized properly. A general lighting level of 50 lux, and 100 lux for reading areas, seems acceptable in rural schools. User surveys should be initiated to clarify this issue.

- The long-term data collection process for determination of use patterns for lighting systems is incomplete. The data collected thus far may well be skewed by early enthusiasm about having lights or, conversely, by lack of a full appreciation of their potential uses. It appears that the average duration of use is about 1.5 hours, but frequency of use is much more variable.

- The cost of providing PV lights in rural schools is highly dependent on the resolution of the preceding two issues. A reasonably designed PV lighting system costing approximately P2000 would be capable of providing an acceptable level of general lighting (about 50 lux) for public meetings and a higher level of lighting (100 lux) in a smaller area for the purposes of reading, studying and lesson preparation.

- There have been no problems with any aspect of the physical installation for any of the DC school

lighting systems thus far. Worldwide experience with small PV lighting systems is much the same, so there is little reason to believe that significant problems will be encountered. The batteries will need replacing at three- to five-year intervals, and light bulbs will need replacement periodically. Use of BTC controllers should ensure that any problems with these can be rectified locally. However, the same cannot be said about the AC installation with an inverter in Shoshong. There have been problems, most of which can be traced to the fact that the system is AC rather than DC.

- Although there are a number of PV lighting installations in place in both the public and private sectors, an installation code has not been agreed upon. It is generally understood that 12-volt DC systems are not as hazardous as 220-volt AC installations, and that codes should take this into account. However, there are areas where special care should be taken with DC, particularly battery safety.

- The clinic electrification work done thus far shows considerable promise for PV-driven R/F units. There have been some problems with first-generation equipment, but newer equipment seems to be better designed, more reliable, more efficient and less expensive.

- Preliminary tests show significant differences in the power consumption of the various R/F units. Since this directly affects system cost, further tests and review of recent testing data from other sources are warranted before additional equipment purchases are made.

- Clinic electrification systems installed early in the program suffered from defective equipment in newly designed products, and insufficient understanding of the operation and maintenance of the systems by users and installation crews. This situation presented an obstacle (justifiable reluctance on the part of MOH) to finding sites for later installations, so that all of the equipment was not installed by the end of the program. As noted, this situation has been clarified and should no longer be a problem.

- Not enough information is yet available to do reasonable life-cycle cost comparisons of PV and propane R/F units. The costs of the latter need to

be carefully measured, and the longer-term recurrent costs of the former need more precise determination before such an analysis can be adequately undertaken.

3. Recommendations

General recommendations concerning the clinic electrification and refrigeration effort include:

- DEE, which now has responsibility for the remainder of the PV R/F units, should initiate discussions with MOH representatives on site selection and eventual installation of these units.

- Provision should be made for monitoring the new units using the same data collection sheets the BRET project used. Users can easily complete these after a minimum of explanation. Later examination of the forms, as well as interviews with the users, will provide much needed data on the performance of those units which have not yet received sufficient field testing.

- Before embarking on system installations, crews should be better trained in the fundamentals of PV electricity as well as its application to the cold chain. This will make for better physical installations as well as enable crews to better communicate proper operation and maintenance procedures to users.

- MOH and MLGL should be involved as much as possible in site selection and local user training procedures, so that misunderstandings do not hinder further dissemination efforts.

- Users should be more involved during site selection and system installation, and should be given specific training in proper operation and simple maintenance procedures before the installation crew leaves the site. Periodic visits to the site should be made, with decreasing frequency, to make sure that the system is operating properly and that users understand procedures and system limitations.

Based on the BRET project's experience with four installed systems, the recommendations for PV school lighting systems are as follows:

- Tests of the lighting intensity level at the Molapowabojang school should be completed. The results would show whether, as anticipated, the task lighting/general lighting approach to school lights is a good one.

- DEE should continue to monitor use of the classrooms over the next year. This is not a time-consuming activity and will yield valuable information about longer-term use patterns of the lights and help in designing more cost-effective school lighting systems.

- Short-term user surveys should be conducted to learn how users feel about the lighting intensity levels. This would help to determine if the currently used levels are acceptable or possibly greater than those required for the common uses of the schoolrooms.

- DEE, possibly with assistance from BTC and in conjunction with other African countries involved in public-sector use of PV systems, should develop standards for installation of PV systems in GOB buildings.

- An evaluation of other lighting system alternatives in rural schools should be undertaken. The costs of generator-powered AC lights or gas lights providing the same level of service should be measured, and a life-cycle costing analysis performed using the PV cost data provided in the PV electrification report.

E. Commercial Solar Water Heaters

Most water heating in Botswana is done either over an open fire or by electric geysers (i.e., conventional, submersed-element, electric hot water heaters). Since this section deals with commercial and higher income residential users, the standard is the geyser system, which is used extensively in Gaborone and other towns which have access to grid electricity. Several facts concerning geyser water heating are worth noting. First, most geyser systems are not well insulated, so heat losses from the storage tank can be considerable. In addition, they are often set so high that the water temperature is near boiling. Since losses from storage are proportional to the temperature difference between the water and ambient air, this practice further increases heat losses, which consumes additional electrical energy unnecessarily.

As mentioned in other sections of this report, Botswana is very fortunate to have a very high and typically uniform solar radiation resource throughout most months of the year--an annual average of over 20 megajoules/m^2-day. Solar thermal water heating is usually the most cost-effective use of solar energy. Since Botswana's climate is generally mild to hot, thermal losses from solar water heaters are reduced as well. Thus, there seemed to be considerable potential for energy and cost savings from the displacement of electric geysers with solar water heaters.

Conceptually, solar water heaters are usually simple systems consisting of a solar collector (often an insulated box with a glazed side facing the sun), storage tank for the hot water, and pump to force cool water from the water source through the collector, where it is heated, and then back to the storage tank. Some simpler systems, called batch heaters, do away with the pump, incorporating the storage tank and collector into a single unit. They are merely an insulated box with one glazed side facing the sun, containing a tank that is usually painted black, which acts both as the collector and storage vessel.

Batch solar water heaters are elegant in operation because they are passive systems, meaning that they require no active components such as pumps and controls. Often, they are not quite as efficient as active systems, but if well designed, they can more than make up for this decreased efficiency by savings on initial capital and operating costs. As previously stated, the life-cycle cost of a system includes both capital and long-term operation/maintenance costs necessary to keep the system working properly. Batch solar water heating systems have little or no operating costs, since they consume no electrical energy. Thus, their higher capital cost (relative to an inexpensive geyser heater) must be balanced against very low long-term recurrent costs, which yield a relatively low life-cycle cost.

The economic aspect of solar water heating is highly dependent on the quality of both the equipment components and installation. As has occurred in many developed countries, solar water heaters were viewed as a simple, cost-effective technology ready for immediate implementation in Botswana, but installers were often insufficiently trained to realize the importance of proper procedures. Unfortunately, many of the installations did not work properly as a result. Moreover, some of the earlier designs used in Botswana, particularly solar collectors with fiberglass glazing, have deteriorated to the point where they no longer perform adequately.

1. Developmental History

At the beginning of the BRET project, there were no commercial manufacturers of solar hot water heaters in Botswana. The solar systems in use, largely in GOB housing in Gaborone, were manufactured mainly in South Africa. At that time, sales of solar domestic water heating systems and a market analysis performed by the Botswana Development Corporation and one Botswana solar water heater distributor, Solar Power, Inc., indicated there was a growing market for solar water heaters in Botswana that could be at least partially met by the local manufacture of such systems.

The experiences of others in the rest of Africa, coupled with the immense amount of research that has already been undertaken in the developed world on solar water heating systems, indicates that well-tested designs already exist for the kinds of commercial systems needed in Botswana. However, importing these systems, even those made in South Africa, would add considerable expense. Locally manufactured systems would not only be less expensive because of lower labor and transportation costs, but such production would also generate local employment, in terms of both manufacturing and long-term maintenance support of the solar water heating systems.

One problem with local production of solar water heaters is that standard designs used in the developing world often require manufacturing equipment and skills which are either not easily available or prohibitively expensive. Thus, the standard designs have to be modified. Since small design changes can dramatically affect the technical performance of a solar hot water heater, it is important to be able to evaluate the effect of such design changes on prototypes before starting production.

In the revised project log frame, several coordinated efforts were specified to develop the capacity for the local manufacture of solar hot water heaters in Botswana. These efforts focused on the development of systems that could be produced locally at low to moderate cost and the comparative

testing of prototypes with imported units that are commercially available locally in terms of both technical performance and cost. Thus, the BRET project decided to seek an appropriate local manufacturer, whose experience in related efforts would ensure that adequate quality control levels would be maintained during production. Experience elsewhere has shown that the greatest problem in local manufacture was adequate quality control and the skilled assembly of systems.

During the second year of the project, work was carried out with Solar Power of Gaborone to develop a research and development proposal for the potential manufacture of low- and moderate-cost batch solar water heating units. The BRET project funded a portion of the research and development costs under a memorandum of agreement between the project and Solar Power, initiated in December, 1983.

Discussions with the University of Botswana's (UB) Department of Physics were also initiated, with the intention of having UB develop a solar hot water heater testing program to evaluate the designs developed by Solar Power and compare their performance with other locally available collectors manufactured in South Africa. UB faculty submitted a proposed testing procedure to the BRET project in May, 1984, which was then reviewed by ARD's senior engineer, Mr. Richard McGowan, who made suggestions to slightly modify the procedure as well as instrumentation options that might be used in the tests. UB sought BRET funding for the proposed instrumentation. This was agreed on in principle and much of the equipment was procured. UB was also loaned a complete set of monitoring equipment from the BRET wind pump program for examination so that the instrumentation package they were developing could benefit from its design considerations.

The BRET project also provided RIIC with funding to help them disseminate small solar desalination systems and provide a solar technical staff member to work on the development of institutional solar water heating systems. Part of this agreement was that RIIC would do substantial work on simple batch institutional solar water heaters, and BRET staff talked with RIIC personnel on numerous occasions about potential designs for this technology. However, no development work was done due to staff vacancies, changes and problems in the RIIC solar section.

2. Results and Conclusions

Solar Power sent the BRET project plans of its various proposed prototypes (none of which have yet been manufactured). Technical suggestions for changes in the prototypes made by BRET/ARD technical staff were apparently ignored. Solar Power seems intent on a very highly technical approach, using expensive

manufacturing equipment which must be imported from Taiwan. The regular status reports from Solar Power to the BRET project that were initially agreed on were few in number and less than informative. Although several discussions were held between the interested parties, no satisfactory resolution of the concern of the BRET technical staff about the quality and expense of the planned production units was forthcoming. The designs did not reflect local manufacturing capabilities, and the resulting costs of proposed production units seem likely to be beyond the means of the proposed user audience. Solar Power never produced a single prototype unit for testing by the BRET project and UB, although the delivery of 20 units for testing was agreed on.

Consequently, all of the funds originally intended for this project had not been disbursed as of the writing of this final report. Solar Power has proceeded with the construction of a building to house the factory and has apparently procured the necessary manufacturing equipment from overseas. Production should start sometime in 1986, but the cost and quality of the units to be produced are unknown at this time.

3. Recommendations

First, while Solar Power seems intent on following its highly technical approach to the production of solar water heaters, the outcome of its program should be closely monitored by the GOB in terms of market acceptance of its production units (none of which have yet been produced). Certainly, no additional funding of Solar Power's research and development effort should be considered until the success or results of their approach have been confirmed.

Second, if Solar Power, Inc. does not produce inexpensive, solar water heating systems that meet certain quality standards, the GOB should explore the possibility of aiding another private-sector effort to produce and market functional solar water heating systems.

F. Passive Solar Design, Construction and Promotion

Current design and construction practices in Botswana have resulted in most buildings being cold in winter and hot in summer, unless mechanical heating and/or cooling systems are used. Improved energy design of buildings has the potential to achieve much more acceptable thermal conditions inside structures that do not use energy for heating and cooling, and to dramatically reduce energy use in buildings which do utilize mechanical heating or cooling. In addition, for buildings that use electric lights during the day, better design can significantly reduce the amount of energy used for this purpose. To develop capabilities for improved building energy design in Botswana and promote its utilization, the BRET project undertook four different types of activities:

- technical development,
- experimental demonstration buildings,
- providing the GOB with assistance on specific design projects, and
- training and education.

A comprehensive description of all this work can be found in a separate BRET report, ENERGY DESIGN OF BUILDINGS IN BOTSWANA -- BRET PROJECT ACCOMPLISHMENTS, CURRENT STATUS AND RECOMMENDATIONS (Blair Hamilton, ARD, Burlington, Vermont, August 30, 1985). This section provides only a brief summary of the BRET project's passive-solar/low-energy building design activities. Because of the way that BRET building energy design efforts developed, the activities covered here do not correspond exactly to the titles provided in the revised log frame (see Section II). However, all of the log frame outputs listed under items 6.0 ("Urban and Rural Passive Solar Buildings Designed, Constructed, Monitored and Evaluated") and 7.0 ("Design, Monitoring, Analysis, Reporting and Promotion of Passive Solar Houses and Office Buildings") are discussed in this section.

1. Developmental History

Technical Development

When BRET activities in building energy design were initiated, there was little technical information available that had been developed or adapted for Botswana's specific conditions. In the few cases where passive solar building design had been a significant concern, accomplishments were due largely to the

designers' experiential knowledge, backed up (for the most part) by technical information developed for situations other than Botswana. No written material existed on building energy design that was specific to Botswana, and the few available references were of only limited applicability. Quantitative energy analysis of buildings designed by architects was commonly done only for large structures that were to be heated or air-conditioned, and even this analysis was limited primarily to sizing of the mechanical equipment.

To develop passive-solar and energy-conserving building design to a level where it could be applied more widely to future construction in Botswana, significant technical development was a critical activity for the BRET project. Limited technical development activities began early during the life of the project and took the form of the development of designs by ARD for the demonstration passive solar house and office building built by BRET. Further in-depth development occurred mainly during the 18-month period from January, 1984 to July, 1985, primarily through six ARD consultancies. The project's technical development activities fell into seven major topical areas, which are summarized below.

First, a reference materials data base that would be useful and necessary for improved building energy design in Botswana were identified and collected. If certain information was not already available, it was developed by the BRET project for future reference. The data base included climatic design materials, information on the properties of building materials and their assembly, and a bibliography of existing publications relevant to building energy design in Botswana.

Second, the identification of energy design strategies appropriate for buildings in Botswana in terms of heating, cooling and daylighting was undertaken. These were then systematically categorized, organized and evaluated with regard to different types of buildings. Specific recommendations for appropriate design strategies were developed separately for SHHA, "mid-level" and high-cost housing, and small commercial and office buildings.

Third, an adaptation of a detailed copmuter simulation model, CALPAS3, was done so that it could be used to evaluate the energy performance of buildings in Botswana. This permitted the BRET project to conduct much of the analysis required for other design tasks and make this information available to building designers in Botswana.

Fourth, a passive solar design workbook was prepared from the results of all of the technical development work up to that time. These materials were assembled in a 250-page reference workbook in early 1984 for use in a training program conducted by

the BRET project. When a second series of training workshops was held in early 1985, additional workbook information was developed.

Fifth, a thermal analysis/evaluation of building components for various ceiling/roof, window and wall options for Botswana was conducted both through parametric studies using computer models of the components and experimental measurements of component performance in the field. Portions of this work are described in a number of BRET project reports on specific building designs, but it is dealt with in more general terms in PARAMETRIC STUDIES OF THERMAL OPTIONS FOR LOW-COST HOUSING (Philip Niles, ARD, Burlington, Vermont, April 30, 1985). Based on an evaluation of ceiling/roof options, a low-cost cardboard roof system was developed in early 1985 and field-tested in SHHA housing. This effort is documented in a separate report, INSULATED CARDBOARD CEILINGS (Tones Meijer, BRET, Gaborone, Botswana, March, 1985). From an analysis of ventilation cooling, designs for more effective center-hinged casement windows were developed in 1984. These windows were used in demonstration buildings in 1985 and promoted through a special BRET publication, "Windows for Improved Ventilation" (a catalog supplement by Tones Meijer, BRET, Gaborone, Botswana, August, 1985).

Parametric studies of wall components suggested that solid walls displayed better thermal performance than those made of hollow blocks. Accordingly, it was determined that the use of "Cinva-Ram" stabilized earth blocks should be investigated. The thermal conductivity of these blocks was determined experimentally by the BRET project and found to be similar to typical concrete block. Based on these results and their potentially lower cost and greater use of local resources, the project decided to use Cinva-Ram blocks in a number of demonstration buildings. This occurred first in a village training facility (VTF) in Shoshong in 1984, using a block press borrowed from RIIC. Four local young men were trained in the theory, operation and use of the machine. They then made blocks for half the price of concrete block in Shoshong, according to the contractor's estimate. Based on this experience, the BRET project asked RIIC to build block presses, two of which were completed before the end of 1984. These were used in further construction at the VTF in Ditshegwane and four SHHA demonstration houses.

Sixth, simple quantitative design aids and general rules of thumb are required in the early stages of any design. A set of such rules of thumb was developed, including supporting tables and charts.

Seventh, ARD building energy design consultants developed a new, simplified building energy analysis technique specifically

for Botswana in early 1985. Its applicability is limited to simple buildings, but the technique is easy to learn, quickly applied and can be used iteratively to determine the effects of varying the different design aspects. It is the only technique developed specifically for Botswana's conditions, and its capabilities may be unique in the world. The method is based on original thermal analysis work conducted in Botswana by ARD's building energy consultant, Mr. Niles.

In its initial and simplest form, this method consists of a seven-page, fill-in-the-blanks form which guides the manual calculation of a number of key parameters that indicate a building's thermal performance. This manual technique was partially automated for implementation on personal computers. In this version of the technique, the designer has only to enter the building description information in the appropriate boxes on the spread-sheet form. All the calculations are carried out automatically, and the results for a given set of inputs appear almost instantly in another area of the spread-sheet. Iterative changes in the inputs are a trivial task, which encourages more thorough exploration of the various building options in order to achieve the best thermal performance.

Experimental Demonstration Buildings

A key element of BRET project activities in the area of energy and buildings was the design and construction of numerous structures, with two principal purposes:

- to experimentally evaluate a number of different building design concepts, materials and components; and
- provide highly visible demonstration buildings where energy was a prime consideration in the design.

Toward these ends, the following buildings were designed and constructed by the BRET project:

- the Shakawe-EC passive solar house in Gaborone,
- BTC office, library and shop in Gaborone,
- village training facilities (VTFs) in Shoshong and Ditshegwane, and
- SHHA demonstration houses in Gaborone West, Gaborone North, Francistown and Lobatse.

In addition, four conventional buildings were constructed for the BRET project at RIIC. All of these building projects are briefly described in the following subsections.

Shakawe-EC Passive Solar House

The Shakawe-EC is a passive-solar, energy-conserving redesign of a standard BHC design, the Shakawe-A Type II. This approach was taken so there would be a known reference for comparison with the measured cost and performance of the Shakawe-EC. ARD designers, Mr. David Norris and Mr. Peter Temple, completed their design and thermal analysis in mid-1982. BHC did the detail drawings for the house and supervised the construction, which began in October, 1982 and was completed in April, 1983. Microcomputer monitoring equipment was installed in June, 1983 to measure the thermal performance of this house and continued through mid-1984. The results of this monitoring effort and a detailed computer modeling analysis can be found in a separate BRET project report, MEASURED PERFORMANCE ANALYSIS OF THE SHAKAWE-EC: A PROTOTYPE PASSIVE SOLAR HOUSE FOR BOTSWANA (Blair Hamilton, ARD, Burlington, Vermont, October, 1984).

BTC Buildings

The BRET project's second major building project was the design and construction of a complex of buildings that now houses the BTC. The buildings were designed in 1982 by an ARD architect and engineer, Mr. Norris and Mr. Temple (respectively), and included complete site development with office space, library facilities, a workshop and demonstration area (see the BRET project report titled DESIGN OF DEMONSTRATION PASSIVE SOLAR BUILDINGS, Peter Temple and David Norris, ARD, Burlington, Vermont, February, 1982). Wall and roof insulation, shading, nighttime ventilation and high levels of daylighting were intended to reduce the demand for electrical cooling, heating and lighting. The design won an award of merit in the commercial category at the Second U.S . Passive Solar Design Competition, held at the U. S. Knoxville International World's Fair in July, 1982.

BTC arranged for a private architect to do the detail drawings and oversee construction, which began in November, 1983 and was completed in late 1984. In early 1984, it was decided that the BRET project would not be housed in the complex and BTC alone would occupy it. A BRET project microcomputer data collection system was installed to monitor the office and library in late 1984. These monitored data, together with occupant interview and computer modeling of the office building were used to conduct a detailed performance evaluation, which is discussed in another BRET project report, PERFORMANCE EVALUATION OF THE BTC

PASSIVE SOLAR OFFICE BUILDING (Blair Hamilton, Beth Sachs and Gabaipone Masire, ARD, Burlington, Vermont, September, 1985). This evaluation includes an economic analysis using cost and performance data for the BTC building and makes recommendations for the design of similar structures in the future.

Village Training Facilities

The BRET project constructed two VTFs as demonstration and training centers for its rural technologies, one in Shoshong and the other in Ditshegwane. Each VTF is a series of buildings that shows the application of passive-solar and energy-conserving design features in a village setting.

The VTF at Shoshong was built on a site that had two existing rondavels. One rondavel was not modified, but the other was retrofitted to demonstrate passive solar principles. A new "solar" rondavel was built at the site using Cinva-Ram soil-cement blocks. Finally, an office building was constructed, also of Cinva-Ram block, and included passive solar design features. Construction of all these structures was completed in late 1984. In early 1985, an ARD consultant analyzed the improved rondavel design and reported on the results in COMPUTER ANALYSIS OF THE SHOSHONG VTF SOLAR RONDAVEL (Philip Niles, ARD, Burlington, Vermont, March, 1985).

The Ditshegwane VTF included two passive solar demonstration buildings, a rondavel and a two-room office. Both structures employed many of the features used in the buildings at Shoshong. The Ditshegwane structures were first built in mid-1983. In 1985, they were modified to correct some construction problems and better incorporate some passive solar design concepts.

Demonstrations and workshops were held at both VTFs during various stages of the construction process so that builders and technical personnel could become familiar with all aspects of the buildings. At both locations, there were also sessions where the buildings were shown and described to the chiefs, Village Development Committees and other village inhabitants. In addition to all the residents of both Shoshong and Ditshegwane, over 100 people from other villages and towns have toured the buildings and had them explained as part of BRET project training programs. All the VTF buildings have permanent metal signs, in both English and Setswana, that describe them and their energy design features.

SHHA Demonstration Houses

The BRET project considered it very important to demonstrate the possibilities for making very low-cost homes more comfortable

in winter and summer using passive-solar and energy-conserving design principles. Based on a simple redesign of a basic SHHA two-room house, the BRET project, in conjunction with SHHA and Ntlo Planning Services, designed and built four demonstration houses at the SHHA town offices in Gaborone West, Gaborone North, Francistown and Lobatse.

All of the demonstration houses are similar in design and look very much like standard SHHA houses, but they incorporate passive solar features recommended on the basis of thermal studies conducted by ARD consultants. Design of the houses was begun in early 1985. Construction of the one in Gaborone West was finished in July, 1985, with the others being completed during the next few months.

Each of these houses is located next to the local SHHA ward office, and it is intended that SHHA technical assistants will use them to explain passive solar design. When plot-holders visit a ward office, they can be shown the demonstration house before they begin building their own homes and encouraged to employ these energy-saving practices. Permanent signs mounted on the walls explain each design feature in simple terms, in both English and Setswana. During the construction of all the demonstration houses, a series of workshops was held for local SHHA technical personnel so they could become familiar with all the construction stages as well as the theory and practice involved in each design feature.

Conventional Buildings at RIIC

The project paper anticipated that BRET's technical section would be located in Kanye at RIIC headquarters, where three PCV technicians and their Batswana counterparts were to be located. These plans called for three houses for the PCVs and one building to house a combined office/shop. In a hurry to get the buildings for the technical section constructed, even before the AID contractor arrived, BTC and RIIC decided to construct three standard houses, identical to some already at RIIC. Construction for the BRET project at RIIC also included an office/workshop with a large workshop and six smaller rooms for offices and storage. All of these buildings are the same type of construction as many other RIIC buildings and similar to most Batswana structures. They have none of the energy design features incorporated in later BRET construction projects.

After the opening of the Shakawe-EC solar house in Gaborone, the BRET project worked with RIIC on the design of three additional staff houses. The houses employ a long, rectangular design with a majority of the windows on the north side, a Trombe wall for passive solar heating and an open interior plan for good cross-ventilation. In fact, it could be said that these house

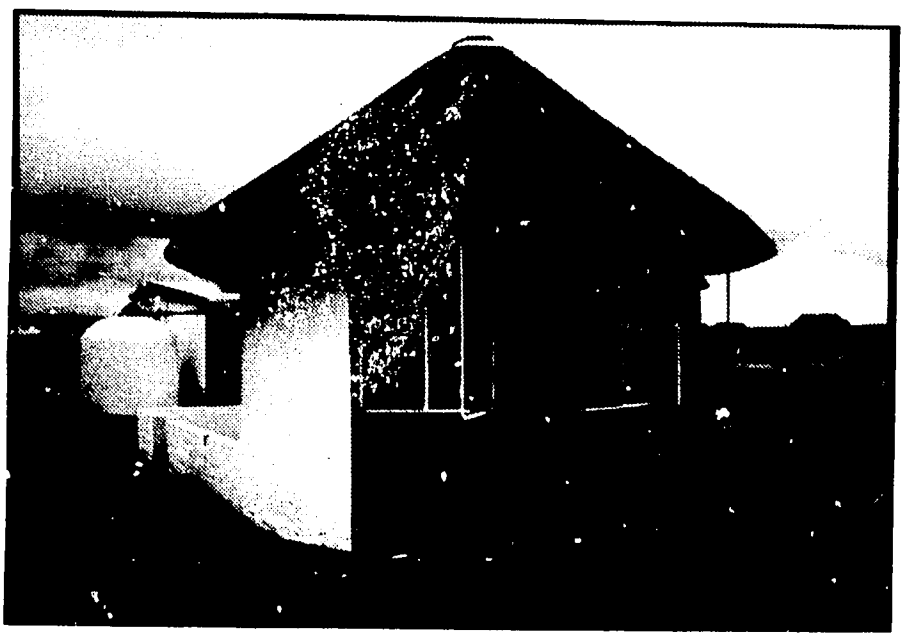
Above, the Shakawe-EC passive-solar house, Gaborone.

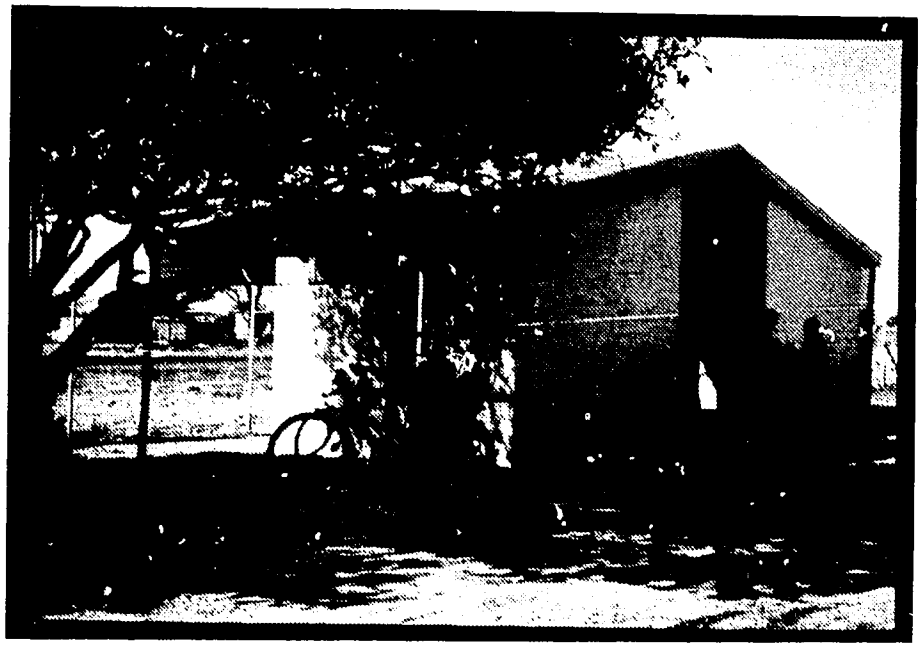
Below, The BTC headquarters, Gaborone. This design won an award of merit in the commercial category at the Second U.S. Passive Solar Design Competition.

BRET's Village Training Facility at Ditshegwane, the prototype of an improved rondavel and small office building.

Window modifications to the Ditshegwane VTF rondavel.

The Shoshong VTF buildings, redesigned by a local contractor as an application of the first passive-solar design seminar.





SHHA demonstration house in Gaborone West, based on BRET building-design concepts.

designs are second-generation designs as they incorporate a number of the suggested improvements which were recommended afte the thermal performance analysis of the Shakawe-EC.

Specific Building Design Projects

The primary purpose of ARD's work on building energy design was not to provide the GOB with design and analysis consulting services. However, some activities necessarily involved reviewing and consulting on a number of current government projects. This work was done primarily in the context of training GOB building design personnel and is summarized in the following subsections.

Vocational Training Centers

This design analysis effort was conducted in conjunction with an architect from the MOW Buildings Department. The projec involved a standard design for four vocational training centers (VTCs), the first of which is being built in Selebi Phikwe. In addition to a general review of all the buildings, site planning etc., two detailed analyses were conducted on a typical classroo building. The complete methodology and results for both of thes analyses are contained in two reports--FENESTRATION DESIGN FOR DAYLIGHTING OF VOCATIONAL TRAINING CENTER CLASSROOMS (Scott Matthews, ARD, Burlington, Vermont, January 29, 1985) and THERMAI PERFORMANCE OF PROPOSED VTC BUILDINGS (Philip Niles, ARD, Burlington, Vermont, February 7, 1985).

Tutume Health Center

This project was carried out in collaboration with the architect from the MOW Buildings Department who is responsible for design of government health facilities. In addition to evaluating the design options for a typical patient ward, a more general analysis was performed to evaluate the economic impact of passive heating and cooling design in such facilities. A full report on this analysis can be found in THERMAL PERFORMANCE ANALYSIS OF THE TUTUME HEALTH CENTER (Scott Matthews, ARD, Burlington, Vermont, February 28, 1985).

Type-C Staff Housing for District Councils

This project was conducted in cooperation with the MLGL Council Architect, who had developed a preliminary plan for a new standard housing design, referred to as "Type-C." Thirteen modifications of the original building design were evaluated using the CALPAS3 computer program. A complete report on this

work appears in THERMAL ANALYSIS OF TYPE-C STAFF HOUSES FOR DISTRICT COUNCILS IN BOTSWANA (Philip Niles, ARD, Burlington, Vermont, March 1, 1985).

Mid-Level Housing

This project involved design development for new "mid-level" housing, proposed by the MLGL Housing Office. This investigation by the BRET project was carried out in conjunction with the MLGL Housing Office and the responsible architect from BHC. A number of different room layouts were developed, and options for wall and ceiling construction explored. Given the cost constraints on other variables, special attention was paid to ventilation design. The final design employs the insulated cardboard ceiling and center-hinged windows promoted by the BRET project.

The basis of the recommendations for the wall and ceiling construction of mid-level housing is discussed in PARAMETRIC STUDIES OF THERMAL OPTIONS FOR LOW-COST HOUSING IN BOTSWANA (Philip Niles, ARD, Burlington, Vermont, April 30, 1985). The suggestions for ventilation design are described in VENTILATION RECOMMENDATIONS FOR MLGL/BHC MID-LEVEL HOUSING (Scott Matthews, ARD, Burlington, Vermont, January 16, 1985).

Revisions of the SHAKAWE-EC Design

Another project, conducted jointly by the BRET project and the responsible BHC architect, was the design of a second-generation, standard high-cost house, based on an earlier project evaluation of the SHAKAWE-EC experimental demonstration house. This effort was precipitated by a request from AID for some new high-cost homes to be built by BHC and their suggestion that they be based on the SHAKAWE-EC design. While preliminary designs were being developed, the project was canceled when AID's schedule required them to acquire some existing BHC houses. However, the conclusions resulting from the analysis have been incorporated into the design of other high-cost homes by the participating BHC architect.

New Chancery in Lusaka

This project was undertaken at the request of the MOW Buildings Department and in conjunction with the senior architect responsible for this project. The evaluation focused on a large atrium in the original plan. Some concerns had been raised about summer conditions in this space, and a thermal analysis confirmed that it would indeed be very hot unless some design modifications were made.

A number of alternatives were explored, including the substitution of various types of glass with different solar transmission properties, increased ventilation and a completely new roof design. The recommendations of this analysis have been incorporated in the final design. The analysis and its results are covered fully in NEW CHANCERY FOR LUSAKA -- ATRIUM THERMAL ANALYSIS (Scott Matthews, ARD, Burlington, Vermont, March 12, 1985).

Training and Education

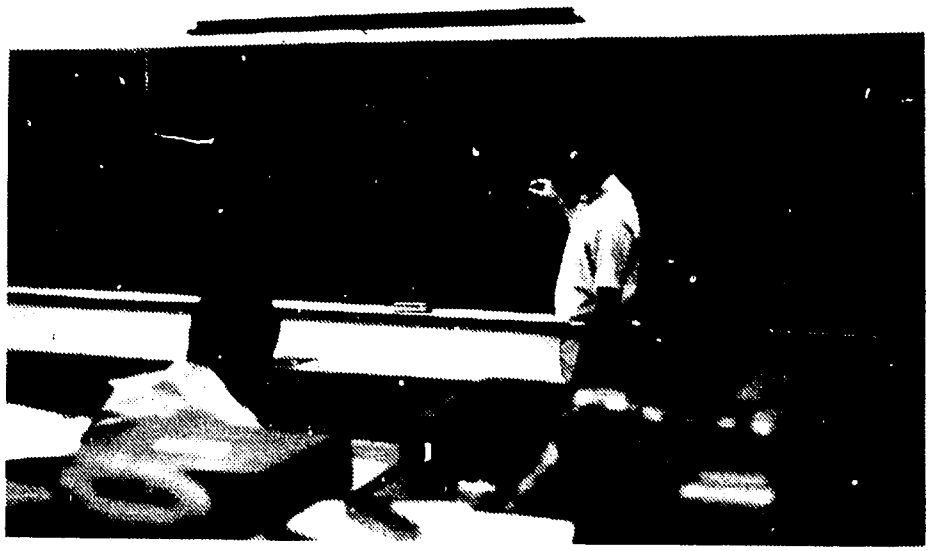
Almost every activity described in this section included a training/education element. This section summarizes the BRET activities that concentrated most directly on training in building energy design.

Most of the BRET project's formal training was carried out through a program of workshops conducted in 1984 and 1985. The first of the three workshops took place over seven days from February 27 to March 6, 1984. It was an introductory, but extensive, training program in passive solar design for GOB technicians, with an average attendance of 25 at the sessions.

The first workshop for architects was held on March 7 through 9, 1984. In addition to the many participants who stayed on from the preceding workshop for technicians, this workshop was attended by a majority of the architects from the GOB Ministry of Works' (MOW) Buildings Department as well as those from the Ministry of Local Government and Lands, BHC and the private sector, for a total of 32 trainees.

Partly in response to requests for additional and more advanced training, the BRET project conducted a more intensive workshop from January through May, 1985. In this series, 10 four-hour sessions were held on a biweekly basis. A total of approximately 30 people received training, with an average attendance of about 20 at each session.

A number of other half- and all-day workshops on building energy design were conducted by the BRET project. These were largely intended for technicians and were held primarily for local government technical officers, including building inspectors, SHHA technical assistants and construction supervisors. Some were conducted at the project's VTF and others at the SHHA demonstration houses. Often, the sessions were held during the construction of demonstration buildings in order to realistically illustrate certain design concepts. It is estimated that over 100 people participated in these BRET training sessions.



Above, ARD's passive-solar design engineer reviews a design problem during first Passive Solar Design Seminar for technicians.

Below, villagers and local craftspeople gather for an explanation of passiv solar design features in the Shoshong VTF office block.

On-site inspections during the construction process provided the opportunity to show seminar participants key features of the BTC headquarters.

To varying degrees, building energy design was a part of the U. S. training programs sponsored by the BRET project for several Batswana, both from within and outside the project's staff. Approximately six BRET staff members received introductory training on building design as part of their technical training programs in the United States.

One BRET project staff member, Ms. Gabaipone Mmasekgoa Masire, attended a specialized three-day short course on "Principles of Low-Energy Building Design" as part of her 1985 training program at the Florida Solar Energy Center (FSEC). She also became familiar with many of the passive cooling research projects being conducted at FSEC during her three-month course of study there. Simultaneously, she pursued academic work at the Florida Institute of Technology, which included courses in the principles of heat transfer and engineering thermodynamics, both of which are useful in the thermal analysis of buildings.

Mr. Mopati Ntsimanyana, an architect from the MOW's Buildings Department, received the most extensive overseas training program in energy and buildings sponsored by the BRET project. He had participated in earlier training activities in Botswana and was designated by the Buildings Department as the architect they wanted to develop advanced skills in building energy design and analysis. His training was conducted at California Polytechnic State University in San Luis Obispo from April through June, 1985. It included a full load of courses in the architecture program as well as tutorials in building energy design and extensive touring throughout California to inspect various low-energy building projects.

2. Results and Conclusions

The BRET project has demonstrated that good building energy design can save energy and improve the indoor thermal environment of buildings and overall quality of construction at little or no cost. The results of the project's research, development, analysis and experimental evaluation have shown that:

- current state-of-the-art building energy design can typically reduce heating and cooling loads in Botswana buildings by over 50 percent at no additional cost over conventional construction;

- small incremental investments in better design for buildings that use auxiliary heating and/or cooling can yield recurrent cost savings on the order of five times the cost of the improvements; and

- state-of-the-art design can produce buildings for most applications where acceptably comfortable

conditions can be maintained with no auxiliary heating or cooling.

The potential energy savings are significant and can be realized with relatively little effort, in view of the magnitude of the benèfits involved. Specific results from BRET project activities in building energy design are summarized in the remainder of this section.

First, adequate reference material resources on building energy design in Botswana were developed by the BRET project. However, the dissemination of building energy design publications has been limited, as has widespread access to all of the energy design reference material resources developed and assembled by the BRET project.

Second, the BRET project engaged in substantial development of the full range of building energy design concepts applicable to buildings in Botswana. A high level of technology development was achieved for three types of systems:

- window placement and sizing for solar heat gain and/or cooling load avoidance;
- selection of wall and roof materials, construction techniques and surface treatments to promote solar heat gain and/or avoid cooling loads; and
- use of thermal mass for passive cooling and/or solar heating.

Four additional technologies were developed to a moderate extent:

- window and wall shading for cooling load avoidance,
- natural ventilation cooling,
- forced-ventilation mass cooling, and
- infiltration reduction.

Third, the CALPAS3 building energy analysis computer model was successfully adapted for use in Botswana, and the MOW Buildings Department was provided with the equipment needed to run the model. One Batswana architect from the department received detailed training in using the program, and approximately six other designers have a working knowledge of it.

Fourth, the BRET building energy analysis technique is a significant new design tool that makes it possible to rapidly assess the thermal performance of simple designs. The manual version of this calculation method has been used in BRET

workshops and by several designers since those training sessions to evaluate current building projects. The computer spread-sheet version of the calculation method was used on sample buildings by six trainees at the 1985 workshops. It has received only limited use since then, but is perceived as a very valuable tool by both the trainees and ARD building energy design consultants. The technique is easy to use and produces results for any number of design variations very rapidly. It is probably one of the best building energy design tools available in the world today and can also be applied immediately in neighboring countries with similar climates. Whether the method receives widespread use in Botswana in the future depends on BRET project follow-up efforts.

Fifth, parametric studies of building components and designs by the BRET project led to the development of specific prescriptive design guidelines for different types of buildings (SHHA, mid-level and high-cost housing as well as nonresidential buildings). These guidelines include specific information on:

- building site planning,
- insulation levels,
- wall and roof construction,
- window selection, sizing and placement, and
- wall color.

Sixth, the low-cost cardboard ceiling developed and promoted by the BRET project has been well received and appears to be a promising option for low-cost housing.

Seventh, window designs for improved ventilation, prepared and advocated by the BRET project, are now being produced by both of Botswana's two major window manufacturers. These designs are being accepted by building designers and increased use of them in the future is likely.

Eighth, Cinva-Ram block appears to be a promising technology for low-cost, rural construction. It has been well received by both contractors and clients associated with BRET demonstration building projects. While Cinva-Ram block does not offer any thermal advantage over solid concrete block of similar thickness, it costs less, promotes greater utilization of local resources and requires less energy in the manufacturing process.

Ninth, monitoring and analysis of the Shakawe-EC solar house provided valuable information on the performance of a number of energy design concepts. During the monitoring period, the Shakawe-EC achieved acceptable indoor conditions with <u>no auxiliary heating or cooling</u>. In the winter, the average daily

temperature was 6°C higher inside than out. During the summer, the monitored daily indoor and outdoor average temperatures were very similar, but the design reduced day-night temperature swings from over 12° to under 4°. Based on the calibrated computer simulation model, if the Shakawe-EC used heating and air-conditioning to maintain temperatures between 20 and 28°C, the annual auxiliary heating load would be 2.4 gigajoules (GJ) and for cooling, 20.4 GJ. A similar, nonsolar house would have used 9.9 GJ for heating and 51.6 for cooling. Thus, under such conditions, it can be said that the energy savings attributable to the Shakawe-EC's design are 63 percent, compared to a similar, conventional home.

Tenth, monitoring and analysis of the BTC office and library buildings yielded valuable data on the potential of applying improved building energy design concepts to nonresidential structures in Botswana, as well as information on the cost-effectiveness of the individual design elements. These results include:

- the thermal performance of the BTC office and library has been essentially consistent with the original predictions of the building's designers--the fact that a building of this scale and complexity is performing as expected should give designers greater confidence in using passive heating and cooling techniques for similar future buildings in Botswana;

- the occupants are pleased with the BTC office and library as work environments--from their perspective, it would be desirable to improve some aspects of building performance, but the overall level of occupant satisfaction is high;

- as built, the BTC office is thermally far superior to a conventional office building, and computer thermal simulations show that it is significantly better thermally than a high-cost conventional design--if comfort zone limits of 20 to 25°C are used, the passive design reduces the conventional building's cooling load by 77 percent (a savings of 14,144 kwh), the heating load by 51 percent (4,313 kwh) and the total thermal load by 69 percent (18,457 kwh);

- several design changes could be made to lower construction costs without affecting thermal performance, including the elimination of wall insulation, redesigning the roof and eliminating the louver system; and

- if the BTC office was heated and cooled to maintain the desired comfort range of 20 to 25°C, in the first year alone, the operating cost savings would be five times greater than the annualized increase in construction costs attributable to energy design improvements--over 30 years, the savings would be approximately seven times greater than the cost of the improvements.

Eleventh, training and education activities reached a large number of people and significantly advanced both technical capabilities and public awareness. In quantitative terms:

- 25 persons attended the first seven-day intensive training session in March, 1984;
- 20 participated in the 1984 three-day advanced professional seminar;
- 25 individuals took part in the 1985 10-workshop series;
- 13 received small group and individual training in use of the calculational techniques;
- 12 persons were instructed in computer oepration;
- two received overseas training;
- eight designers participated in collaborative design projects with ARD consultants; and
- over 100 technicians attended single-day workshops and training sessions.

In addition, over 500 people have toured BRET demonstration buildings to date.

Twelfth, BRET project consultation on current government building design projects has significantly improved the design of those structures, lowered their energy requirements and provided an example of how the energy design concepts promoted by the project can be applied to the GOB's practical needs for future building design and construction.

3. Recommendations

Detailed recommendations for future building designs, GOB policy in this area and follow-up to the BRET project are presented in a separate report (ENERGY DESIGN OF BUILDINGS IN BOTSWANA--BRET PROJECT ACCOMPLISHMENTS, CURRENT STATUS AND

RECOMMENDATIONS, Blair Hamilton, ARD, Burlington, Vermont, Augus 30, 1985). A very brief summary of those recommendations follows:

- the training, technical support, research and analysis provided by the BRET project need to continue, preferably through institutionalization of those functions by the GOB;

- limited continuing professional technical assistance to the GOB from outside Botswana in the area of building energy design is needed for the next three to five years;

- policies should be established to implement recommended energy design improvements in all new government buildings, by incorporating specific language in the terms of reference for building projects and allocating approximately one percent of each project's cost for improved energy design;

- overseas training of Batswana design professionals should be improved to include strong programs in building energy design, as reflected in the choice of schools and curricula--formal agreements with one or more qualified institutions are recommended;

- supplementary training needs remain for technicians, which should be met through the development of curricula at the Polytechnic and Brigades, as well as through in-service programs for district and town council technical officers and technicians;

- nine important, but uncompleted, technology development tasks are identified in the report cited above, to be pursued by the GOB after termination of the BRET project; and

- a review of public policies and standard practices affecting building energy design should be carried out--such a study should identify barriers to the implementation of energy-efficient building design and recommend means for overcoming these obstacles, including the reform of policies and utilization of incentives, regulations and standards.

G. Rural Development RETs

The project paper defined two types of technologies, those for use by rural households for domestic activities and those for use by institutions providing critical services, e.g., water systems. The preceding sections have described BRET's work with institutional RETs. This section describes the development and dissemination experiences with rural domestic technologies, selected as a result of the village energy survey work described in the Energy Needs Assessment Section of this report.

The next step was to match end-use requirements with potential technologies. For each end-use of firewood--the villages' primary energy source, it was necessary to select RETs that would have the greatest chance of success, given the economic, sociocultural and environmental characteristics of the villages. The BRET staff developed a list of issues for consideration within these three general categories and rated potential technologies on each factor. By category, these factors included:

- economic -- life span, cost to user/selling price, affordability, dissemination costs, profitability, need for credit facility, potential for employment generation, skill development costs, research and development costs/time, capital investment and operation costs;

- sociocultural -- changes in interdependencies, skills required for construction, operation and maintenance of the device, time needed for full development and use of the technology, amount of change required in behavior/activity patterns, reflection of stated preferences/taboos, impact on sex and age roles/division of labor, degree to which the technology would induce in- or out-migration and wealth differentiation (extent to which the technology would change or maintain differences in wealth in the village); and

- environmental -- effects on vegetation, soil, water and air quality, animal migration, noise level and pest control.

Every RET that had the potential to respond to an important end-use (e.g., cooking, water heating and space heating) was then examined in terms of these criteria. Each technology was given a ranking, and the final selection of devices for project development was made based on the results.

The first round of technology selection yielded a range of RETs with the potential to meet the end-uses prioritized during the survey, as shown in the table below.

End-Use	Technology
cooking	earthen stoves portable sheet metal stoves retained heat cookers
space heating	thatch insulation improved rondavel passive solar buildings
water heating	simple, batch solar water heaters
food preservation	evaporative cooler pedal-powered sorghum de-huller

Once technology selection was complete, it was necessary to further prioritize technologies in order to allocate staff time in an appropriate manner. Technologies selected for development and pilot diffusion were:

- earthen stoves,
- portable sheet-metal stoves,
- retained heat cookers,
- improved buildings, and
- simple solar water heaters.

The BRET project installed earthen bread ovens at its two VTFs in cooperation with RIIC, which maintains an ongoing extension program for this technology.

The additional rural domestic RETs identified above (thatch insulation, evaporative coolers and pedal-powered sorghum de-hullers) and described in the project paper were found to be of little immediate application. Literature searches were conducted on these technologies, in part to determine the scope of work that would be involved in their development for Botswana and in part to compile relevant information for future researchers. Literature searches and engineering design analysis indicated that these technologies were not yet ready for development and adaptation, from a technical perspective and, therefore, in need of substantial research and development. No further development by the BRET project seemed warranted or practical in terms of

need, staff resources and time. The following sections discuss the project activities, results and recommendations for earthen stoves, portable sheet-metal stoves, retained heat cookers, simple solar water heaters and earthen bread ovens. Improved building design is discussed in Section III.F and so is not covered here.

1. Earthen Stoves

Developmental History

As described in Section III.A, cooking is the primary end-use of firewood in rural domestic activities. BRET began earth stove work to respond to this need and the generally low-income level of Ditshegwane villagers. The following activities were undertaken:

- a review of literature for models suited to application in Botswana;
- a review of RIIC's experience with pilot development and dissemination of earthen stoves in the southern district;
- selection of four models, culled from the literature; one design incorporated a space for the water heating tins used in Botswana;
- laboratory and field testing for performance, construction training, replicability and durability;
- evaluation of five units built in Ditshegwane homes;
- a return to the laboratory following the evaluation resulting in more tests of materials, new designs and additional construction training; and
- designs tested in the first round included the Louga, a modification of the Louga to include space for a water heating tin, the Tungku Lowon and a modified Tungku Lowon with a chimney (later to be called the Ditshegwane stove). The second round included the Ditshegwane stove, a molded, one-pot stove, and a three-brick stove, made from very large molded bricks. One fired clay stove was fabricated, but not tested.

Results and Conclusions

BRET's experience with earthen stoves, through two iterations of technology selection, prototype testing and construction training, indicated that high-mass earthen stoves were not practical for Botswana for a number of reasons.

In certain circumstances, high-mass earthen stoves can save wood compared to the open fire. However, the designs tested in the project did not save much wood in actual use. The best performance was a 30 percent savings during supervised cooking tests. The worst was a 15 percent increase. In Botswana, foods frequently cooked do not simmer for extended periods of time, and much energy is lost in heating up the stove mass.

The variation in test results is indicative of how sensitive earthen stoves can be to accurate replication, and two factors further complicate this. The first is that Botswana soils in general do not provide adequate binding qualities for a durable stove, and the quality of soil is highly variable from site to site. The second is that even with close BRET staff supervision, the construction of stoves for testing resulted in variable dimensions.

When the costs of earthen stoves are added up, i.e., staff time, village labor and use of molds or blocks, they total P11 to P28, depending on the model. Earthen stoves, like earthen houses, require continuous maintenance. When compared with the BRET metal stove, earthen stoves do not appear competitive. While village women do possess skills for building with soil mixes, they would only build stoves to sell and would sell their expertise for P7 to P15. Again, this does not compete well with the metal stove. There is also an attitude in general toward earthen construction, which is that it represents the old, not new or progressive way.

BRET's work with a molded stove and fired clay stove was more encouraging than the results for high-mass stoves. However, these lower-mass models would require substantial research and development to ensure durability, replicability and marketability. The report (EARTHEN STOVE CONSULTANCY FOR THE BRET PROJECT, Carmen Penty, ARD, Burlington, Vermont, 1984) spells out specific recommendations for further research and development.

RIIC's dissemination efforts resulted in significant interest in earthen stoves among educators and health workers. The advantages of the earthen stove over the metal stove is that, theoretically, it can be extended for the full range of pot sizes, including institutional ones. An argument might be made then for an earthen stove program to respond to health and safety concerns and feeding schemes, rather than energy conservation.

Recommendations

- High-mass stove promotion efforts should be terminated.

- If a decision is made to pursue earthen stove research and development, work should concentrate on low-mass, fired clay stoves.

- Windbreaks should be promoted as the low-cost approach to fuelwood conservation in cooking, as the earthen stove is not in fact as low-cost a technology as initially anticipated.

2. Portable Sheet Metal Stoves

Developmental History

The BRET metal stove is the most promising village-level technology developed by the project. Developed in response to the same end-use need as the earthen stove, it has the additional advantages of being portable--easily carried between village, lands and cattle posts, and well suited for both heavy, cast-iron pots and more modern aluminum saucepans.

It should be noted here that the BRET metal stove is a first generation stove. It is an improvement over the open fire, not an improvement of an established or indigenous cooking device.

Considerable project resources went into the development of this technology. In addition to the ongoing staff, 10.5 months of consultancy by experienced stove developers was provided by ARD. The full-time position of Metal Stove Promotions Officer was added to the project staff, in recognition of the potential of the stove and the amount of effort involved in its production and dissemination. The following activities were undertaken in the development and dissemination of the portable metal stove:

- design and testing of three laboratory prototypes resulting in the selection of one for user testing in the field;

- controlled cooking tests, performed by village women under BRET staff supervision;

- kitchen performance tests, conducted in village households with BRET staff taking baseline and test-period wood measurements for a week each;

- adaptation of the field-tested prototype for ease of fabrication, mass production, quality control and accelerated consumer acceptance;
- identification and training of skilled artisans to fabricate and produce the stove;
- development of sustainable levels of production among the trained artisans;
- identification of commercial manufacturers;
- pilot diffusion of more than 1,500 stoves in small villages, major villages and towns;
- economic analysis of the stove as a production item;
- preliminary identification of existing organizations with potential for training producers and for production and distribution;
- follow-up of 75 users who had the stove for several months; and
- production of promotional materials that include a poster, calendar, stove promoter's booklet, fact sheets, instructions for use and a history of the stove's development.

Results

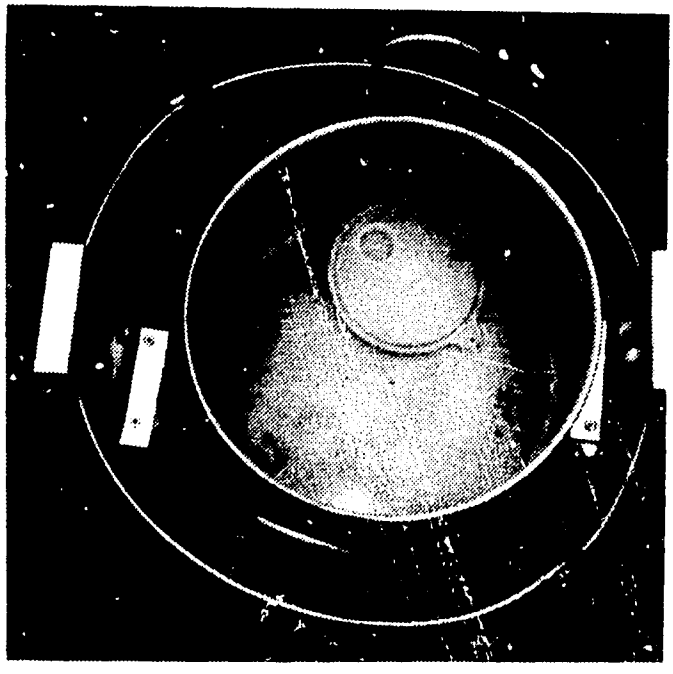
Prototype Development Testing

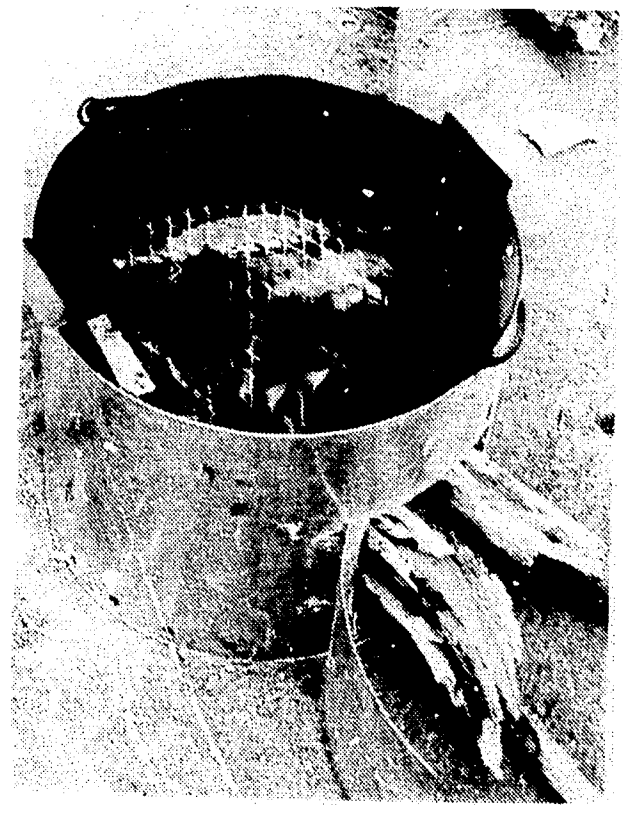
Laboratory tests measured fuel savings of up to 50 percent, and user tests in homes have indicated that the potential savings in overall fuelwood consumption could be as high as 30 percent. In addition to fuelwood savings, food cooks faster on the stove than over an open fire, thus saving time, and the device represents a possible new product for experienced artisans as well as a new enterprise for aspiring sheet-metalworkers.

Two types of user tests were conducted on the metal stove--controlled cooking and kitchen performance or home-use tests. In the former, a standard menu of carefully measured food (sorghum porridge and cabbage) was cooked by 15 village women three times each over an open fire and on a metal stove. These tests were closely supervised by BRET's stove technician, trainer and village facilitator. The women used about 40 percent less firewood to cook the two dishes sequentially on the BRET metal stove than over an open fire. The women were asked what they

Village women prepare for metal stove testing at Ditshegwane VTF.

The BRET metal stove. After several prototypes and adaptations, this model was selected. The stove accommodates traditional three-legged pots as well as modern saucepans.





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An ARD stove consultant trains local artisans to produce the BRET metal stove.

:T stove promoter conducts a quality check on stoves and reviews results with
ıducers.

85C

thought of the stove, and their comments indicated that they were favorably impressed--"It was number one;" "It looked nice;" "It used less wood;" "It cooks faster." A reduction in fuel savings was expected when the stove was used by village women.

For the kitchen performance tests, the same 15 women volunteered to use the stoves in their homes for a week and have their daily wood consumption measured for both the preceding week and the week of stove use. On average, fuel savings of 30 percent were realized during the test, compared to cooking over an open fire. Twelve of the women who participated in the test wanted to buy a stove and did so, paying the BRET project at the rate of P1 or P2 per month. The others could not afford to purchase the stove at all. The kitchen performance tests clearly indicated that the portable metal stove was popular, but in Ditshegwane, people would need time to pay or save for the stove.

Five households in Shoshong were also asked to conduct kitchen performance tests, and the results were similar--fuel savings were good, and all of the women purchased the stove. Those buying the stove in Ditshegwane represented eight percent of the total population, and almost every household with a cash income that uses wood. In Shoshong, all five of the women who participated in the user tests bought the stove, and after a series of demonstrations that were part of ongoing BRET activities in Shoshong, an additional 30 were sold, which represents about five percent of the population.

Preliminary market testing was done in Gaborone by Partnership for Productivity (PfP), who interviewed people coming into the market at Old Naledi, a self-help housing area. Of the 30 people interviewed, 28 indicated that they would purchase a stove. These early experiences encouraged BRET to begin production and dissemination on a larger scale.

Technology Adaptation

The first step in preparing for larger-scale production and dissemination was adapting the prototype. The process was a long and complex one that needed to consider local skills and materials, economy of production, ease of fabrication, accelerating consumer acceptance and quality control. An ARD consultant, Mr. Eric Brunet, successfully integrated all of these considerations and, in fact, developed a second, easier-to-fabricate model of the stove. A removable grill was designed so that the stove could be used with flat-bottomed pots as well as the three-legged, cast-iron pot. The results of his consultancy included detailed production guidelines, plans, templates, materials, layout and techniques for the original stove, the "B" stove, the simpler "Delta" stove and larger sizes of the two models as well as a production training approach for skilled and

unskilled artisans and a logo for distribution to "certified" stove producers--those who met BRET's production standards. It is important to understand that adaptation for production is a time-consuming process that involves not only streamlining the production process but consideration of individual components, their functions, minimum and optimal materials strength and cutting and assembly techniques. This was a major step in the development of the stove, and its value cannot be underestimated. This will be important in the future as modifications to the current designs are considered, prototypes developed and tested, which will face the same requirements of adaptation for production.

Once the production model of the stove was completed and guidelines for layout, cutting and assembly established, the stove was ready for the next step, training producers and determining possible rates of production.

Training for Production

BRET staff realized that from the producers' perspective, it would be the only market for stoves at first, and its initial support would be required to get producers operating at an optimal level. It was agreed to purchase all stoves produced to specifications, provide and deliver materials to skilled artisans, and transport finished stoves from the production site to BRET storage or sales points. This represents a significant hidden subsidy, which will be necessary until clear marketing channels from producers to consumers are established.

Targeted Producers and Training

To encourage producers and determine the level of production that various types of manufacturers could sustain, BRET focused on three types of stove producers:

- skilled artisans;
- unskilled artisans, identified and trained by nonprofit organizations, such as PfP and RIIC; and
- commercial manufacturers.

The ARD stove technician worked with a BRET staff member to develop a training program for skilled artisans and trained eight of them in Gaborone, Molepolole and Mahalapye. RIIC invited BRET to conduct specialized stove training as part of their ongoing blacksmith training program, and PfP identified a client with no previous metalworking experience, who was trained to produce the BRET "Delta" stove. Commercial manufacturers were contacted

primarily to produce a supply of stoves on short notice for a large-scale promotional program.

At the end of each training session for skilled artisans, a stove order was placed, with an estimated delivery date based on the amount of time required to produce a stove during the training workshops. The Gaborone artisans did not complete their first order, as their main product line, for which they have a long-established market, was a higher priority. In Mahalapye, the skilled artisans completed their first order only after much delay and prodding. However, their first order was substandard, and most of the stoves had to be reworked. Eventually, they stopped producing stoves, as the manufacture of their primary products was too time-consuming, and they were not satisfied with the price BRET was offering for the stove. Over the course of a year, the Molepolole group specialized almost entirely in stoves, producing about 175 per month, but they are not yet selling them on their own. The PfP client has sustained production at 50 to 60 stoves per month and has sold some on his own. Commercial manufacturers can produce up to 1,000 large stoves per month, on special order. However, these groups concentrate on bulk orders, and while 1,000 per month is a legitimate potential production figure, the actual period of time from placing an order to delivery depends on other orders that the manufacturer is in the process of filling.

By allowing producers to build stoves at their own pace and guaranteeing a market for their product, an adequate stockpile of stoves for BRET promotional purposes was created--2,545 stoves were produced over a year's time. Of these, 51 percent were the "Delta 6," 31 percent "Delta 3," 14 percent "B Model" and four percent "Super B." However, stove production will have to be accelerated to meet demand, if promotional campaigns are successful. Before turning to the promotional strategies and results, a brief discussion of the potential market and economic analysis of the stove is in order.

Determining the Potential Market

As part of an economic and financial analysis of RETs being promoted by the project, an ARD consultant estimated a potential market for the BRET stove of 60,000 households (see FINANCIAL AND ECONOMIC ANALYSIS OF SELECTED RENEWABLE ENERGY TECHNOLOGIES IN BOTSWANA, Phillip LeBel, ARD, Burlington, Vermont, July 18, 1985). These households have the following characteristics:

- wood is the primary fuel used for cooking;
- these households do not currently use a wood stove; and

- they are located in towns or villages with a population of at least 4,500.

In a study of domestic energy use in three towns and three major villages, 576 households were asked whether they would purchase a BRET metal stove if it saved 10, 20, 30, 40 or 50 percent of the wood they now used for cooking. At the 30 percent savings level, 60.5 percent responded favorably, while at 10 percent, 45.4 percent did so. This indicates fairly substantial interest in the towns and major villages. From there, stoves would presumably find their way into smaller rural villages.

Economic Analysis

As already noted, the current production system involves a significant amount of subsidy. However, economic analyses of the stove indicated that for a wide range of assumptions, the stove is an economic production item and meets the requirements for the GOB's Financial Assistance Policy for small-scale enterprises. Detailed economic and financial analyses of the PRET metal stove are contained in a separate BRET project report, FINANCIAL AND ECONOMIC ANALYSIS OF SELECTED RENEWABLE ENERGY TECHNOLOGIES IN BOTSWANA (Phillip LeBel, ARD, Burlington, Vermont, July 18, 1985). The financial and economic analysis in that report provides the hard data required by GOB decision-makers to determine what kind of continued support the stove effort warranted. With hard data, it confirmed the expectations of BRET staff that the stove's potential importance would justify the value of continuing government assistance.

Market Development and Promotional Strategies

BRET's early experiences with the stove in Ditshegwane and Shoshong were the first signs that the stove market lay in larger population areas, where people had cash incomes and were more likely to feel the pressures of diminishing firewood supplies--in fact, might already be purchasing firewood. Work on stove development programs in other countries substantiates this conclusion. A 1983 Earthscan report (IMPROVED COOKING STOVES IN DEVELOPING COUNTRIES, G. Foley and P. Moss) concludes that "the opportunities for introducing improved stoves are greatest in places where people pay for fuelwood, and traditional stoves are already on sale and widely used." While the potential market just described meets the first criterion, there is no traditional stove used in Botswana at this time. While this has complicated the dissemination process, it has not made it impossible.

According to S. Joseph and P. Hassrick in BURNING ISSUES (UNICEF/ITDG, 1984), four conditions must be satisfied before people will want to own and use a new stove:

- they must be aware of the stove, and the functions it can perform;

- they must have access to the stove;

- they must regard the stove as superior to the technology or practices currently in use and/or other available alternatives; and

- they must regard it as more desirable than other goods or services that they could acquire with the same resources.

With these guidelines in mind, the BRET project undertook a series of activities aimed at generating these conditions in four strategic areas--Shoshong, Molepolole, Mahalapye and Gaborone. Other BRET activities were already taking place in the Shoshong area, and Molepolole, Mahalapye and Gaborone represented large population centers with perceptibly acute shortages of firewood that were close to the project's base of operations.

Two major preparatory steps were taken to make people aware of the BRET stove's existence and potential. These were the release of a draft publication, BRET METAL STOVES: AN APPROACH TO THE DISAPPEARING FOREST, and a series of seminars conducted in Gaborone, Molepolole and Mahalapye. The report provided a detailed account of all project activities undertaken during the development of the stove, with the aim of imparting substantial information on every aspect of the BRET metal stove program to people who were in positions to influence stove promotion, distribution and commercialization. Thus, the draft was circulated to government officers, private entrepreneurs and parastatal and nongovernmental organizations.

The seminars were targeted at individuals in the three locations who:

- had experience in marketing, promoting and disseminating new innovations;

- represented government ministries, departments and extension services at both the central and local levels; and

- were associated with nongovernmental voluntary organizations, the private sector and individual concerns.

The seminars were intended to meet the following objectives:

- introduce the BRET stove to various organizations and individuals who were in a position to promote it;

- discuss promotional strategies and distribution channels;

- review and critique the project's promotional strategy and materials, including the draft publication mentioned above; and

- seek specific recommendations and guidance on implementation of a large-scale field and market test.

The seminars were highly successful in that participants were very enthusiastic about the potential of the BRET metal stove and provided the project with fairly specific guidance and directions on ways to proceed with the stove program. At the end of the workshops, permanent secretaries, senior tribal authorities, the national directors of voluntary organizations, extension workers, VDCs and school principals made the following specific recommendations:

- BRET should use nongovernmental voluntary organizations to promote and sell the portable metal stove;

- spot radio announcements should be developed for a media campaign;

- posters portraying specific messages about the stove should be created;

- the pamphlet, "Use the BRET Stove" should be redesigned and made more explicit, and a version in Setswana should also be printed; and

- four target areas should be selected for implementation of the recommended strategies.

Since four target areas had already been selected, the BRET project proceeded to develop the radio spots and posters, redesign the pamphlet and mobilize voluntary organizations in each target area. The stove promoter began work on the first three tasks, and an extension staff member was assigned to each of the four target areas--the Shoshong facilitators continued to work there and in Mahalapye; the Gaborone facilitator, whose home is in the Kweneng District, was assigned to Molepolole; and the village technologist, to Gaborone. The goal for each target area was to identify and establish core groups of voluntary organizations and individuals, who were willing and prepared to

conduct public demonstrations and sell stoves on a continuing basis.

Promotional Issues and Problems in the Target Areas

The degree of progress in the different areas varied, as each has its own peculiar features, which will be discussed in the following subsections. In an effort to standardize the system to some extent, a stove promoters' handbook was prepared. It included stove facts, tips on conducting demonstrations and making door-to-door sales and record sheets. Promoters were issued a handbook, receipt book and stove pamphlets.

In Gaborone, the first step was to identify the main areas with a significant population of wood users. In the end, three areas were selected--Old Naledi and Bontleng, to the south of Gaborone, and Tsholofelo in Broadhurst to the north. All of the SHHA areas in Broadhurst were included in Tsholofelo. The second task was to identify strategic demonstration sites in these three areas, and three different types of sites were selected--community centers, health clinics and the Red Cross center.

After all of the above issues were finally resolved, the BRET project started to identify core groups of demonstrators from the various voluntary organizations in these areas, with the help of local assistant Social and Community Development (S&CD) officers. This task proved to be very problematic in Gaborone because the members of voluntary organizations are either full- or part-time employees. The situation was further exacerbated by the fact that it was extremely difficult to get members who were working to attend the demonstration and training activities on a regular basis.

Demonstrations were begun at three community centers, one health clinic and the Red Cross center for the few individuals from various voluntary organizations that were available. The turnout at all the community centers was very low, with the highest attendance being four at Old Naledi, apparently because there was also a seminar going on. Demonstrations at the health clinic were conducted on child welfare days. This particular day was considered the most suitable because many people take undernourished children to the clinic for feeding on those days--the turnout for demonstrations ranged from 20 to 50. The demonstration conducted at the Red Cross center was not for the public per se, as it was mainly intended to familiarize Red Cross members with public cooking demonstrations and solicit their agreement to distribute stoves. While the Red Cross was interested in promoting the stoves, they could not agree to do regular public demonstrations because most of the members work full-time. Still, they did want to conduct demonstrations as part of any other Red Cross activities that might take place.

During the second week of public demonstrations and training for core demonstration groups, the whole operation became very difficult to implement. The main problem was that a number of voluntary organization members who were part of the core groups stopped showing up at demonstrations. This resulted in the cancellation of most of the demonstrations for that week.

At the end of two weeks, it became apparent that there were serious difficulties with this strategy, which can be summarized as follows:

- voluntary organizations are not currently a viable channel for stove promotion in Gaborone;
- community centers are not necessarily places that people frequent, especially during the day;
- in most cases, the people taking children to health clinics on child welfare days are maids (domestic servants); while they constitute a viable multiplier group, they are not likely to be potential stove buyers because of their income level;
- S&CD officers in Gaborone do not have strong connections with voluntary organizations; and
- although the urban cash economy represents a potential market, different techniques must be used to provide information and access to the stoves.

In view of these difficulties, a new approach was taken. It involved identifying individual women who were willing and prepared to promote and sell stoves. They were to be paid a commission of P2.5 per demonstration and P17 for every 10 stoves sold. These individual sales agents were issued a standard book for keeping essential records, such as the number of demonstrations conducted, attendance at each demonstration, number of stoves sold, etc. The individual sales agents were to sell stoves door-to-door and conduct demonstrations at their homes for neighbors as well as at selected strategic sites, such as shopping areas or the home. This approach had a different set of difficulties. While people were generally interested in the neighborhood demonstrations, they rarely bought the stove. Reasons offered included its cost and their lack of money at that time, but things did not change much at the end of the month when people had paychecks in hand. Two hypotheses were considered:

- that the stove would be more attractive (prestigious) if it were sold in shops or at least demonstrated in shopping centers;

- that it was not always accessible to people, and perhaps if it were, sales would increase.

Attempts to move into the commercial sector in Gaborone, formal and informal, identified further issues in production and marketing of the stove. Hardware and general trading stores in Gaborone were approached about stocking and selling the stove. While they agreed to take some, they did not actively promote the stove, and it had to compete with other, more well-known consumer items. In general, these stores are crowded with existing stock, and the stove is physically not a small item.

The informal commercial sector faced other problems. While several hawkers and vendors were willing to take a stove or two, it was a bulky item, not easily moved between home and selling point in any quantity. In addition, selling in the informal sector is a marginal, often precarious enterprise, and the opportunity to sell stoves is attractive only if they are more likely to sell than the products the hawker/vendor is currently handling. As long as stove sales are part of a GOB activity, a license is not required, but when the stoves become open market items, it will be. The attractiveness of the stove as a sales item will have to be high to overcome these difficulties. To date, the BRET project has been unable to determine the most successful strategies for promoting the stove in urban areas, which may be largely due to a simple lack of awareness or familiarity with wood cooking stoves.

The initial response of PVOs in the <u>two large villages</u> was exciting. They were enthusiastic and seemed committed to conducting the demonstrations and selling the stove, as a fundraising mechanism as well as a community service. Molepolole was easy to organize, and therefore progress was faster, primarily because the senior tribal authority in Molepolole is a stove user and committed to all strategies for decreasing firewood consumption. Mahalapye was a bit slower, in part because BRET staff were also involved in time-consuming activities in Shoshong. The PVOs did extremely well at organizing and conducting demonstrations, and weekly demonstrations were held at schools, clinics and kgotla meetings. However, they were unable to distribute the stove effectively or to actively promote the stove and motivate people to purchase it. Only 80 stoves were sold in Molepolole and Mahalapye combined over a two-month period.

Two limitations faced by PVOs in terms of stove distribution were personnel resources (i.e., not having someone full-time who was accessible to the public at any time for a stove purchase) and storage. In Molepolole, a storage space was rented by BRET, but with several groups participating in the sales, it was nearly impossible to keep track of inventory and keys to the facility. In Mahalapye, the District Council provided storage space, but

that meant that the stoves were available only during working hours. Stoves had to be taken from storage by a demonstrator and then delivered to the buyer. Thus, a purchaser had to contact a group member, which was inconvenient if the buyer was not attending a demonstration, and wait for delivery. Training and working with PVOs during the initial stages of the stove promotion effort required a substantial amount of staff time and resources, and none of these groups continued to demonstrate and sell stoves for any significant period of time without the support of the project.

Nonetheless, the demonstrations that were conducted did provide widespread publicity and information about the stove. The combination of demonstration venues, i.e., schools, clinics, and kgotla meetings, covers the spectrum of villagers. The major task in these two areas is no longer fostering awareness of the stove, but increasing its attractiveness and accessibility in regularly frequented places.

Since Shoshong was a pilot village, demonstrations were conducted there over 18 months as part of the pilot testing program. The BRET project decided to include Shoshong in its large-scale field and market testing program so that public demonstrations could be done in a much more concentrated manner than before. Two core groups of demonstrators were identified to promote and sell stoves. The VTF had a sufficient number of stoves in stock for those who were to be involved in promotion and sales efforts. No new sales can be directly attributed to the change from the BRET project to core voluntary groups in carrying out stove promotion. This indicates that the Shoshong market may in fact be saturated, and further substantiates that the main market for these stoves is in larger population centers.

While the first round of fieldwork in the targeted areas was underway, the stove promoter worked on developing radio spots, posters, pamphlets and newspaper advertisements. Two graphic design and media production companies and another marketing consulting firm were contracted to prepare promotional materials. These companies were up to two months late in producing the desired materials, and in the end, their work was unsatisfactory. It proved to be very difficult to communicate the project's promotional concepts to them, and pretests of the materials on BRET staff indicated that they clearly missed the mark. In most cases, the graphics were too complicated, patronizing or failed to communicate any message at all.

A private graphics designer was identified to produce the posters. Finally, a single poster was produced, and the stove promoter completed a Setswana/English pamphlet. Radio announcements were also developed and sent to Radio Botswana. After initial delays caused by some staffing problems at the radio station, the spots were aired. Unfortunately, the first

round did not include information about where people could see or buy stoves. The second round of radio spots will correct that problem.

This preliminary promotion work was slow because of the nature of the voluntary groups, delayed production of materials and the fact that the stoves were not easily accessible, but had to be taken from storage by a demonstrator for delivery to the buyer, which proved to be a cumbersome system.

An accelerated stove program was begun in June, 1985 that included the PVOs that had worked with BRET, teachers, and clinic workers in several new sites. The results of BRET's early work in the four target areas provided a significant amount of information for the formulation of subsequent approaches to stove promotion and sales. The key was to locate, as much as possible, demonstrations, sales and storage at the same or nearby locations.

Teachers were of key importance in the accelerated program. Those who promoted BRET stoves worked directly in school or from their homes, which provided prospective buyers with a fixed point where stoves could be obtained. In addition, schoolchildren are an excellent multiplier group, as they take news to their families and neighbors. Finally, as civil servants, teachers do not require compensation for stove sales as they do this work on a voluntary basis.

The accelerated promotion included new sites, including Francistown, Lobatse, Mochudi, Ramotswa and Kanye; newspaper advertisements to create new demand and build on word-of-mouth publicity, and two additional field staff members, hired on a temporary basis to move from site to site, identifying people, such as teachers and other civil servants, who would promote and sell stoves, and to talk with retailers in these areas. By the end of the project, more than 1,500 stoves were distributed and sold in all of the target areas.

While the project was able to develop promotional strategies and some distribution channels, they are still heavily dependent on BRET support. A fully independent production and distribution system represents the ideal situation, but the duration of the project and constraints operating in the commercial environment and culture did not permit adequate investigation and planning of such a new system. To do this will require further experimentation and continued promotional efforts with a new product.

Food vendors at rural agricultural shows cooperate with BRET to demonstrate the fuel-savings of metal stoves.

Bakwena Paramount Chief describes the extent of deforestation he has witnessed and his positive experiences with the BRET stove.

Molepolole stove seminar participants grill meat on the BRET metal stove.

Below, seminar participants meet local stove producers in their village.

Above, community volunteers demonstrate the stove to new mothers, waiting to be attended at the clinic.

Left, the BRET stove is demonstrated as part of a tour of the VTF at Shoshong.

User Experiences

Follow-up work with BRET stove users was important because the stove is a first-generation model. The follow-up program was intended to assess the stove's attractiveness, durability and whether it was actually meeting the need for fuel-efficient cooking, as planned. A record of the names and addresses of stove buyers was kept by BRET for sales made directly by staff members. Teachers, sales agents and others have been asked to do the same to facilitate continued user follow-up and stove evaluation.

From April to July, 1985, questionnaires were distributed and follow-up interviews conducted to determine how well the stove was meeting user expectations and needs. As part of ongoing project activities, follow-up visits were made to Ditshegwane and Shoshong households. In addition, participants at BRET seminars for extension workers were asked to complete a questionnaire on stove use. Finally, interviews were conducted with a limited number of stove purchasers from Molepolole and Mahalapye. A total of 75 responses was obtained from the various sites for people who had used a BRET stove for one to 19 months. Of these, users from Ditshegwane and Shoshong and six extension workers participating in the BRET seminars had been using their stoves for over a year.

Briefly, the results from the follow-up interviews and questionnaires for the sample of 76 stove users are as follows:

- 58 respondents are still using their stoves regularly and 17 are not;
- of those who are not using their stoves regularly, eight said it was a matter of preference, two indicated that their stove smoked and two mentioned that the stove accommodates only a single pot;
- 36 respondents indicated that they still build open fires;
- in terms of perceptions of fuel use, 42 said the stove used less wood than an open fire, 18 felt it was about the same amount, and 15 did not respond to this query;
- with regard to perceived advantages, 47 said the stove cooks fast and saves wood, 17 mentioned its portability, 12 noted the speed of cooking alone, seven said it was economical, two noted that the stove protects the fire, one mentioned the stove's design, one said it was easy to use, one said that

it was convenient during the rainy season and eight had no comment;

- relative to perceived disadvantages, 40 respondents had none to report, 38 said the stove was too small in that it could accommodate only one pot, 16 felt the metal was too light, four mentioned problems with smoke, one said it was expensive and one that it is too low to the ground; and

- in terms of recommended design changes, 42 said nothing, 33 felt it should be made large enough to handle two pots, 18 thought heavier metal should be used, one said the stove should include an ashtray and one wanted a chimney.

When asked how they had learned of the BRET stove, 28 said they had attended a demonstration, seven mentioned sales agents, three found out at a seminar, three from a poster, three heard about it from friends and one said through a pamphlet. Although only 39 respondents answered this question, demonstrations seem to be the major means of dissemination for the BRET stove. They have also been the primary method of generating awareness and motivation. The radio spots, which ran for a short time, did not seem to have much of an effect. The radio message should be reevaluated, redesigned if necessary, and tested on the air again.

Three respondents indicated that their stove grates needed to be replaced, and three more said their grills required replacement. Two of the grates are in households which have had stoves for less than a year, and the third is in the one home that has had a stove for 19 months. This is such a small number that the replacement of the first two grates may be solely a matter of appearance, rather than actual deterioration. As the network of producers develops, replacement parts should begin to be available through stove distribution channels. The BRET project anticipated that the stove's grate and grill would need to be replaced after a year, and approximately 80 to 100 users will have had stoves for that long by the end of this year.

Conclusions

First, the BRET stove is a first-generation stove of this particular type and quality in the Botswana market. Because it is unique relative to most commodities in local markets, its dissemination will have to rely entirely on local promotion.

Second, the BRET project's two years of stove work in the two pilot villages, Ditshegwane and Shoshong, and subsequent promotional efforts in towns and urban areas of major villages

indicate that the market for stoves lies primarily in urban centers and major villages. This conclusion is further supported by the experiences of development efforts elsewhere. Subsequent stove work and follow-on activities should be concentrated in these areas.

Third, while PVOs are viable demonstration agents, they are not very effective as sales agents.

Fourth, although stove promotion and sales are being effectively carried out in schools and other government institutions, this method of distribution is not desirable in the long run.

Fifth, the relatively undeveloped commercial culture in Botswana has hampered the stove promotion effort. Thus, a much more protracted, long-term national promotion strategy and continued external support are needed.

Sixth, as of this date, the BRET project feels that for a number of reasons, the commercial sector is a rather weak and slow distribution channel for stove promotion and sales. While staff agree that stoves should be sold through both formal and informal commercial outlets, the following issues need to be resolved to establish a more sustainable mechanism for stove marketing:

- a decision on the subsidy question needs to be made immediately, i.e., what level of subsidy can continue and how will it be provided;

- depending on the resolution of the subsidy issue, a more realistic stove price should be set to facilitate a profitable markup that is acceptable to the commercial sector;

- a concerted national stove promotion campaign, using radio, posters and pamphlets should be undertaken--this activity should be carried out vigorously enough to build confidence among stove distributors that a larger market is aware of the product they are selling;

- an effort should be made to find practical ways of both encouraging stove producers to sell directly to consumers and linking them to commercial distributors; and

- a policy regarding the replacement of stove parts at various intervals should be formally integrated into the stove production system.

Seventh, from the promotion work done in the major villages and urban centers, it appears that the "Delta 6" sells best. Of all the stoves sold to date, over 80 percent have been the "Delta 6" model. Thus, BRET staff believe that future production should concentrate on this stove. In addition, the bottom part of this model should be modified in response to consumer reactions. The skills of producers who have not been fabricating the "Delta 6" will probably have to be upgraded to encourage production of this model.

Eighth, the small stoves are not selling at P15.00, even though the large and small models differ only in terms of size, not efficiency. To BRET staff, it appears that the primary factor behind poor demand for the small stove is the fact that the large model costs only P2.00 more. Consumers would rather pay an extra P2.00 for a larger stove with a movable tripod. Also, the stoves are most efficient when used with the largest possible pot. Hence, cooking with a small pot on the "Delta 6" will not be as efficient as cooking on the "Delta" or "B" stove.

Ninth, a greater effort should be made to explore and overcome obstacles to stove distribution in the commercial sector. The project's operating assumption is that this method of distribution, particularly the informal commercial sector, is the only channel that holds any real potential for self-sustained stove marketing.

Tenth, among users surveyed, there appears to be a general trend toward satisfaction with the BRET stove, as most respondents still use theirs and 42 had nothing to say about the design. However, given that 36 households also build open fires and 33 felt the stove needs to be bigger, there seems to be a need to reconsider the original design parameters. A more detailed analysis of stove usage patterns would provide specific guidance for such a redesign. A two-pot stove may be possible, but only a thorough testing and development process will show whether it is preferable to using two of the current stove model. Users clearly perceive and appreciate the fact that the stove saves fuel. Still, further detailed data collection is probably advisable, as relying on users' recall is not an accurate measure of amounts of fuelwood saved.

Recommendations

The BRET stove warrants continued government support, and MMRWA has submitted a project memorandum to the Ministry of Finance Development and Planning for a continuation project. The following BRET recommendations were incorporated into that document:

- Intensified promotion activities in current and new target areas:
  --posters and additional booklets should be designed and distributed;
  --radio announcements should begin again as the number of target areas increases;
  --actively encourage people to purchase the stove size that suits their daily cooking pattern to optimize fuel savings;
  --this process must motivate consumers and, thus, build their confidence in producers and distributors;
  --it is important that current momentum not be lost.

- Substantial attention must be given to the commercialization process:
  --this includes an assessment of the current subsidy and pricing of the stove;
  --determining what forms of subsidy are appropriate and how they can best be delivered, i.e., direct/indirect, to producers/consumers, etc.;
  --establishing direct links between producers and distributors;
  --establishing a reliable supply of raw materials;
  --exploring further the most appropriate production and distribution channels;
  --determining how production costs might be lowered;
  --integrating production and sale of replacement parts with the production/distribution system.

- Training new producers in major population centers to ease the problem of transport of stoves to sales points--RIIC is a likely location for training new producers.

- While the commercial manufacturers in Gaborone can produce large quantities of stoves at a price comparable to small-scale artisans, it is the BRET project's recommendation that small-scale artisans, Brigades or BEDU produce the stove and sell it directly.

- Follow-up studies of users and a review of cooking practices in the larger population centers should be undertaken to determine the extent to which the stove meets needs and expectations. As the few data on users so far indicate that a two-pot model is desirable, such studies would fix essential design/redesign parameters and establish the lifecycle of replacement parts.

3. Retained Heat Cookers

Developmental History

The retained heat cooker (RHC) is the third cooking technology selected for development and pilot diffusion in response to the need for reducing consumption of firewood for rural domestic activities. To use an RHC, a pot of food is brought to a boil on a fire or stove and simmered for a specified period of time, depending on the food and taste/consistency preferred. At the end of that time, the pot is quickly placed in a well-insulated container where it continues to cook, using the heat retained in the pot, food and water, protected by the insulation. This method of cooking is well suited to the most popular foods cooked in Botswana, as they come to a boil and continue to cook for 30 to 45 minutes and up to 6 hours.

RHCs became popular in Europe during the First and Second World Wars in response to fuel shortages. A commercial model called the "Wonderbox" has been demonstrated in Gaborone and Serowe, so the idea is not totally unknown in Botswana.

The technical performance of the RHC was well-established in Europe, the United States and Lesotho. BRET's work focused on determining cooking times for local foods; determining how the RHC could be used with traditional three-legged pots; quantifying the fuel savings when used with firewood, paraffin (kerosene) and gas; and most important, determining its acceptability in rural areas and methods for its dissemination. Project activities included:

- working with a community group to determine cooking times for local foods and adapt the RHC for three-legged pots;
- conducting controlled cooking tests with local women using open fires, the BRET metal stove, paraffin and gas cookers;
- pilot diffusion that included conducting demonstrations, offering free trial periods of use, teaching extension workers to make and use RHCs;
- following up to determine use patterns over a six-month period;
- financial and economic analyses of the device; and
- publication of results and conclusions.

A three-legged pot is inserted into a homemade RHC. The cushions have been stuffed with sawdust. Later, it was determined that a box filled with straw/thatch, covered with a cushion, was the easiest, least expensive way to use the RHC with three-legged pots.

Workshop participants practice cooking with the RHC.

Workshop participants practice cooking with the RHC.

Below left, a dissemination experiment demonstrating the RHC and metal stove together. The RHC became the primary focus of attention. Below right, extension workers discuss the merits of the RHC with BRET's Village Technologist.

Workshop participants cut and stitch RHCs.

Results and Conclusions

BRET's work with members of several PVOs in Shoshong over a six-week period resulted in the information for a recipe book, information on owner-building RHCs, and a core group of experienced and committed RHC users. The women brought materials from home for containers, cushions and insulation, and in the early stages, cooked food in the demonstration RHC and worked on their own while the food was cooking. Later, they were able to cook in the RHCs they had made. BRET learned that while fabric was generally easy to find, insulation was a problem. Drought affected the availability of thatch; newspapers are rare in the village. One woman carefully saved feathers over an eight- to 10-week period, and another broke a cultural pattern by using clothing/blankets for food preparation. The demonstration RHC was a commercial one. The pattern was used by most of the women. Variations on cushion shape and fabric were tried for the three-legged pot, and in the end, the group decided to put the pot directly into a container filled with thatch, covering it with a cushion. Over the six-week period, five RHCs were completed, and cooking times had been determined for rice, mealie rice, porridge, samp and beans. This work became the beginning of a cookbook. The cooking times were similar for all types of insulation used, i.e., thatch, old clothes and feathers.

The second activity involved eight women from a village near Gaborone. Each woman cooked eight meals each with one type of cooking device (open fire, BRET stove, gas stove, paraffin stove) and the RHC. The RHC and open fire resulted in 40 percent savings, and savings were 50 to 60 percent with the other devices. This indicates that all households are potential RHC users.

A "user test" in Ditshegwane and Shoshong was, in fact, a kind of "free trial offer." In each village, five percent of the population was asked to take and use the RHC for a month, following a series of demonstrations to generate interest. In Ditshegwane, 10 extension workers and teachers participated in the test. In Shoshong, 40 households participated, but only 19 follow-ups were completed, but all foods were prepared satisfactorily, i.e., to the user's taste, with no difficulties encountered. In Ditshegwane, samp, meat and mealie rice posed problems with respect to taste. Because the Shoshong group had more available expertise, it is not surprising that their experiences were better, as the earlier group could provide informal advice and encouragement. It is also possible, especially with samp, because it requires four to five hours in the RHC, that someone in a household could not resist opening the cushions and/or the pot, causing heat loss.

Ditshegwane and Shoshong residents were given a "free trial period" of one month to use the RHC. Extension workers and teachers participated in Ditshegwane, and in Shoshong, 34 women participated. Subsequently, 50 extension workers were trained in Mahalapye in the construction and use of the RHC. The extension workers were involved in a five-day Introduction to RETs Workshop, and used RHCs daily for meal preparation. Follow-up questionnaires were sent out after six months, and 23 were returned. The responses led to the conclusions below. In addition to these groups, 172 other women were trained for one day in the construction and use of RHCs.

The follow-up results were encouraging and led BRET to the following conclusions. First, the RHC can be used to cook the most frequently used food items in Botswana and will save 40 to 60 percent of the fuel used.

Second, the RHC is economically attractive if it is used 50 percent of the time; the opportunity cost of extra cooking time is valued at zero; the cost of firewood is valued at three thebe per kilogram; and there is no real increase in the real price of firewood. (There is considerable debate about the opportunity cost of the extra cooking time--valuing it at zero is a compromise between the view that it is a cost and the view that the time the food is unattended is in fact a benefit.) While more time is required for cooking, the RHC users surveyed do engage in other domestic activities while food is unattended in the RHC, so the argument can be made that at least it reduces the amount of time involved in domestic activities.

Third, the frequency of use and the skill and confidence required to use an RHC are education issues, and dissemination approaches have been designed to successfully address those issues.

Fourth, the RHC can be made by its owner or purchased--BRET experience indicates that users who make their own RHCs have more confidence with and satisfaction from the device.

Fifth, demonstrations are effective in generating interest, but guided practice is necessary to develop skill and confidence in RHC use (providing guided practice will increase training/dissemination costs).

Sixth, the potential market for the RHC includes every household that does not currently have one, as the RHC can be used in combination with every cooking device.

Recommendations

BRET recommends a modest program of training and extension to be carried out by trained members of three targeted extension cadres. An additional recommendation is that further investigation of commercial potential be undertaken and, if warranted, substantial training be done with existing commercial sewing groups to encourage them to take up production and marketing of the RHC.

As indicated above, the RHC is well suited to be an energy-conserving cooking method for Botswana. A modest program of expanded dissemination is in order and should include the following activities:

- Additional follow-up of current users should be undertaken after, for example, nine and 12 months of use to determine:
  --change in frequency of use,
  --estimated number of hours made available per week, based on frequency of use,
  --how to encourage more frequent use,
  --changes in frequency with which certain foods are cooked,
  --lifespan of cushions and insulation, and
  --any unanticipated results of long-term RHC use.

- BRET staff could conduct interviews and gather and record data. Assistance would be required to detail the questionnaires and analyze data.

- Home economists, ACDOs and adult literacy assistants should be trained in:
  --use and construction of RHCs in such a way that they gain sufficient confidence and proficiency to train others to use them, and
  --methods for teaching others to use and construct RHCs.

- Commercial sewing groups, e.g., BEDU, should also be trained as above. If they become convinced of the RHC's advantages, it is possible that the entire effort could become completely commercialized.

- Patterns, samples and cookbooks should be provided to the groups intended to act as trainers. The resources and expertise for developing these materials and undertaking the training activities already exist among current BRET staff.

- Based on the experience with these training efforts, an in-depth market study should be conducted to

determine whether there is sufficient interest to justify commercialization.

- Commercial groups should be assisted in determining whether local production of RHCs can be competitive with the homemade and/or imported commercial model.

- If local production is viable, a national radio campaign (supported by home economists, ACDOs and adult literacy assistants) should be undertaken to publicize the benefits and availability of RHCs.

- The activities related to potential commercialization of the RHC would require short-term expertise beyond the current skills of BRET staff, but staff input would be important.

4. Earthen Bread Ovens

Developmental History

Baking bread was not a major cooking activity in either of the two pilot villages, but there was some interest in earthen bread ovens in Shoshong. RIIC's work on this technology was known, and villagers hoped that the BRET project would be able to assist them in acquiring ovens. The project's initial plan was to introduce bread ovens once some work on the earthen stove was underway, as this would be a complementary effort, responding to community interest. Although the work on earthen stoves was discontinued, it was felt that bread ovens should be introduced, given the significant level of interest and the fact that income generation was important to the village.

Results and Conclusions

In cooperation with RIIC, two earthen bread ovens were built at the Shoshong VTF in late 1984. RIIC conducted a 12-day workshop in oven construction and maintenance, and also provided training in baking bread and the use of earthen ovens. For several months thereafter, a group of eight village women baked regularly, making 30 to 60 loaves per day, seven days a week. They were able to sell all the bread they made and established a good reputation in the community. Unfortunately, the selling price was set slightly below that of bread being brought in from Mahalapye, and was not related to the cost of materials and labor. Thus, over time, the quantity of bread baked was determined by the amount of money available for ingredients.

The BRET project's concerned response to community pressure raises some issues about this technology and its dissemination. First, one important issue (in the context of a renewable energy project) is that the oven's efficiency and fuelwood consumption is unknown, as RIIC has yet to carry out efficiency tests on earthen ovens. Thus, it is hard to determine whether the device's income-generation value outweighs the additional pressure on the fuelwood supply.

Second, the income-generating value of this technology, as it is currently being used, is questionable. While the women do keep detailed records of sales and receipts for purchases, they do not know how to price the bread to cover their costs. Because the whole group started the project, they are reluctant to reduce staff in order to increase "profits."

Third, the training provided by RIIC was good, but limited. The key to the long-term success of this enterprise is sound training in small business management.

Recommendations

Based on these experiences, it is necessary to take the following steps before undertaking any further dissemination of earthen bread ovens:

- fuel efficiency tests must be performed;
- a financial analysis of bread baking as an enterprise must be done to determine whether it is really economically attractive; and
- a small business training program must be developed for entrepreneurs who wish to acquire and use an earthen bread oven.

5. Simple Batch Solar Water Heaters

Developmental History

Although water heating is not the primary end-use of fuelwood in rural areas, cooking fires are also used to heat water, and limited development of this technology seemed to be an appropriate complement to the BRET project's stove work. Comparative laboratory tests were done on seven prototypes, with capacities ranging from 15 to 30 liters and estimated costs of P14 to P49. The models that performed best in the laboratory were taken to Shoshong for user testing. They included:

- concentrating collectors,
- a large insulated box,
- five-liter tins in wooden boxes, both insulated and uninsulated, and
- a solar pillow.

Shoshong was selected for the user tests because the villagers had more of the required resources and skills for utilization of this technology, and a generally higher income level, which seemed to indicate that the chances for successful dissemination of solar water heaters were probably higher than in Ditshegwane. The most popular model from the user tests was then used to train potential producers and to extension workers at seminars to introduce them to RETs. An economic analysis on the workshop model was completed in June, 1985, and follow-up questionnaires from users were received in July to August, 1985.

A complete review of this technology is given in a separate BRET project report, DEVELOPMENT AND DISSEMINATION OF VILLAGE SOLAR WATER HEATERS (Judith Oki, ARD, Burlington, Vermont, August, 1985). A full economic analysis of simple batch solar water heaters can be found in the BRET report titled FINANCIAL AND ECONOMIC ANALYSIS OF SELECTED RENEWABLE ENERGY TECHNOLOGIES (Phillip LeBel, ARD, Burlington, Vermont, July 18, 1985).

Results and Conclusions

Laboratory tests indicated that all of the solar water heaters produced water between 45 and 55°C in both summer and winter. The performance of these models was also acceptable during the user tests, as all users reported general satisfaction with the units. During discussions following the week of home use, the uninsulated wooden box that holds three tins (total capacity of 15 liters) emerged as the most popular model. It also performed the most consistently, and the tins were the same as those already in use in the households.

Construction workshops in Shoshong, a village carpentry workshop in Ditshegwane and larger workshops designed to introduce RETs to extension workers were geared to further determine local production capacity for solar water heaters as well as gather additional data on user experiences. These workshops spanned a period of one year and resulted in the installation of 21 solar water heaters in households for long-term use.

The first workshop in Shoshong was held during September, 1983, with seven people in attendance. It was designed to enable the participants to:

- construct at least one solar water heater with one or two other people;
- describe the components of the unit and their function;
- demonstrate how to fill and empty the solar water heater; and
- show how to position the device so that it captures the most heat.

By the end of 1984, a total of 27 solar water heaters had been constructed at the various workshops, and 21 had been installed in households to permit some long-term assessment of the units' utility and durability as well as user interest.

It is possible to train people to use the solar water heater, and there is some willingness to use this type of batch system among community innovators (i.e., those members of nongovernmental organizations in the villages who were willing to participate in the user tests, subsequently purchased the heaters and continued to use them for 10 to 12 months, as well as extension workers who built heaters during a workshop and used them for a six-month period). The people in these groups also place some value on their time and recognize the advantages of coming home at the end of the work day to find warm water. The construction experience provided participants with practical experience in fitting the glazing, which requires periodic replacement.

An economic and financial analysis of the solar water heater indicated that the workshop production method resulted in a per unit cost which is out of reach for most rural villagers and not attractive for the benefit(s) derived. This model of solar water heater is not economically viable, although it appears to meet the needs of some community members. (Early on in the project, it was appropriately accorded the lowest priority of all the BRET project's village technologies.) Thus, this particular type of model of solar water heater warrants no further consideration.

Recommendations

- Any further work on very inexpensive solar water heating systems would need to begin by gathering the data necessary to determine the actual benefits of

using the device--i.e., how much fuelwood is used in a household to heat water to what temperature.

- The next step would be to determine the price required to make the solar water heater economical and financially attractive, given a range of possible fuelwood prices.

- If it is possible to design and build a model that delivers the required quantity of water at the right time and temperature, pilot diffusion could begin again.

- If this new model were economically viable, precut kits with assembly instructions might be the best approach, as it was successful in the BRET project's experience with extension workers.

6. Recommendations for All Domestic RETs

The best chance for successful dissemination of rural domestic RETs is in villages where the firewood problem is perceived as immediate and people have the resources to purchase the technologies. Thus, dissemination activities should focus on those areas, regardless of whether they are towns or villages.

The two RETs that are currently ready for dissemination are the retained heat cooker and portable sheet metal stove. It is reasonable to expect that over time, production and marketing of both devices could occur through a completely autonomous system, and the next steps taken should be aimed at developing those systems.

Given the status of the entrepreneurial environment in Botswana, continued external support from the GOB for work on these two technologies will be required for some time to come. External support for both the metal stove and retained heat cooker should be concentrated on two simultaneous groups of activities:

- continued dissemination of these RETs,

- the development of commercial systems for these devices, and

- a technical/design review and financial analysis of a two-pot metal stove.

Dissemination activities should be carried out primarily through multiplier groups--i.e., targeted extension services, including teachers, who are trained to demonstrate the devices

and encourage their use. Subsequent activities should build on the strength of the decentralized district-level extension networks, while developing interest on the national level at the same time. At the national level, two channels should be explored for institutionalizing/formalizing dissemination:

- the Rural Extension Coordinating Committee, and
- the Women's Affairs Unit of the Ministry of Home Affairs.

Commercialization of these two technologies is beyond the scope of current BRET staff members' skills. A local consultant should be identified to enable MMRWA to determine the specific issues to be resolved and develop a plan for resolving them.

Continued expansion into major villages and towns should be monitored closely to ensure that demonstrations and training are appropriate and provide any necessary follow-up.

A plan for training extension workers to demonstrate and train others in the use and construction of retained heat cookers should be developed and scheduled with DETs in Kweneng, Mahalapye, Kgatleng and the southern districts for the next year. The training should include an introduction to RETs along the lines of the workshop for extension workers described in this report. In addition, it should include opportunities for participants to develop and practice training and demonstrations for others. The decision to make the training available can then be made at the district level, enabling individual extension workers to respond to the needs in their villages, prior to any policy decision. A follow-up schedule should be drawn up at the conclusion of each training event with the participants.

Radio spots for the retained heat cooker and BRET metal stove should be developed and aired. These spots should include a motivational statement about saving time and/or money, information about the devices, and where they can be seen and purchased.

A follow-up study of metal stove and retained heat cooker users should be conducted to determine the extent to which the devices are meeting their expectations and needs for fuel-conserving cooking technologies. This study should take place after a reasonable number of people have used the devices for at least six months. It should include in-depth direct observation of a subsample of households for a week and/or a sequence of unannounced visits to determine actual usage patterns as well as foods, utensils or other instances where the devices are not meeting user needs.

The retained heat cooker cookbook should be distributed to all current users and potential multiplier groups.

The BRET project has discussed the production and distribution of the metal stove with metalworking brigades and the retained heat cooker with BEDU. These preliminary investigations should be completed.

Since the expected life of the metal stove grate is one year, plans must be made soon to produce this part and make it available to those who need it.

Demand for the BRET metal stove must be projected and steps taken to ensure that production can meet demand. This includes careful consideration of the production capacities of small-scale tinsmiths as well as large-scale manufacturers. While it is preferable to encourage production of this technology by small businesses, it may not be practical.

No further dissemination is warranted for the BRET project's other rural domestic technologies--earthen stoves and bread ovens and simple batch solar water heaters for households.

H. Institutional Assessment

1. Developmental History

In the technology development process, village and district leaders and institutions have been viewed and used as key resources in village selection, community entry, assessments and RET dissemination. There is a wide range of institutions that can have a potential impact on RET dissemination, and the conclusions presented here reflect their diversity as well as local differences in specific institutions. The BRET project began its work by using government institutions in the two pilot districts to select a pilot village in each. Village institutions then became key sources of information during the process of selecting pilot villages. The success of this approach was partially due to the degree of decentralization that exists within the GOB.

The GOB has decentralized a number of services and established mechanisms for village-level input to national development planning. Key institutions in this effort have been and will continue to be important to the success of the project's efforts in both villages. At the village level, Village Development Committees (VDCs) are established to plan and implement village development activities. While this is an externally imposed structure, in a sense, it serves two very important functions:

- it is an existing assembly of responsible villagers that any new development project can coordinate its activities with; and
- it provides input to district-level development planning.

The comparable structure at the district level is the District Development Committee (DDC). DDCs are responsible to and appointed by the elected District Council and work closely with the District Extension Team (DET) in the implementation of development plans and priorities. The administration of extension services in Botswana is decentralized--i.e., priorities and administrative support are provided by local government authorities (District Councils). Technical direction is established at the national level. Two notable exceptions to this scheme are the cadre of Rural Industrial Officers (RIOs), which is still administered by the central government, and Agriculture Demonstrators, who are administered by agricultural districts that do not coincide precisely with the government's administrative districts. In general, much effort has gone into evaluating the effectiveness of extension workers and determining

the best way to ensure the coordinated delivery of extension services at the district and village levels. While this is a large and complex undertaking, it recognizes that extension work is a generic process with specialized content areas, and as such, much can be accomplished by strengthening coordination and cooperation at both the district and village levels. Both DETs and Village Extension Teams (VETs) were established to effect this coordination and cooperation.

2. Results and Conclusions

Ditshegwane

The population of Ditshegwane is 821 (1981 census). The Ditshegwane VDC was an important group for the BRET project for a number of reasons. The most influential people in the village are on the committee, and VDC leaders also head virtually every other voluntary organization, including the Botswana Council of Women (BCW) and PTA, for example. The village has a VDC, Village Health Committee (VHC), BCW, PTA and 4B Club. The memberships of the VDC, VHC and BCW overlap to a large extent. Teachers form the bulk of the PTA, and the 4B Club is predominantly school leavers.

Full-time, resident extension workers include the Adult Literacy Assistant, Family Welfare Educator (FWE) and Enrolled Nurse. The primary schoolteachers and head-teacher are also considered extension workers in a way. Nonresident extension workers include the Assistant Community Development Officer (ACDO) and Agriculture Demonstrator, both of whom live in neighboring villages, and the RIO at District Headquarters, who is responsible for the entire district. There is one general trading store in the village plus a smaller "restaurant" and bar/bottle store. The trading store and bar/bottle store are owned by the same family.

Shoshong

The population of Shoshong is 4,600 (1981 census). The village has a VDC, VHC, BCW, YWCA and PTA. Full-time extension workers include Agriculture Demonstrators, an Adult Literacy Assistant, ACDO, FWEs and Enrolled Nurses. There are two primary schools in the village and a new, community-funded junior secondary school. An RIO has just been appointed to the Mahalapye Subdistrict. The Senior Tribal Authority (STA) in Shoshong has a deputy, although the STA is responsible for more than one village. Shoshong also has a Sub-Land Board Office. There are nine shops and restaurants in the village, plus three bar/bottle stores.

Shoshong is located in the Central District, the largest in Botswana in terms of size and population. Further decentralization has occurred in the Central District, so Shoshong is located in the Mahalapye Subdistrict. The subdistrict functions fairly autonomously with fully staffed district offices. After the first year of the BRET project, it was recognized by the project and Central District authorities that it would be more appropriate and relevant for the project to work with subdistrict officials. The roles of each type of village institution and an assessment of whether they are a facilitating or inhibiting factor to RET dissemination are discussed below.

Village Development Committees

Members of these committees are elected and generally older, well-established, well-known, respected individuals, usually from the upper end of the village's income scale. Tribal authorities are ad hoc members of the VDC, as are extension workers and the head-teacher(s) of the primary school(s). The VDC's established role is to initiate and implement village-level development activities, disburse local government funds for development priorities set by the village and coordinate efforts with the DDC. Seminars are held, as district-level priorities allow, to provide VDCs with training in various aspects of leadership, problem solving and project planning.

While VDCs function differently from village to village, the existence of a committee with this mandate and composition is a great boost to new development efforts, especially those that do not originate in the village. A criterion for village selection in both districts was the level of activity and organization of the VDC. In both villages, the VDCs were active in acquiring local government funds for activities--in Ditshegwane for school construction and Shoshong for a village woodlot. VDC members assisted in acquiring the necessary land for project construction, suggested enumerators for the village energy survey and reviewed the survey findings.

The VDCs in both villages took full responsibility for the planning and execution of the opening of the Village Training Facilities (VTF) and provided their sanction/authority for many other events as well. A successful strategy for BRET activities in Shoshong was a "preview" of RETs for VDC members. It enabled the members to tell others in the community about the RETs and gave them confidence in the project's value to the village.

In terms of RET dissemination, caution must be exercised to ensure that dissemination activities do not center wholly on the VDC because it has the potential to be an elite class in some respects. In Ditshegwane, where the tribal authority is

autocratic and the VDC is perceived as the authority's new group, there was a general feeling in the village that RETs were for the elite, not the general populace. In Shoshong, several VDC members had made the transition to convenience fuels (gas and kerosene) and hence, were not a true market for village-level domestic RETs. Most VDC meetings were characterized by discussion and interest in PV electrification systems for household use and water pumping for livestock and/or irrigation. While the VDC is an elected group, it may not necessarily be representative of all community members. Clearly, VDCs must be involved, informed and participate in RET dissemination activities, especially information-sharing, but this is not enough to guarantee acceptance of RETs in the community.

Tribal Authorities

The traditional authority of chiefs in Botswana has not waned--in fact, it has been incorporated into modern government in that traditional authorities are paid civil servants and a House of Chiefs complements the elected parliament. The issues that any single village chief becomes involved in range from administration of customary law to all aspects of village life, including development projects. The chief's support is required to gain access to the kgotla meeting, a kind of "town meeting" which is regularly attended by seniors in the village and as many other individuals as have time. The kgotla is one of three forums that the BRET project found were important media for communicating information to villagers. Three venues were used to cover an entire village for information-sharing--the kgotla, school and clinic.

The support of tribal authorities is critical for gaining access to inclusion in the agenda for a kgotla. For example, on one occasion in Ditshegwane, the project's failure to adequately inform and coordinate with the chief resulted in his scheduling a major customary law case at the same time as a BRET activity, which made it difficult for villagers to attend the BRET presentation. In the end, the project had to postpone its event until the case was over toward the end of the day.

Village Health Committees

The VHC is a voluntary group, chaired/organized by health facility staff. In Ditshegwane, the memberships of the VHC and VDC overlap, so the VHC was not utilized as a separate group. In Shoshong, the VHC proved to be an effective group of demonstrators and promoters of village RETs. They formed the basis of an ongoing group of village players who wrote and performed skits portraying problems involved in the use of fuelwood and potential solutions offered by RETs. The time

invested by the VHC in Shoshong was undoubtedly related to the energy, enthusiasm and support that the BRET project and RETs received from clinic staff and individuals on the committee. While the VDC is composed of the most prominent people in the village, who are often employed full-time, the VHC includes more individuals who can juggle busy domestic schedules to participate in skits, demonstrations, etc.

While the success of the Shoshong VHC in RET dissemination may be a single and somewhat isolated case, BRET attendance at a VHC seminar for a number of committee members from the Central District revealed that VHCs are concerned about home accidents--including paraffin poisoning and burns among children. This is a natural link to the potential advantages of fuel-conserving cooking devices. Continued efforts should be made to participate in seminars for VHCs.

Village Extension Teams

To a large degree, Village Extension Teams (VETs) are neutral in terms of assisting in RET dissemination. The VET's intention is to coordinate and cooperate in disseminating new information/practices and an assessment of village needs. VETs provide a mechanism for sharing and developing dissemination strategies, and it is possible to schedule joint kgotla presentations, so that groups organized by other extension cadres can be used. It also provides a kind of peer group for facilitators and those engaged in the dissemination of RETs. The BRET project's primary use of VETs was to coordinate and share kgotla meetings in Shoshong and gain access to farmers' committees, etc. The project found it far more effective to simply network with other extension workers in the village than actually participate in the VET. BRET training of extension workers was done at the district level and did not include many village teams. A future training strategy might incorporate targeted VETs, which could assist in RET dissemination and strengthen the extension teams.

District Extension Teams and Other District Institutions

The District Extension Teams (DETs) were of key importance in the identification and selection of training participants for RET efforts. In a single presentation or letter, all the extension cadres for a district can be contacted, and although the response varied across cadres, the DET's organization was a great help to BRET project efforts. As the DET concept grows and becomes more effective in identifying district-wide needs and extension resources, this group will become more significant in the dissemination of new concepts or technologies.

Private Voluntary Organizations

The BCW, Red Cross and YWCA are active in most villages and have proved to be effective groups in the district and subdistrict headquarters for RET demonstration and training. Nationally and in towns, they are less effective. In Section III.H, the discussion of portable sheet metal stoves covers the BRET project's experience with PVOs in more detail.

Extension Cadres

While a large degree of decentralization has occurred, there is a general need for a national mandate to incorporate fuel conservation into ongoing extension services. At the village and district levels, the BRET project enjoyed a relatively high degree of success in reaching and engaging extension workers in the continued demonstration and promotion of technologies. It is appropriate that these workers disseminate RETs as warranted by their judgment of local conditions where they are assigned, but a national directive will be required to formally incorporate such activities.

Assuming that corrective measures can be taken, one temporary constraint is that the membership of the Rural Extension Coordinating Committee (the national equivalent of DETs and VETs) is open only to those groups that perform extension services full-time and does not currently have a mechanism for coordinating with development projects. Since MMRWA does not have an extension mandate, it was not possible to gain access this group. As the committee is considering a plan that would enable new information and services to be provided through the retraining of relevant cadres, it will be important for new projects to have access to this group, either by asking the committee to formally constitute a reference group for its activities for the life of a development project or allowing ministries/pilot project staff to join the committee on a temporary basis.

Now that village and district institutions and a general view of extension services in Botswana have been described, the following subsections focus on specific extension cadres.

Assistant Community Development Officers

As a whole, this cadre has been important in the dissemination of RETs at both the village and district levels. ACDOs generally know the whole village and have a good overall perspective on village problems/issues, not as they relate to a given aspect of village life. In addition, because they are

responsible to register and assist destitute persons, they have more direct experience with the poorest in the village and the circumstances surrounding localized poverty. They are frequently interested in using innovative approaches and new technologies in their continuing work on village mobilization and the relief of poverty. They are members of most village committees, and since their mandate is so general, RETs are yet another content area to complement their overall skills.

Turnover in the ACDO cadre is high, which operates as both a facilitating and constraining factor. It is constraining in that in any given village, it takes time to build the necessary rapport and gain the trust to make a community worker effective, and transfers that occur after a year or two make continuity difficult. On the other hand, the positive aspect of relatively frequent transfers is that well-trained ADCOs take information and skills to their new area of assignment. ACDOs frequently conduct village workshops on a range of issues and skills, from planning to build a community center to teaching sewing, improved cooking and hygiene. Thus, it is easy for an ACDO to organize local workshops and, given adequate training in RETs, include these technologies as a content area in workshops.

ACDOs are frequently hampered by problems with transportation and other supporting services, which would affect RET dissemination as it does their other content areas. Nonetheless, this cadre is considered of key importance to further dissemination of RETs.

Home Economists

Home economists are part of the Social and Community Development Department that includes ACDOs. They are few in number, generally assigned to large villages and frequently must serve a number of villages. They have the equipment and budgets to conduct sewing and cooking courses, and are also assigned to town councils. They invited the BRET project to supplement their ongoing cooking and sewing courses. While this makes them a natural multiplier group for cooking devices, and the RHC can be included in their sewing courses, they came to rely on project staff to do those demonstrations/training. The addition of staff from an "outside resource" to their workshop provided some relief for them and a refreshing change of pace for participants. It is recommended that all home economists be given BRET metal stoves and RHCs as part of their equipment, which has been done in the Mahalapye Subdistrict and Gaborone Town Council. The devices can then be demonstrated as part of ongoing workshops, regardless of whether they are treated as separate content areas.

Health Cadres

Two key health extension groups are FWEs, who are assigned to both small and large health facilities, and Health Education/ Nutrition workers, who are generally assigned to larger centers, but do move around to some extent. Both of these cadres have expressed significant interest in both cooking devices to complement their nutrition programs and the large BRET stove for their direct feeding programs. The Health Education Unit of the Ministry of Health has purchased 400 stoves for distribution, and follow-up will determine the success of this experience as a dissemination strategy for getting stoves into individual homes. Health personnel at both the village and district levels are responsible for Village Health Committees and thus, have the potential to mobilize additional village groups and demonstrate cooking devices from a health perspective.

Agricultural Demonstrators

The BRET project did only limited work with agricultural demonstrators (ADs). Their primary interest has been in water pumping devices, since it relates to a recent horticultural development scheme and ongoing problems of providing water for livestock. This cadre is responsibile to provide information on small-scale woodlots as well. Joint pilot schemes to use water provided at pump test sites for group horticulture programs are just beginning, and it is too early to comment on the success or failure of this linkage.

Rural Industrial Offices

Early on in the project, RIOs were viewed as natural links for artisan-produced RETs. Their mandate is to identify local producers and assess/find training that will enable artisans to be more successful. It was hoped that they would facilitate BRET project efforts, especially in terms of stove production, but this did not occur for several reasons. First, as a beginning step in their own work, RIOs are engaged in surveys of producers in their districts. This is an enormous task given the fact that there is only one RIO per district or subdistrict. Second, the priority of the national Financial Assistance Policy (FAP) has resulted in RIOs spending much of their time on the development and review of FAP applications with entrepreneurs who stand a high chance of success in new ventures. Third, there are certain individual biases among RIOs about what constitutes a viable product.

Collectively, RIOs were interested in the market for the metal stove, and indicated that if the BRET project could demonstrate a market, they would be able to cooperate in finding

producers and assisting in establishing the enterprise. Over time, that became a highly individualized effort. For example, some focused on bread ovens and Cinva-Ram blocks, which were or tangentially related to BRET activities. The area in which RIC were useful was in combining RIIC's ongoing village skills training programs with RET production. However, this had partl more to do with RIIC's success and the perceived value of its training than with RETs per se. Stove production was added to the village blacksmith program and the fabrication of solar wat heaters to the village carpentry program. In both cases, trainees were identified by RIOs. In the long run, this link could prove to be a great boost to RET dissemination, and forma incorporation of the BRET metal stove into the RIIC blacksmith program seems a real, practical possibility.

Adult Literacy Assistants

There are three levels at which adult literacy assistants (LAs) have worked successfully with RETs. The first is incorporating retained heat cookers into sewing lessons conduct by adult literacy group leaders (ALGLs). This is an exciting possibility because the lesson is a productive activity for participants while the food is cooking in the RHC, and the grou meet regularly, thus providing the opportunity for long-term, guided cooking practice and others with which to share experiences and recipes. Guided cooking practice has proved to be critically important to long-term success and satisfaction with retained heat cookers. Including this device in literacy group meetings affords an excellent opportunity to provide such practice, while simultaneously demonstrating the potential valu of the time that food is unattended in the retained heat cooker The second area where LAs are well-versed is in the use of popular theatre to motivate communities. The experience of the BRET project in Shoshong indicates that this is a very effectiv technique for problem presentation and RET demonstration. The third level where LAs offer a dissemination opportunity is printed material for new literates.

Other Institutions

Two other far-reaching institutions require mention. They are the RIIC and BTC. Both are very active in the area of RETs. The RIIC's willingness to integrate training for stove producers in their village blacksmith program is an opportunity that shou be maximized as stove development continues. The RIIC's clarity about extension efforts--i.e., geographical areas of impact as well as technologies--helps delineate where additional and complementary resources need to be directed. The BTC headquarters is a passive-solar building and as such, has provided an opportunity for further dissemination of informatio

about energy conservation in buildings. In addition, their interest in PV power for electrification and pumping provides impetus for that technology.

3. Recommendations

First, a series of RET reference groups should be established and/or continued, including groups for PV, pumping, buildings and stoves/cooking.

Second, linkages and closer collaboration between and among the RIIC, BTC and MMRWA Energy Unit should be related to assessment approaches that are clearly agreed on.

Third, further dissemination efforts should build on the opportunities presented by the institutions described in this section and other sections of this report on the individual technologies.

Fourth, dissemination efforts should focus primarily on groups that can carry out such work now. For example, these groups include ACDOs, FWEs and Health Education Nutritionists.

Fifth, the best chances of success for RET dissemination are found in larger centers with populations of at least 4,500 to 5,000. In addition, 40 to 60 percent of the households should fall in middle-income groups.

I. Awareness and Outreach

1. Developmental History

The BRET project's plan was to initiate awareness activities at the village level and then proceed to the district and national levels in sequence. The bulk of the project's experience was gained at the village level, with some outreach at district and national levels. It was deemed appropriate to work at the village level first (i.e., complete the pilot testing of diffusion strategies) before moving on to the national level. The range of extension activities undertaken in the pilot villages over the life of the project resulted in a recommended package for village awareness, and strategies were developed for use in subsequent dissemination campaigns. Before describing the specific BRET village, district and national awareness activities, this subsection provides a general discussion of the project's efforts in this area. (A complete description and analysis of extension activities is contained in the BRET report titled EXTENSION ACTIVITIES OF THE BRET PROJECT, Judith A. Oki, ARD, Burlington, Vermont, September, 1985.)

Generating awareness at the village level occurred in various stages over the life of the project and was interspersed with many other activities in the pilot villages, such as user tests, VTF construction, workshops, etc. The results of the village energy survey indicated that people were well aware of problems surrounding the use of firewood--the time and effort required to collect it, increasing distances that had to be traveled to gather wood and rising costs in situations where wood was purchased. However, villagers were not aware of "demand" strategies to address these problems. In both Ditshegwane and Shoshong, people knew that planting trees was a possible solution, but a long-term one. In fact, the VDC in Shoshong had attempted to establish a community woodlot with saplings from Serowe, but difficulties with water supply and technical advice hindered the full development of that project. Thus, BRET project activities focused on heightening an awareness of both "demand" (e.g., the use of fuel-conserving household devices) and "substitution" strategies (i.e., employing RETs for water pumping, lighting, refrigeration and building).

During the technology selection and prototype development phases early in the BRET project, Ms. Erika Morgan (ARD's renewable energy media and public education specialist) developed a series of standard approaches to preparing awareness actviites for a range of audiences. This consultancy was timely in that the project was considering a number of technologies, but premature in the sense that it was not ready to actually design and develop dissemination campaigns for specific technologies.

Ms. Morgan worked with the PCV graphics artist to help develop her skills in preparing illustrated materials for public information. A separate report on this work (AWARENESS PLAN AND IMPLEMENTATION PLAN FOR THE BOTSWANA RENEWABLE ENERGY TECHNOLOGY PROJECT, Erika Morgan, ARD, Burlington, Vermont, February, 1984) provides complete guidelines for a series of awareness strategies to be used in the development of materials for RET diffusion campaigns, including posters, radio spots, newspaper advertisements and workshops.

The BRET project worked with a number of private design firms in Gaborone and had an in-house graphics artist for some time. A common and frequently insurmountable problem was the conflict between graphic communication and artistic presentation. This is an understandable difficulty in working with relatively inexperienced commercial artists, and if the project had been able to use more experienced, existing government services, it might have been avoided. The BRET graphics artist had several exploratory conversations with the Department of Nonformal Education and Agriculture Information Services. Both were interested in assisting the project in the development of dissemination materials as they had time. However, the schedules of those involved could not be coordinated, so BRET work was done in-house or by the private sector. Fortunately, the project was able to use some photographs, although it was frequently difficult to find just the right picture to convey a particular message. In the end, a freelance graphics designer was found who could communicate the desired information while preserving her artistic integrity.

2. Results and Conclusions

Village Awareness Activities

The village energy survey found that people were cognizant of the problems associated with gathering and burning firewood. The task of the BRET project was to confirm that village leaders were also concerned about these problems and develop an awareness of RET options.

Structured discussion groups were held with VDC members, tribal authorities and extension workers to share the survey results, thereby confirming that the formal village leadership were aware of the problems indicated in the survey's results. These meetings were organized around verbal presentations of the survey results and discussions of the potential of various RETs. There was a clear consensus about the importance of the firewood issue and interest in possible RET solutions to this problem.

A second set of discussions was held with members of voluntary organizations and adult literacy groups, which were aimed at increasing the number of people sharing the same perception of the fuelwood problem and potential role of RETs in conservation efforts. These discussion groups were organized around "picture codes," drawings of women cooking or collecting firewood, etc. The drawings were very simple and intended to trigger conversation about whatever issues participants associated with them. Problem definition was straightforward, and the possible solutions that were discussed included planting trees, extinguishing fires immediately after cooking, building windbreaks and saving charcoal. RET options were not well-known among those attending, although there was interest in what those options might be.

When the RETs under development were ready for a larger audience, a series of awareness activities was conducted at key locations--main kgotla meetings (traditional gatherings called by the village chief), sub-kgotlas or wards (smaller units of the village and clinics on special days for mothers with children under five. With announcements at the primary schools of when and where activities would take place, these events proved effective in providing information about RETs to almost the entire village.

Information about the technologies was presented in a variety of ways. First, BRET staff members made presentations, which generated a lot of discussion and requests to see the devices.

Second, skits were developed by village players and organized by the BRET village facilitator. The skits portrayed the well-known problem of fuelwood shortage and a series of consequences, ranging from a humorous satire of men being required to eat food that was barely cooked, because the women and children could not gather enough wood in a day's time to cook a simple meal, to more serious scenarios, such as women collapsing from the effort of collecting wood. Over a period of time, the skits were embellished by audience response and participation. The village players were all highly regarded by the community, and the presentations resulted in widespread interest in RETs as fuel-conserving devices. A second series of plays contrasted households using the BRET stove with those that continued to use an open fire. Among the benefits of stove use that the villagers chose to portray were relaxed women who had time to listen to the radio, happy husbands who could enjoy fully cooked meals prepared using only a few sticks of wood, and fewer burns and accidents.

Third, an integrated demonstration of three village technologies--the BRET metal stove, retained heat cooker and simple batch solar water heater--was designed to stimulate and

determine the level of interest in each specific RET. The demonstration consisted of:

- a brief introduction on the need for fuel conservation and presentation of the three devices;
- filling the solar water heaters and orienting them properly;
- starting a fire in the BRET metal stove and bringing the porridge or rice to a boil before placing the pot in the retained heat cooker;
- the demonstrator continued to answer questions, while cooking a relish on the BRET stove to put in a second retained heat cooker;
- when everything was ready, participants were invited to wash their hands with the water from the solar water heater and then sample the food that had finished cooking in the retained heat cookers--their responses were usually a combination of surprise and pleasure at the temperature of the water, quality of the food and very apparent fuel savings.

In general, these introductory events were concluded with an invitation to purchase the devices or participate in construction workshops.

Schoolchildren are very reliable messengers. Thus, the BRET project deemed it worthwhile to target them specifically. The highest primary school classes and junior secondary school students were invited to the completed VTFs for demonstrations and explanations of all the RETs. In addition to the household technologies, the VTFs are examples of simple passive solar building design, and are equipped with PV-powered radios and lights.

The combination of awareness activities at kgotla meetings, clinics and schools covered all segments of the village population. The inclusion of the sub-kgotlas in Shoshong was important, as it is a large village and although people may not walk the distance to the main kgotla, any event in their sub-kgotla is readily apparent and even those who are only mildly curious will stop by to see what is happening. The integrated demonstration worked well to foster general awareness and curiosity, and potential RET users could then follow up by purchasing a device or attending a workshop. The times for scheduled workshops were announced at the same places.

In addition to the above activities, it is important to note that the existence of VDCs was a great help in organizing village

activities. VDC members are generally elected, which indicates that they are highly regarded in the village, and are viewed as hard workers and leaders. They meet regularly, which gave the BRET project an opportunity to stay in touch with the feelings o: the community, as well as to solicit their ideas and participation in events.

After the BRET project carried out its general awareness activities in the villages, it was time to move on to determine who might perform similar duties in other villages in the district and expand the awareness of RET options in other locations.

District Awareness Activities

BRET project activities at the district level involved both direct outreach by staff members and the development of selected multiplier groups. Direct outreach work included BRET participation in annual rural agriculture shows and district extension team (DET) meetings. Efforts to develop multiplier groups included workshops for selected extension workers and presentations in districts where the project was active.

Direct Outreach

Each year, the Ministry of Agriculture organizes rural agriculture shows in its operational districts. Exhibitors include farmers and ranchers who display prize crops and cattle as well as various extension services, including agriculture, social and community development, and youth clubs. Private entrepreneurs sell food, soft drinks and beer, and hawkers frequently set up stalls to sell their wares. The two-day shows take place on Fridays and Saturdays during June and July, typically in the largest village of an agricultural region/ district.

The BRET project participated in rural agriculture shows to heighten its visibility among community members (for whom the show is a major annual event), district officials and other extension cadres. The project first attended the shows in Molepolole and Mahalapye in 1983. The following year, Serowe was added for several reasons--the project was planning to expand its activities into that area, district officials encouraged the project to do so and Serowe is the headquarters of the Central District.

The portable sheet metal stove and retained heat cooker were viewed as the most promising technologies, and it was agreed that the project would exhibit these and conduct actual demonstrations. However, this proved difficult since fires were

not allowed in or near the exhibition stalls. BRET staff member asked the people who were cooking food for sale to use the stove and refer interested people to the project's stall. At the stall, a dismantled stove was displayed to encourage possible producers.

The rewards of participating in the 1983 rural agriculture shows were limited. As many as 300 people, including groups of schoolchildren, did stop by the stalls and became familiar with the acronym "BRET" and the project's work. In addition, there was significant interest in BRET work on water pumping and PV electrification, but those technologies were not included in the display. Thus, the agriculture shows were viewed as an effective way of directly reaching an area beyond a single village, but on that was staff-intensive and perhaps premature in this case. For the following year, it was anticipated that the village RETs would be ready for sale at the shows, and simple demonstrations or photo displays of pumping and electrification technologies could be prepared.

The year between shows was very busy, and the village RETs were ready for dissemination in 1984. The lessons of the first year resulted in the following changes in planning for and participating in the agriculture shows:

- a chairperson was appointed for each show, and the number of staff participating was limited to five;
- the demonstration units, information packets, etc. were packaged for easy reassembly to facilitate moving from site to site;
- a simple PV demonstration and hand pump were added to the exhibit; and
- the project reserved both exhibition and cooking stalls, and arranged for community groups to prepare food using the metal stove and retained heat cooker at the cooking booth.

In summary, the major disadvantage of the rural agriculture shows was that there seemed to be little payoff in terms of motivating people to act on the interest generated and acquire RETs, even when the devices were sold at the show. Given that each show took approximately 15 to 20 person-days of time, the results were disappointing. The major advantage was that the shows permitted the BRET project to disseminate to a wider audience in targeted locations where RETs are available, in contrast to radio which reaches all areas, including those where the technologies cannot yet be found. The shows also served a team-building function and improved staff morale by placing the

work of the BRET project on a level comparable to the activities of other extension networks.

DET meetings include the senior officers of every extension cadre operating in a district. The teams were set up to coordinate and integrate extension services on a district-wide basis, thus enabling extension workers to respond to localized needs within the overall framework of national policy and avoid unnecessary duplication of effort. Thus, this unit proved to be an effective group for both information-sharing and -gathering. The DETs in the Kweneng and Central Districts were of key importance in selecting the villages in the early days of the BRET project as well as identifying participants for district-level training workshops and seminars later on. The BRET project attempted to participate in regularly scheduled DET meetings and did so with mixed success.

Developing Multiplier Groups

While the direct outreach strategies just described relied very heavily on BRET personnel and resources, other strategies developed by the project focused more on involving and providing information to potential multiplier groups--people who were in contact with large numbers of villagers and could share that information in the course of their work. Multiplier groups were identified based on their responsibility for conservation, improved cooking techniques, nutrition and health, and income generation. In addition, schoolteachers and assistance community development officers (ACDOs), who are concerned with the general welfare of their communities, were considered to be good multiplier groups.

The major activity for multiplier groups was a workshop for extension workers from the Central and Kweneng Districts. DETs were asked to select and send participants from all of the extension cadres to the week-long training session. The goals of the workshop were to:

- discuss the need for RETs,
- provide an overview of RETs,
- determine how different extension groups could assist in the dissemination of RETs, and
- evaluate the usefulness of the workshop for other extension workers.

By the end of the workshop, it was clear that most extension workers were interested in all of the village RETs and saw

opportunities to incorporate information about them in their work.

A summary of possible applications of village-level RETs by extension workers is as follows:

- metal stove--Family Welfare Educators, Home Economists, ACDOs and head teachers for the purposes of nutrition education, reducing accidents in the home, income generation and feeding schemes as well as firewood conservation and personal use;

- retained heat cookers--all cadres listed for metal stoves and Adult Literacy Group Leaders for nutrition education, reducing home accidents, income generation, sewing classes and personal use; and

- simple batch solar water heaters--Family Welfare Educators and head teachers for instruction on improved personal hygiene, and all of the cadres for personal use.

In addition, to build awareness, adult educators saw opportunities for material and information for new literates as well as fresh content areas for popular drama.

While a number of follow-on activities were planned by working groups for application in their home areas, the BRET project was unable to determine whether or not these occurred, as all staff members were needed to work on metal stove promotion, which precluded the necessary follow-up. Still, the project was able to jointly sponsor a community workshop with a very active ACDO in the Mahalapye Subdistrict, and it was clear during the session that she will be able to continue conducting similar workshops. Continued BRET activity in this area would definitely lead to further dissemination and awareness of RETs.

National Awareness Activities

As already noted, the BRET project was reluctant to proceed with a full-scale national dissemination campaign until it had gathered some experience at the village and district levels with sound technologies. However, some general activities were undertaken to share information with an audience beyond the two pilot districts. These efforts included articles in the DAILY NEWS on specific BRET activities, such as the opening of the solar house, development work on earthen stoves and the passive solar building design workshop; two articles in KUTLWANO, the national magazine--one early in the project and another about the extension workshops described above; and an in-house monthly newsletter, MARANG, which was circulated to district officials,

central government offices, para-statal organizations and workshop participants to keep them apprised of developments ir the BRET project. Once the metal stove was ready for dissemination beyond the field-testing stage, radio spots were developed to promote that technology.

Though the project's experience with the media was limite some general conclusions can be drawn. First, radio has prove to be the most effective means of implementing national awaren campaigns and has been used successfully for a number of government efforts.

Second, newswriters need assistance with the new vocabula and concepts involved in the application of most RETs, and the Setswana translation of these concepts is very difficult. To ensure technical accuracy, time must be invested with writers news releases should be written ahead of time.

Third, the Department of Information Services is well organized with offices in all district headquarters. Staff members from those offices are usually available to cover even in the district. For very high-level activities (i.e., those involving a minister or permanent secretary), it is also helpf to inform the department's central office in Gaborone, as they may want to send supplementary staff to the event.

Fourth, an underused channel of information networking wa the ministry's own newsletter, MMRWA NEWS. In future, it is suggested that the ministry encourage all of its projects to prepare items for the newsletter and ask the newsletter's edit to solicit items from project staff.

Fifth, while fuelwood problems were clearly articulated a the village level and an issue that district-level authorities discussed with the BRET project, a national radio series on th issue should be considered. It may be timely now for several reasons which did not exist at the project's onset:

- the formation of the Forestry Association of Botswana and their success in establishing a national tree planting day indicates a national level of concern and a concrete step that can be taken by individuals and communities;

- the rural energy study now has information about fuelwood supplies and proposals for supply strategies;

- there are RETs that can help reduce the demand for firewood on the individual household level.

Certainly, bringing the fuelwood issue further into the public arena will make large-scale implementation of all future dissemination activities easier.

3. Recommendations

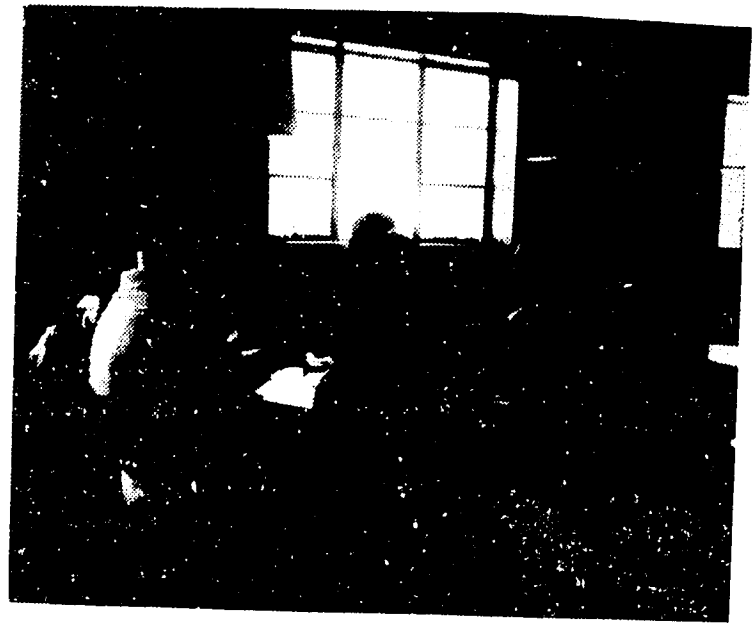
First, a radio campaign on the fuelwood problem should be initiated. The first phase might focus on this issue in a straightforward manner, followed by information on activities that the government, FAB and/or other organizations are promoting to address the problem. MMRWA's Energy Unit should work with the FAB and/or BTC as well as other relevant groups on the content of the campaign.

Second, follow-on activities should include continued information-sharing and participation in seminars at the district level to encourage continued promotion of RETs.

Third, an energy feature should be included in MMRWA NEWS.

Fourth, consideration should be given to using the BRET booth at the show-grounds for an annual display on energy issues and options.

Extension workers discuss energy needs and RET applications during a BRET seminar to develop multipliers.



This PV panel was one of several RETs demonstrated at the Rural Agriculture Shows. BRET's Extension Coordinator explains PV power to interested listeners.

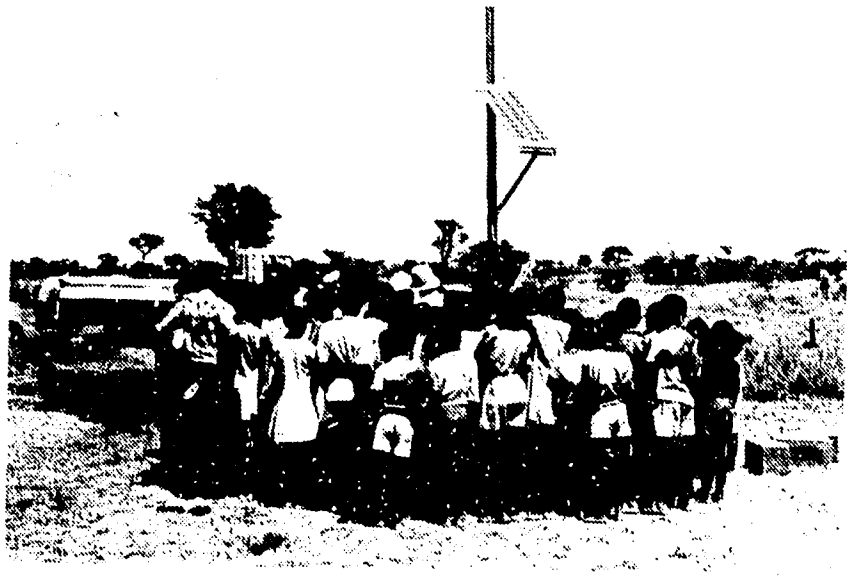
Rural Agriculture Shows provided an opportunity to reach beyond the pilot villages to a larger audience.

BRET staff prepare a demonstration at the Shoshong VTF.

Village players perform a skit they designed on energy problems and RETs at the Shoshong clinic.

School children are willing listeners, as BRET technicians explain the PV-powered anemometer installation.

BRET's strategy included community education at every installation site.



The official opening of the solar house provided the opportunity to introduce passive solar design to His Excellency, the President of Botswana, the U.S. Ambassador, the Minister of Mineral Resources and Water Affairs and several other high-level decision-makers.

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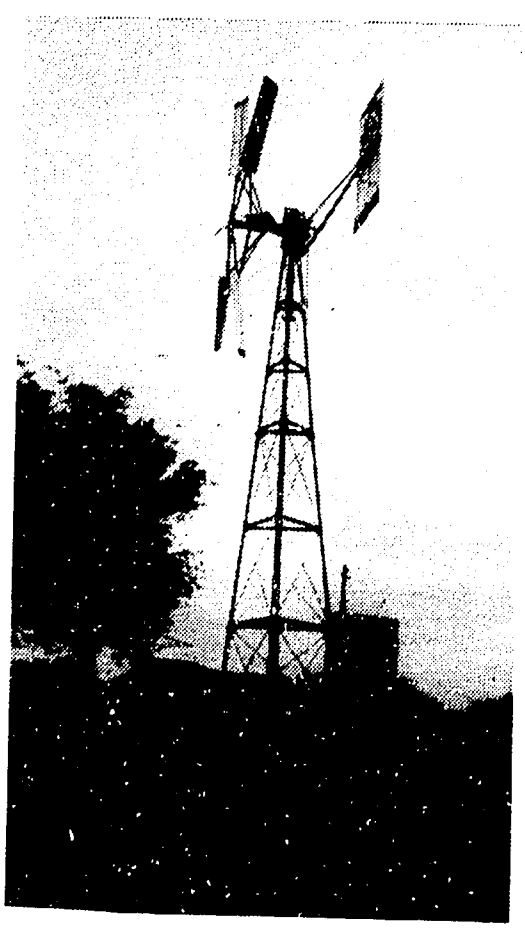
BRET staff prepare for a training workshop at the Shoshong VTF.



In addition to use and construction of rural domestic RETs, seminar participants toured other installations, including these pumps.

One of 172 women trained to use and construct RHCs.

An artisan trained to produce the BRET metal stove examines his work.

J. Training

1. Developmental History

Training was a major element of the BRET project's strategy. Its purpose was to develop those skills needed for the technical management of specific RETs, extension and dissemination as well as increase villagers' capacity to manage, produce and maintain RETs. Training was provided for BRET staff, RET users and producers and RET multipliers. The training issues were different for each group and, taken as a whole, represent the scope and complexity of skills development for continued renewable energy activities. In addition to training actually delivered throughout the life of the project, an analysis of training and institutional needs was conducted in April and May, 1985. The results have been published in a BRET project report, TRAINING NEEDS ASSESSMENT FOR RENEWABLE ENERGY TECHNOLOGIES, George Burrill, ARD, Burlington, Vermont, June 12, 1985. The training of BRET staff members as well as training that was not specific to a particular technology is discussed in the next section (III.L). The remainder of this section describes RET training activities conducted for users, producers and multipliers.

In terms of village RET training, the BRET project undertook the following activities:

- production training for the BRET metal stove--eight producers to receive training were identified by the BRET project as well as one PFP client and eight blacksmith trainees in RIIC's village blacksmiths program;

- metal stove promotion training for PVOs was conducted in Molepolole, Mahalapye and Gaborone;

- use and construction of retained heat cookers--workshops were conducted for PVOs, community members, adult literacy groups and extension workers;

- construction of simple batch solar water heaters--12 village carpenters were trained in a joint program with RIIC as well as 85 extension workers in Mahalapye and Molepolole; and

- earthen stove construction--five women in Ditshegwane and 12 from Mogoditshane were given training in building this technology.

The following <u>institutional RET training</u> activities were provided by the BRET project:

- use and monitoring of PV lighting systems--teachers and community leaders in Oodi, Ditshegwane and Shoshong were given an orientation in the proper use, monitoring and data collection for PV lighting;

- a comprehensive training program in passive solar building design was held for architects, engineers, technicians and draftsmen at the central, district and town planning levels--in addition, one architect received specialized training in the United States;

- an orientation on RET water pumping systems was conducted for council water technicians;

- an introduction to RET pumps was provided in selected communities where field tests were being conducted;

- windmill systems instruction, including on-the-job training and skills assessment, was completed during the installation of a wind system at Sedibeng, and DWA trainees were given a half-day overview of wind use for water pumping by an ARD wind consultant;

- instruction in PV electrification was provided in conjunction with training for the Madiba Electrical Brigade in 12-volt DC wiring during the PV installations at the Lentsweletau, Shoshong and Mabule health clinics;

- anemometry instruction, along with orientations for schoolteachers and police at wind installations throughout Botswana, was aimed at training participants to take readings from the compilator--teachers involved their science classes in this activity; and

- passive solar construction workshops, combined with a series of meetings held as each structure was built, introduced passive solar concepts, explained the building's design features and further explored the applicability of this technology to Botswana.

2. Results and Conclusions

Village RETs

First, 16 tinsmiths were trained in the production of the BRET metal stove, eight as part of RIIC's blacksmith program. In addition, the production of metal stoves by trainees identified by the project has been monitored closely. Follow-up on RIIC trainees is needed to determine how they have used their training.

Second, 12 village carpenters were trained to construct the project's simple batch solar water heater. Given the decision to discontinue work on this technology, the Shoshong group was retrained in the production of Cinva-Ram blocks. One of the Ditshegwane men is also doing work with youths who are out of school.

Third, 172 women were trained in the use and construction of retained heat cookers during the course of the BRET project.

Fourth, 85 extension workers were trained at week-long seminars in the use and application of RETs. A similar seminar was conducted for 25 villagers in Mookane at the request and initiative of a trained extension worker. The seminars for district extension workers represented a high point in the BRET project's efforts to move out of the pilot villages into surrounding districts. Participants were selected by DETs and represented every extension cadre but the RIOs. During the workshop, participants identified rural energy needs/problems (such as the shortage of wood, high cost of other fuels and difficulties with water supplies) as well as possible solutions. They were then introduced to the full range of RETs by actual use and construction experience with the village technologies, and tours of water pumping installations and the Shoshong VTF and clinic, where they saw passive solar buildings under construction and PV applications for two-way radios, lighting and refrigeration. Participants then focused on the further dissemination of RETs, the role of the BRET project and how they could help. Based on the skills of the various extension cadres, most are now able to conduct RET workshops. Others would benefit from a workshop that focuses on training methods.

Institutional RETs

While the BRET project experiences just described did much to educate relevant groups about specific RETs, a substantial amount of training (primarily of a short-term, local nature) will be needed to ensure adequate skills among Batswana for the future. The report title TRAINING NEEDS ASSESSMENT FOR RENEWABLE

ENERGY TECHNOLOGIES provides detailed information on the project's RET training activities, required competencies, personnel and the need for future involvement with particular organizations on specific technologies. The full range of institutions related to the installation, use, operation, maintenance and repair of systems was considered, and attention was given to potential local training options.

3. Recommendations

First, the training recommendations provided in the specific technology sections of this report should be implemented.

Second, continued emphasis must be placed on user education for all of the technologies developed by the BRET project to ensure that optimal use is made of these devices. Community orientations for newly installed RETs are critically important in assuring proper use of the unit, demystifying the device, establishing a sense of ownership and responsibility, and helping avoid vandalism in the case of PV panels.

Third, demonstration kits for all of the village-level RETs, including promotional materials, should be supplied to all new graduates of the S&CD course at the university and extension workers so they can add those materials to their work in the field.

Fourth, as GOB priorities for long-term, widespread use of institutional RETs are established, necessary and complementary training efforts described in a separate BRET project report, TRAINING NEEDS ASSESSMENT FOR RENEWABLE ENERGY TECHNOLOGIES, should be used to guide the relevant departments. Certification procedures and job scales will need to be formulated for the new skill areas and work descriptions.

K. Developing GOB and Batswana Capabilities

1. Developmental History

Throughout the project, this issue has been addressed in the following ways:

- by providing training to project staff on the job and in local, third-country and U. S. seminars, workshops and courses;
- by planning project activities to link project staff and GOB institutions which have or might take on RET activities in the long term; and
- by building the project experience into the newly formed Energy Unit of the Ministry of Mineral Resources and Water Affairs.

The first approach related directly to the stated project output, the second to overall project approach and the third to management and administration of the project. The activities undertaken in each general area are summarized here; results and conclusion follow.

The project had the good fortune to identify its own Batswana staff and select individuals with skills that they were eager to apply and adapt to project activities. As there were not many people in Botswana with academic degrees or experience in RET development and dissemination, on-the-job orientation and training were used to identify existing skills and skill areas which need to be built into local, third-country or U. S. training programs. Local training was provided in-house by ARD staff and consultants and through the Institute of Development Management. Most of the training for village facilitators was conducted in Botswana. Third-country opportunities were used to enable BRET staff to put their experience and work into regional and larger contexts. Thus, U. S. training was designed to both fill the specific training needs of staff members that could not be met locally or nearby and build on work experience in the project as well as individual strengths and skill development needs.

Local training was provided over the duration of the project, as follows.

May and September, 1982--Village survey training for extension staff and survey enumerators.

February, 1983--Staff workshop to examine the project as a community development effort; review extension and training techniques and identify project applications; develop a basic understanding of project technologies and required inter-organizational relationships; develop procedures for monitoring and evaluating technical, socioeconomic and overall project activities; plan future project activities; develop leadership and team skills.

June, 1983--Facilitator Training Workshop designed for the three staff facilitators to improve their understanding of project activities and how they fulfill project goals; understand the application of a community development approach to project activities; learn to set goals and objectives and organize and plan work; and develop evaluation and monitoring skills (data collection).

November, 1983--Communications skills workshop for facilitators, conducted by the Institute for Development Management.

January, 1984--Training Tools for Village Audiences, conducted by the project trainers, Motswana and Peace Corps, to enable facilitators and selected extension workers to design and practice approaches for conducting demonstrations of and user training in village-level RETs. Consultants were used to provide orientation to staff about their areas of specialization. Scheduled training sessions included:

- public awareness strategies;
- stove development and testing;
- research methodology design, implementation and analysis;
- design and sizing of wind pumping systems;
- economic analysis of RETs; and
- passive solar building design.

In addition, periodic on-the-job training for facilitators included the design and implementation of user tests for village RETs.

Third-country events included study tours, seminars and exhibitions. All were intended to provide BRET staff with a broader perspective on RET development and dissemination and begin to build regional networks. Specific events were:

- two separate week-long visits to the Lesotho RET project to look at specific technologies and project activity centers;

- Rural Development Technologies '82, an exhibit in Bulawayo, Zimbabwe;

- a six-week study tour of appropriate technology centers in India;

- participation in an international fuelwood conservation conference in Zambia;

- Making Use of Renewable Energy, a seminar convened by the Zimbabwe Solar Energy Society; and;

- installation and operation training at the Kijito Windmill production facility in Kenya.

Local and third-country training occurred throughout the first three years of the project and was used as additional information for shaping U. S. training programs.

Early in the second year, individual staff members worked with project management to specify the additional training they required out-of-country. In addition to job-specific training areas, training was also identified to enhance each staff person's ability to participate in extension activities and economic, institutional and environmental analyses of RETs.

In 1983, training in the United States was provided for four staff members, based on their individual training needs assessments. The Project Coordinator counterpart felt that his strengths lay in technical design, management and technical training and that energy management skills would best complement his educational and work experience. He felt that his work with other project teams would be enhanced by strengthening management skills, ability to design, monitor and evaluate RETs and developing skills in making energy policy in general and RETs in particular. He indicated that some management and evaluation skills could be learned on the job, but learning to design RETs and develop energy policy could best be learned in outside training programs.

The Solar Technician felt his strengths lay in his basic knowledge of engineering principles, mathematics, technical drawing and fabrication. While he felt confident in his ability to test and design solar water heaters and metal stoves, he wanted to strengthen his skills in solar design for heating/ cooling buildings and working with PV electrification, refrigeration and pumping. He felt that strengthening his skills

in the areas of wind systems and water pumping would enhance his overall role and usefulness to the project.

The Wind Technician was confident in his general mechanical abilities and was eager to strengthen his knowledge and ability to apply hand pump design, monitoring and testing, windmill site selection, system sizing and installation and report writing. He was interested also in strengthening the technical team's effectiveness by learning team planning skills and resolving interpersonal communication difficulties.

The Village Technologist felt she needed a better understanding of the project's main technologies, especially the ones related to food preparation. She felt her greatest needs were for extension training, and she was keenly interested in becoming familiar with microcomputer-based energy, economic and financial software packages.

A training package was developed for the summer of 1983 for these staff members. It included an introductory overview of the state-of-the-art RETs and their development, including the range of solar technologies, windmill applications for water pumping, experimental techniques and design, and instrumentation and monitoring. Field trips were taken to activity sites in the New England area and Brace Research Institute in Canada. Specific content areas were subsequently covered in depth, tailored to individual needs, and the group met together at the conclusion of the program for project planning skills and planning application of training to their BRET project jobs.

Specific courses were as follows:

- U. S. Application of RETs (ARD, Burlington, Vermont);
- RET Research and Development (Brace Research Institute of McGill University, Montreal, Canada);
- Energy Management and Planning (six weeks, Brookhaven National Laboratory, Upton, New York, for the Project Coordinator);
- Initiating and Managing Integrated Rural Development (12 weeks, U. S. Department of Agriculture, International Training Division, Washington, DC, for the Extension Coordinator and Village Technologist);
- Selection, Installation and Maintenance of Wind and Solar Pumps (New Mexico State University, Las Cruces; Wind Baron Corporation, Phoenix, Arizona; Blue Sky Water Supply, Billings, Montana; ARCO

Solar, Inc., Los Angeles, California, for the Solar and Wind Technicians);

- Use of Personal Computers for Processing Technical and Economic Data (University of Vermont, Burlington, Vermont); and

- Project Planning and Application of U. S. Training (School for International Training, Brattleboro, Vermont).

Training assessments were also done for the Extension Coordinator and Trainer, but they left the project for personal reasons before the courses were begun. The positions were filled after six months. In April, 1984, the Project Coordinator also resigned to become Senior Energy Officer of MMRWA's Energy Unit. His job in the project, which included both technical and administrative management, was divided in two, and a coordinator was hired for each position.

The second round of U. S. training was designed around the individual needs of three coordinators, following the same sequence of on-the-job training, consultation with project management to develop a needs assessment and the identification of suitable programs.

The Extension Coordinator brought a strong social research background to his BRET staff job and felt he needed more training in adult education and management. The Administrative Coordinator was interested in learning more about project management systems and administrative procedures. The Technical Coordinator was interested in developing her technical design and testing skills, becoming familiar with instrumentation for monitoring and evaluation of RETs, and developing complementary management skills. The following courses and independent study arrangements were made, with training undertaken in late 1984 through early 1985:

- Managing Extension Services (12 weeks, USDA/ITD, Madison, Wisconsin, for the Extension Facilitator);

- Project Development and Management (10 weeks, University of Connecticut for the Administrative Coordinator);

- Solar Energy Research and Applications (three months, Florida Institute of Technology for the Technical Coordinator);

- Testing/Monitoring Solar Water Heaters (Florida Solar Energy Center for the Technical Coordinator);

- Managerial Excellence for Women (four days, Boston University for the Technical Coordinator);

- Interpersonal Skills in Management (five days, University of Massachusetts for the Technical Coordinator);

- Adult Education (Center for International Education, University of Massachusetts, Amherst); and

- Troubleshooting Electronic Equipment for Solar Radiation Data Collection (Becjman Associates, Inc., Providence, Rhode Island).

U. S. training was also provided for the most experienced facilitator in the Management of Extension Services. More detailed information and a discussion of all these training activities can be found in two BRET project reports--OVERVIEW OF STAFF TRAINING: BOTSWANA RET PROJECT (ARD, Burlington, Vermont, April, 1984) and OVERVIEW OF U.S.-BASED TRAINING FOR BRET PROJECT TECHNICAL COORDINATOR (ARD, Burlington, Vermont, April, 1985).

2. Results and Conclusions

A total of eight BRET staff members received training in the United States in management, extension, training, research methodology and specific RET applications. Staff evaluations of their training programs were extremely positive. Evaluations of U. S. training indicated a higher level of confidence in the contributions each staff member could make to project activities and continued development of RETs in Botswana. The project management training received was well regarded, and participants returned to BRET eager to apply new insights and abilities. Further, the personal value of the management training was recognized for any future employment. The Energy Management course was immediately relevant to the Project Coordinator, who assumed duties as the Senior Energy Officer in MMRWA. The four facilitators were trained, primarily in Botswana, to perform a wide range of community-based activities related to needs assessments, user tests and the dissemination of RETs.

Skills currently available to further RET development and dissemination include:

- community motivation through participation in community meetings, demonstrations and training workshops;

- project planning, monitoring and evaluation;

- research design and implementation;

- RET evaluation and monitoring;
- collecting user data; and
- installation and operation of several RET systems.

In addition, through the third-country experiences, project staff have gained an understanding of regional efforts and where Botswana stands in relation to neighboring countries. The feeling after the Zimbabwe Solar Energy Society Conference was that BRET's activities should have been presented, i.e., that it was felt that Botswana had a contribution to make in such a forum.

Three issues arise from the staff training experience:

- On two occasions, Rural Development Technologies '82 and the Zambia Fuelwood Conference, there was inadequate coordination with GOB policy groups. While BRET was a GOB project, the primary liaison points for conference organizers were with other ministries. It is hoped that as the Energy Unit continues to reach out to relevant ministries, this will be avoided.
- Certificates from the U. S. training programs are not officially recognized by the GOB system for linking training with job qualifications/ scales/salaries, as they do not fit within the normal certificate structure. While it is understandable that training efforts in new areas, geared primarily to forwarding project goals and developing skills necessary to sound implementation of the pilot project, it may disadvantage staff in trying to enter the established system. This is especially true at the technician level, for both technical and extension staff.
- The interest and investment in training for staff in a pilot project implies some longer term interest in the skills being developed. While a pilot project would hopefully move into another phase, it is not always guaranteed that all aspects/skills/staff will move. This issue needs to be addressed clearly to avoid disappointment and wasted human resources.

Integration with Other Institutions

As part of the overall approach to implementation, BRET was successful in building linkages with several key institutions at the local and national levels. Those institutions are described

in the body of this report in the relevant technology and extension sections. Efforts to build linkages with national institutions with overall responsibility for technology development and assessment met with less success. The primary vehicle for coordination, the Botswana Renewable Energy Activities Committee (BREAC), was only resuscitated in 1984. It was plagued by the numerous difficulties that inter-ministerial groups encounter, including scheduling conflicts and ambiguity of purpose and authority. The committee was successful in sharing information among the three primary actors in the renewable energy field, BRET, the BTC and RIIC, but was not successful in establishing an advisory role for end-use institutions. The creation of the Renewable Energy Activities Coordinator's post in MMRWA's Energy Unit should enable more focused attention on the development of this committee.

MMRWA Energy Unit

As mentioned, BRET's first Project Coordinator counterpart was taken from the project to become head of the MMRWA's new Energy Unit, which also had oversight of the BRET project. BRET was the first development project of the unit and, as such, provided the basis of information for continuation projects. The information provided throughout the technology development and dissemination process and the assessment approach enabled the Energy Unit to select those technologies that seemed most responsive to need, most promising in socioeconomic terms, and most deserving of GOB investment. The final technology reports prepared by BRET were written to provide current status of the technology and map out recommendations for further government action.

3. Recommendations

First, the overall role of the MMRWA Energy Unit must be clearly established with other ministries, departments and institutions, especially those related to renewable energy and technology development (e.g., the Department of Forestry, BTC and MLGL).

Second, BREAC needs to be strengthened and developed into an advisory and technical group that is comprised of relevant end-use and extension ministries and departments as well as the primary organizations currently working on RET development. BREAC representation for government departments that BRET has established working relationships with should be actively solicited.

Third, the post of renewable energy activities coordinator should be filled as soon as possible to begin implementing the

recommendations already listed and to ensure proper coordination and integration of selected follow-on activities.

Fourth, follow-up should be done with trained BRET personnel who are no longer directly working with follow-on activities to identify possible opportunities to expand and incorporate RET awareness and maintain options should future openings in the government occur.

IV. LESSONS LEARNED

The purpose of this section is to draw attention to the key lessons and/or issues that arose during implementation of the BRET project. The lessons discussed here relate mainly to carrying out similar projects in Botswana, although generalizations to other countries or types of projects can easily be made.

The very nature and intention of a pilot program like the BRET project is to be experimental. By design, the project was supposed to create a learning situation, where it was clear that both technologies, dissemination methods, etc. would be examined, tried and judged applicable or inappropriate. That is, the BRET project was intended to determine the technologies, strategies and institutional approaches that would likely be successful if a similar, larger effort were mounted in the future. Thus, it is to be expected that some technologies, diffusion approaches, etc. would be found inappropriate or less than optimal and dropped from the project or given a very low priority. In this final report, the results, conclusions and recommendations for all of the technologies, project outputs and activities have been described--they comprise a detailed set of "lessons learned." Rather than repeat them here, this section focuses on general overall lessons learned during the course of the BRET project.

A. Project Design

Several aspects of the BRET project's design that affected the project throughout its life are worth noting. It was found that two of the assumptions made in the project paper were not entirely accurate. The first was the existence of research and development capability in Botswana. As it turned out, this was not always the case, and BRET-funded research conducted by local groups produced uneven results. Sometimes, this seemed to be a matter of resources, but in other instances, it was also a function of personnel. The GOB should continue to build the necessary skills to conduct research and development work on RETs by training personnel. The second assumption was that RETs are acceptable. In fact, this was a hypothesis to be tested during the life of the project. Clearly, some RETs were found acceptable, and others were not.

The project paper called for short-term training for BRET staff members outside Botswana. This training was found to be very effective except for:

- problems associated with people being away from their jobs; and

- the fact that by its very nature, short-term training does not fit into the GOB's standard certification and training recognition formats.

Certainly, long-term training of individuals prior to the start of the field project would have solved both these problems, but would also have delayed project start-up by five years or more. Adequate skilled personnel and allowances for delays in work due to the absence of staff attending training programs must be planned into a project's design. Of greatest importance, the GOB needs to develop some ability to recognize short-term training in a meaningful way.

As already mentioned, the project design called for most of the research and development work to be done by other organizations, which proved to be impractical in many cases for a variety of different reasons. Consequently, a greater amount of technical research and development work was undertaken by ARD staff than had been originally envisioned--for example, all of the stove design and development/testing work required large amounts of ARD technical consulting time. In retrospect, the project design should have included a field engineer on the ARD team, which was partially accomplished by sending an ARD engineer, Mr. Jonathan Hodgkin, into the field for the last 10 months of the project. In any project of this size or complexity, it is impossible for the coordinator or team leader to carry out extensive research and development or technical work in the field in addition to the administrative duties associated with this position. There is simply not enough time to do so, and these two roles are best separated.

Another important lesson has to do with the length of both RET projects and pilot projects similar to the BRET effort. Clearly, four years is too short a time frame. The project did accomplish the major outputs specified in the project paper as well as the general objective of identifying attractive technologies, effective dissemination strategies, etc. However, to finalize some of the testing and experimentation activities, a longer time frame is needed. More time is also necessary to allow technologies or the technology transfer process to reach a successful conclusion in the private sector or be institutionalized in public-sector organizations. That is, more than four years is mandatory for the execution of a complete dissemination program.

For a project that requires the establishment of a new organizational unit and skills as well as implementing an iterative technology development process, a period of at least 10 years should be allowed. The technology development and dissemination process is lengthy and complex for each individual technology, and the BRET project called for the investigation of more than 20 RETs. Several attempts were made by the project,

AID and MMRWA to reduce the number of technologies under consideration and sharpen the focus of BRET efforts. Still, external pressures and expectations resulted in a certain amount of tension and necessitated the continuation of work in some areas of low or even dubious priority.

Nevertheless, the BRET project was successful in providing sufficient information for MMRWA to further prioritize and reduce the group of technologies deserving development in the future. The ministry identified four projects in the Sixth National Development Plan. Three of these involve technologies developed during this pilot project, and the fourth is the rural energy supply project that will address the fuelwood issue from a supply perspective.

B. Project Administration and Management

One lesson to be drawn from the early administration of the BRET project is that clear lines of authority, responsibility and roles must be defined as soon as possible. In addition, authority and responsibility must mesh in an appropriate way. In the absence of such clarity, as well as commensurate authority and responsibility, it is difficult to resolve differences in priorities, strategies and approaches. In fact, MMRWA did clarify and modify appropriate duties and roles, but an earlier review of the structure proposed in the project paper and more clearly defined duties would have saved a great deal of time.

The GOB system of warranting project funds was extremely smooth. Funds were available when needed and as requested. Further, land for demonstration buildings, housing for expatriate staff, project vehicles and office space were all available at the beginning of the BRET project. This allowed project staff to focus immediately on project organization, planning and implementation.

The project executive committee (PEC), chaired by the Deputy Permanent Secretary of MMRWA and attended by MMRWA, AID and the Ministry of Finance and Development Planning was an effective tool for project administration. The opportunity for all relevant groups to review plans and activities and discuss requests for expenditures streamlined the approval process considerably and provided continuous monitoring of project progress.

The Botswana Renewable Energy Coordinating Committee was formed during the project design phase. It was an inter-ministerial committee that served as a reference group for the project design team. Such a committee has the potential to expand the resources available to individual members of the design team and the project, prevent the subversion of project

activities and increase the chances for long-term success after the pilot phase. This committee was reactivated in late 1984 to serve as a review and advisory board, comprised of representatives from organizations active in the area of renewable energy and end-use ministries. This second phase of the committee was not well established by the end of the BRET project, but the value of such an advisory group is recognized. The committee failed to get consistent and widespread representation from different ministries--frequently, the only organizations in attendance were BTC, RIP/RIIC, the BRET project and MMRWA. While this did serve as a forum for the exchange of information, it was not broad enough and failed to include the end-use ministries, as intended.

The BRET project was successful in getting the end users of water pumping technologies and building design information together on several occasions. The Botswana Renewable Energy Activities Committee (BREAC) will want to continue to hold meetings with these groups and form others as well. At the same time, it should encourage the member ministries to actively participate in committee activities.

C. Energy Extension Services

While the BRET project relied on its own staff of village facilitators, a more appropriate channel for the dissemination of RETs seems to be groups that have an interest in and responsibility for end-use activities associated with a particular technology. The success of the seminars for extension workers and linkages formed with local government authorities responsible for water supply and buildings indicates that this is a better dissemination channel than project staff at VTFs. Teachers, home economists, adult literacy group leaders and assistant community development workers are well established and interested in disseminating information about RETs.

The VTFs proved to be most helpful as part of the technology development process, not in the area of dissemination. They were also of assistance in the project's survey activities in terms of providing access to villagers as well as facilitating the field testing of domestic RETs and providing vital feedback on technology performance.

D. Technology Development, Assessment and Dissemination Process

As a means of structuring the BRET project's pilot phase for the development and testing of promising technologies, the methodology for an iterative, learning laboratory approach (described in Appendix A) was sound and extremely flexible and responsive. Continuous assessment of the technical,

sociocultural, economic and institutional issues surrounding this innovative process helped plan and develop strategies that were responsive to issues of concern. One of the project's major successes was that it discarded a number of technologies early on, such that technologies that eventually turned out to not be worth pursuing did not take large amounts of project resources--that is, the main portion of BRET resources was expended on the project's successful developments and impacts.

Thus, the technology development, dissemination and assessment process can be seen as successful in two ways:

- it was a successful experimental process, allowing the project to discard plans to do further work on particular technologies at this time; and

- the process operated to direct the major part of project resources toward the most important and successful avenues of technology development.

In summary, the technology development methodology is suggested for continued use with RETs in Botswana. It can be employed equally well with any technology that is being developed for either the general populace or rural areas.

APPENDIX A

Technology Development, Dissemination and Assessment Model Used by the BRET Project

The technology development, dissemination and assessment approach used by the BRET project was the basis of ARD's origi proposal to AID. That proposal outlined the general work plan for the project, including the following efforts and activitie

- redefining, refining and reassessing the BRET project's purpose and outputs, as well as searching for appropriate technologies for Botswana's rural areas;

- collecting necessary data for problem definition, analysis and resolution, not only in terms of technologies, but for awareness campaigns, extension and other project activities;

- selecting technologies based on "needs-driven," rather than "technology-driven," considerations;

- gathering relevant sociocultural, economic, technological, energy and organizational/ institutional data at the village level to understand the energy needs and technological potential in rural Botswana, beginning with energy surveys in pilot villages as the first step in an iterative planning process for choosing and transferring technologies;

- selecting technologies by moving through decision points related to goals, needs, social/cultural patterns and economic analysis;

- making adaptations in technologies used elsewhere, and in Botswana institutions and organizations;

- testing potential RETs in the laboratory, at the project's village training centers and in the field;

- completing additional surveys and similar data collection efforts, as already noted, necessary for the experimental process with various technologies; and

- developing clear objectives and the means for evaluating both project performance and technological innovations, including technical performance, financial and economic costs and

benefits, social and cultural acceptance, institutional appropriateness and transfer or extension strategies.

The BRET project employed and further developed ARD's process for technology development, from the perception of energy-related needs to promoting widespread use of technologies that meet those needs. This process (graphically presented in the figure on the following page) served as the basis for most of the activities undertaken during the project's life and guided the development of each RET. As the figure shows, the process appears to be basically linear, but does allow for feedback at major decision points. In this way, devices were modified, new ideas introduced and decisions made about technology production, dissemination and follow-up.

The Project as a "Learning Laboratory"

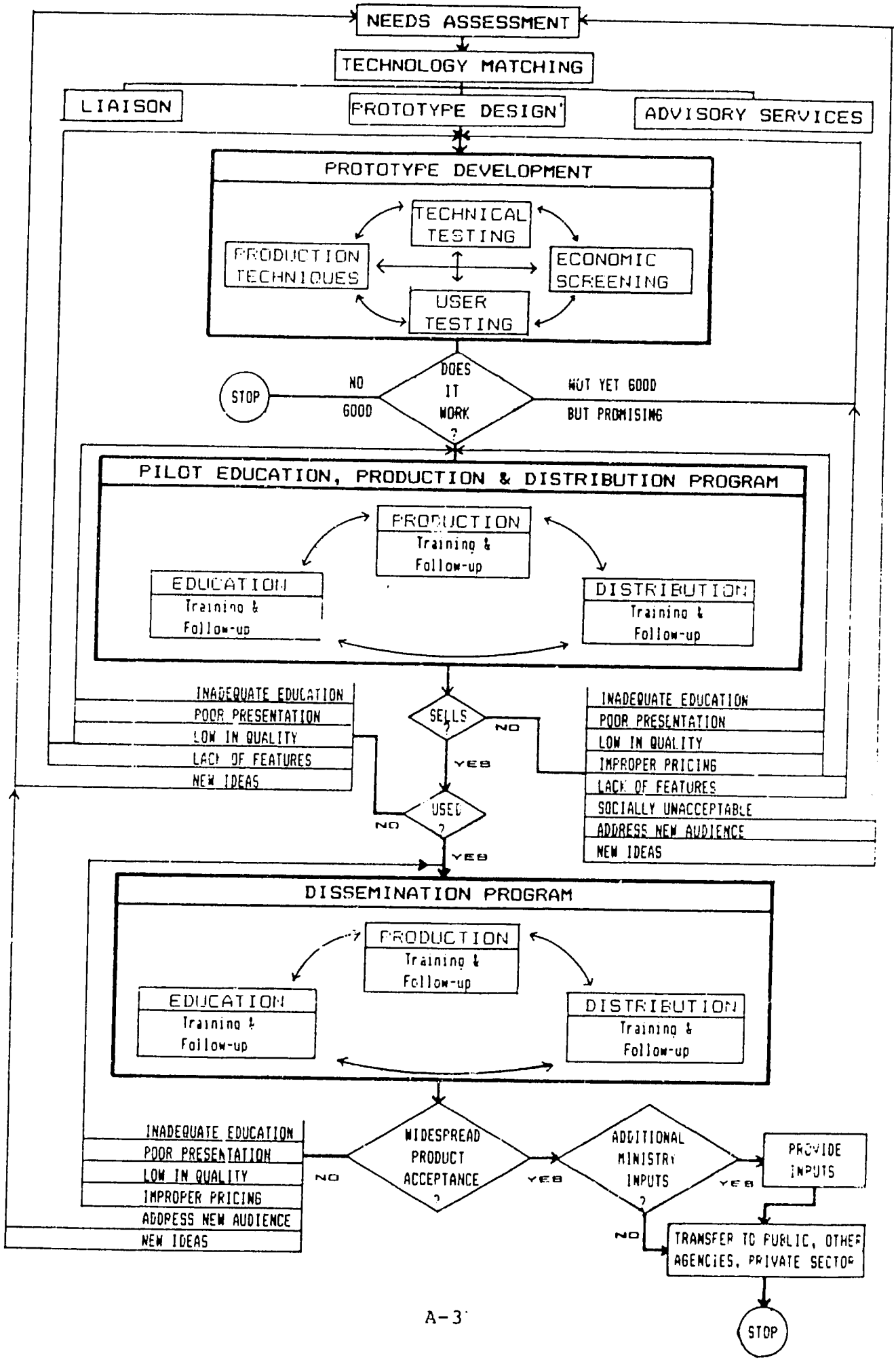
Overall, the BRET project employed a "learning laboratory" approach. Basic to this approach is the fact that efforts were needs-driven, as opposed to technology-driven. The fieldwork and needs assessment conducted as part of the village energy survey at the start of the project provided the initial impetus and foundation for subsequent technical activities. After energy needs in two of Botswana's rural villages had been assessed, technologies were matched to those needs, prototype devices constructed and tested, and finally, if a technology showed promise in meeting an identified need, limited field trials were conducted. Feedback is an integral element of the learning laboratory approach to ensure that any problems that arise during field trials can be addressed in the workshop. During the course of the project, the progress of each RET was plotted on a flow chart, and every device had to go through five major steps before it received public acceptance status. Only after a device had made it through the entire development and testing process was it considered for release to the general public.

General Description of the Technology Development Process

The BRET project was involved in research, development and dissemination of two categories of RETs, which moved through the technology development process in different ways, as is discussed subsequently for particular steps in the process. The two types of technologies were:

- rural domestic RETs, targeted at rural households to conserve fuelwood used for cooking, lighting and heating; and

TECHNOLOGY DEVELOPMENT PROCESS



- institutional RETS, intended for community, district and government agencies for water pumping, small-scale electrification and building projects.

The technology development, dissemination and assessment process consisted of five distinct stages:

- needs and resource assessments,
- technology identification, matching and selection,
- prototype development and testing,
- comprehensive field testing and pilot education, and
- widespread dissemination or transfer to the public domain.

In addition, a specific analytical method was used during the process for technology assessment. It is described in a separate section below.

Community and entrepreneur involvement took many forms during the BRET project and was an essential part of every step in the technology development process. Since ARD was using a recognized community development framework, "community involvement" refers to the project's relationship with all individuals, leaders, organizations, and GOB staff and programs related to the geographic areas or technologies of interest. Community input was solicited through a number of activities, including surveys, discussions, interviews with leaders, conferences and seminars, consultations, and requests for assistance in evaluating particular devices or planned dissemination strategies.

Research and development was an essential aspect of the BRET project, with four different types of activities:

- social research and development into needs assessments, dissemination strategies and institutional capabilities;
- renewable energy resources assessments that involved the installation of monitoring equipment and subsequent data collection and analysis;
- development of new devices, such as the sheet metal stove, simple solar water heater and wind-driven mono pump; and
- field testing of off-the-shelf RETs under Botswana's conditions.

Since the project dealt with both technical and social matters, an interdisciplinary staff was needed to carry out its research and development efforts in both areas.

Five Stages in the Technology Development Process

One -- Needs and Resource Assessments

The first step in the process includes the assessment of the target population's actual or perceived needs. Needs can be identified through a number of sources and activities, such as interviews or surveys of the people or communities involved. Many institutions have relevant information about documented needs, and some have even had experience in attempting to meet those needs. This type of information can be gathered by interviewing staff members or reading reports. Some needs have been documented in reports on past studies and assessments as well as in national development plans. Thus, when developing a particular technology, the starting point for a needs-driven project is a clear picture of the need(s) that can be met by the particular technology under consideration.

The initial stage in technology development also includes an attempt to collect enough reliable data to make a realistic assessment of available amounts of renewable energy resources. In Botswana's case, these resources include biomass, firewood, wind and solar radiation. In some cases, there was only limited existing information on these energy sources, so it was necessary to develop data-gathering programs. Potential resources in terms of organizations, institutions, manpower and skills must also be assessed to aid in the selection of technologies and dissemination strategies. Finally, financial and economic resources must be assessed and considered.

Two -- Technology Identification, Matching and Selection

At this step in the development process, a complex issue is addressed--identifying potential technologies that can use the available resources to meet existing needs. It may be possible to utilize or modify a known RET, or an attempt can be made to develop a totally new device. Since the latter option requires considerable research and development time and resources, the BRET project focused on using or modifying existing technologies. However, its work on the wind-driven mono pump with RIIC approached the development of an entirely new technology. On the other hand, development of a new pedal-powered sorghum de-huller was investigated, but not pursued, because there would have been insufficient time during the project to complete the necessary resource assessment and research.

Three -- Prototype Development and Testing

Following needs identification and the selection of appropriate RETs, a number of potential technology designs are considered and prototype models developed. Actual working units are constructed and tested. Important considerations include both potential energy savings and information from the assessment of existing or potential social, institutional and construction skill resources for eventual production and dissemination of the device.

Actual working prototypes are tested in the research and development lab to determine how well they work, whether they are likely to satisfy identified needs with less work and increased energy efficiency, and the potential economic savings. Once these questions are answered, it is also necessary to consider potential social costs and institutional structures required to implement eventual construction and dissemination of the technology.

In the case of the project's institutional RETs, prototypes were installed in field settings to examine their operation under natural conditions and determine whether the devices could be operated and maintained by local technicians. From these tests, it is possible to estimate the kind of additional training required for operation and maintenance personnel. In the case of the BRET domestic technologies, these devices were constructed and/or used by villagers to assess their performance under fairly normal, daily use by ordinary people, not trained lab technicians. In each case, a thorough testing and data collection procedure was developed and employed.

Four -- Comprehensive Field Testing and Pilot Education

By the time the BRET project reached this step with a particular technology, it had already found that the device was more efficient and afforded potential energy savings in comparison to the technique(s) used previously. Still, some questions remained about the technology's performance under typical field conditions, whether potential savings would be actualized, and the skills and costs involved in maintenance and repair. Before proceeding with nationwide dissemination, any new RET should be operated in the field by many ordinary people and/or technicians in conjunction with careful monitoring. This step helps identify operational problems and training needs, and solidify plans for general dissemination. For the project's institutional technologies, this step was actually part of the data-gathering undertaken to answer the questions just noted.

Villagers and institutional representatives were invited to demonstrations of rural domestic RETs and installations of

institutional technologies to become acquainted with the potential of these devices to meet personal or institutional needs using existing renewable energy resources in Botswana. These working demonstrations proved to be much more informative and convincing than written information, theoretical discussions or even pictures.

Five -- Widespread Dissemination/Transfer to Public Domain

When a technology gets to the final step in the development process, it is ready to become part of the general social, cultural, technical and institutional scene. For rural domestic RETs, dissemination may involve large-scale GOB or government-supported campaigns. In some cases, these efforts will involve only the extension cadres, while in others, the combined efforts of extension personnel, producers and entrepreneurs will be required. The degree of involvement by various parties will depend on whether the technology is intended to be made by the owner or produced commercially. The dissemination of institutional RETs means developing national policies and programs, as well as the purchase and installation of technologies through numerous ministries, departments and district councils. In most cases, no single institution, ministry or department can handle the entire dissemination process, as it requires inter-organizational skills, planning and cooperation. With transfer to the public domain, project activities such as training local artisans to produce BRET stoves or fostering the private manufacture of wind machines and solar water heaters were the preferred strategy.

Technology Assessment

Whenever the BRET project was involved in technology assessment--primarily during stage three of the development process discussed above, but sometimes as part of other steps in the process as well--the model presented in this subsection was employed. All of the reports on individual technologies are organized according to the five areas involved in any substantial technology assessment:

- technical,
- economic/financial,
- social/cultural,
- institutional/infrastructure, and
- energy/environmental.

There are at least three topics involved in a technical analysis:

- the specifications, engineering design and component parts of the device;
- a study of the technology's performance--how much work it can do with what resources; and
- reliability and durability of the equipment, and concomitant needs for maintenance and repair during the technology's life span.

The economic/financial analysis involves a study of a technology's cost and the value of its benefits in comparison to other devices that can be used to accomplish the same task, regardless of whether they use fossil fuel or renewable energy resources. Both financial and economic analyses can be performed, and require reliable, valid financial figures for costs and benefits, including all hidden costs and subsidies, shadow prices and discount rates. In general, there are non-quantifiable factors that figure importantly in the decision-making process, which must be articulated in addition to the quantifiable parameters. Consequently, it is necessary to clearly specify all of the assumptions relating to these analyses. Common approaches, assumptions and types of data collected can be used for any analysis and comparison of technologies that perform a similar task, such as water pumping.

Technology introduction has an impact on existing social/cultural structures. At issue here are identifying these impacts, the sociocultural institutions that are affected, problems attending the introduction of a particular device, social and cultural obstacles to technology transfer, potential changes in social patterns required for technology acceptance, existing or new cultural or social structures that might be useful for introduction of the RET. Again, common assumptions should be articulated and agreed on for comparisons between existing and new technologies.

The institutional/infrastructure analysis concerns organizational resources needed to introduce and maintain the technology. Sometimes, such structures already exist; in other cases, they must be changed; and occasionally, new organizational structures have to be created. Training may be needed and this type of analysis concerns by and for whom, when, where, for how long, etc., as well as what existing or new coordinating and information-sharing groups might need to do. This portion of the assessment model relates to both the informal and formal sectors of the GOB, ministries, departments, districts, para-statal organizations, and private construction and manufacturing firms.

In the energy resource/environmental analysis, it is important to consider Botswana's sunny, hot climate and delicate vegetation base. For instance, increases or decreases in fuelwood consumption could have a substantial environmental impact. This type of analysis is also concerned with how the energy utilized by a particular technology fits into national energy goals and renewable energy objectives, in terms of the energy source used, resources saved and overall effect.

In summary, this technology assessment model can be used for any technology by any organization. Although some groups could complete the entire assessment, it may be more efficient to make it an inter-organizational task, utilizing the competencies of relevant ministries, departments and para-statal agencies to carry out the five types of analyses that make up the total assessment. This sort of inter-organizational approach develops knowledge and potential interest in a technology that crosses disciplinary and organizational lines, which would aid in the eventual dissemination process. If such an approach is taken, the overall technology assessment must be managed by a team that has the necessary interdisciplinary technical, social and organizational skills.

APPENDIX B

Original Log Frame from the Project Paper

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Program or Sector Goal: The broader objective to which this project contributes: GOAL: To improve the economic welfare of the lower to medium income Batswana by increasing their spending and earning power through introduction of renewable energy technologies (RETs) derived from locally available resources which are cheap and abundant; and to minimize dependence on imported petro fuels and to decrease the growing demand for fuelwood through RETs and awareness of conservation needs.	Measures of Goal Achievement: 1. Diminishing rate of increase in lower income Batswana family expenditures due to decrease in increasing family expenditures on petro fuel products for family needs. Expenditures — Expenditures yrs. — yrs. Before RET — After RET diminishing rate of increase 2. Decrease in the increasing volume of petrol fuels imported into Botswana. Quantity Import — Quantity Import yrs. — yrs. Before RET — After RET increasing at decreasing rate 3. Decrease in the increasing amount of time spent on firewood collection by family members.	1. Income data gathered initial Needs Assessment Survey and follow-up income data generated during project internal evaluation of village process. 2. Import/Export data - CSU 3. Family time allocation data collected during initial Needs Assessment Survey and follow-up data generated during project internal evaluation of village process.	1. That RETs will make a visible impact on family expenditures. 2. That RETs are viable substitutes to petro fuel technology. 3. That selected RETs do decrease consumption of wood practised under traditional conditions of Botsı
PROJECT PURPOSE To develop village level awareness for energy use and conservation; to introduce village repewable energy technologies (RETs) which are easily reproduced and cheap; and to research and develop and put into use RETs which are more suitable for institutions and/or entrepreneurs and more geared toward reducing dependence on fossil fuels.	Conditions that will indicate purpose has been achieved: End of project status. 1. Villagers in eight pilot sites aware of decreasing supply of fuelwood around villages and able to relate this factor to inefficient use of fuelwood and aware of other energy sources such as sun and wind for family and entrepreneurial uses. 2. Installment of village level RETs at private individual or village group expense at eight pilot sites.	1. Interviews with villagers during project internal evaluation of village process. 2. Number of village RETs installed in pilot areas. 3. Number of institutional RETs installed in pilot districts.	Assumptions for achieving purpose: 1. That Batswana are not aware of problems related to energy issues affecting their day to day lives. 2. That RETs are socially and economically feasible to different areas of Botswana. 3. That selected RETs do decrease consumption of petro fuels.

3. Installment of institutional and entrepreneurial RETs at entreprenurial or institutional expense in three pilot districts.

OUTPUTS

1. Energy Needs Assessment Date Collection

2. Village Awareness Campaign

3. Village RET and Institutional RET training.

4. Two model solar passive cooled and heated buildings built.

5. Development and Research on Institutional RETs.

6. Installment of village domestic technologies.

7. Installment of small scale wind/water systems.

8. Batswana capacity to manage and implement ongoing extension, training and research after the RET project.

9. National Energy Assessment Study.

Magnitude of Outputs:

1. Date Collection on Energy Use in Botswana in three districts.

2. Village Awareness Campaign in eight pilot sites and eight kgotla museums of village RET demonstrations built.

3. Training

a. One hundred pumper/mechanics trained in wind/hand water pumps.

b. Two hundred government extension workers and villagers and fifty entrepreneurs trained in village domestic technologies.

c. Ten entregreneurs trained in institution solar water heater production.

d. Twelve maintenance trainees in photovoltaic water pumps.

e. Fifty GOB personnel and villagers trained in fuel woodlot management.

f. Twenty-four MRWA and MOH workers trained in electrical generation at health centers and cold chain operation at health posts.

g. Sixteen entrepreneurs trained in pedal powered sorghum dehuller maintenance and four in pedal powered sorghum dehuller production.

4. Construction

Design for house and BTC building complete by Jan. 81 and construction finished by Jan. 82 respectively.

5. Institutional RET R&D

a. Portable wood stove prototypes designed and ten entrepreneurs producing them.

b. One hundred institutional solar water heaters will be installed by GOB or district groups.

1. Village Needs Assessment Survey Date and Analysis.

2. Village Awareness Campaign Notes and Work plan.

3. Training

a. RIIC records

b. VTF records

c. Training materials and equipment purchased

4. AID records

5. BTC/RET records

6. BTC/RET records

7. AID and BTC/RET records

1. No data on village energy use in Botswana.

2. That Batswana are not aware of problems related to energy issues affecting their day to day lives.

3. That there is no trained personnel in RETs in most areas of Botswana.

4. Solar passive heated and cooled buildings are the wave of the future in Botswana in that they are more economic and feasible in the long run.

5. That there is research capacity in Botswana to carry out R&D on RETs.

6. That village RETs are acceptable to villagers.

7. That small scale wind/water systems are feasible for village water supply.

8. That Batswana need to be trained in RET management and administration.

c. Two photovoltaic water pumps will be installed by the RET project.

d. Two integrated water pumping systems will be installed by the RET project at village water supplies.

e. Eight pedal-powered sorghum dehuller grinders will be installed by village entreprneurs and cooperatives.

f. Six health posts will be upgraded with RET cold chain and three health clinics will be energized by a photovoltaic system.

g. Two pilot fuel woodlot sites will be funded under the Rural Sector Grant, which will be used as demonstration sites for fuel woodlot management program.

6. One thousand village technologies will be installed by villagers and enpreneurs.

7. Eight small wind/hand pump systems will be installed by local farmer and development groups in eight small villages or lands areas.

8. Six counterparts will be trained and four facilitators to implement the project after the USAID project ends.

9. A National Energy Assessment Study will be carried out using five months of short-term consultants.

INPUTS	$ 000s	INPUTS
1. Village Needs Assessment Survey	89.0	VERIFIABLE INDICATORS 1. Village Needs Assessment Survey - Designed by sociologist, RET specialist and short-term consultants - Supervised by sociologist/ extension person and peace corp coordinator - Implemented by RET facilitators - Analysized by extension support and training unit with short-term consultants.
2. Village Awareness Campaign		
3. Training	311.6	
a. Short-term U.S. training (40 person months)		
b. RIIC (1) Contact GOB for government trainees (2) Contact parastatals and NGOs for production and maintenance		

trainees

(3) Train technical RET project trainers

c. VTF

(1) Contact kgotla for village trainees

(2) Contact village group organizations for village trainees

4.	Training Materials and Equipment	834.0
	a. Long-term technical assistance - 6 person mos.	
	b. Short-term technical assistance - 25 person mos.	
5.	Research and Development on RETs	784.2
6.	Construction	266.0
7.	Others	1019.3
	TOTAL	$3304.1

2. Village Awareness Campaign

- Designed by sociologist, RET specialist/trainer, short-term consultants and non-formal education unit, MOE
- Supervised by sociologist/ extension person and peace corp coordinator
- Implemented by RET facilitators with support of headquarters staff

3. Training

a. RIIC - short courses in institutional RET production and maintenance in technical detail and some village domestic technology training for facilitators and entrepreneurs approximately 25 courses during three years for two weeks.

b. VTF - one to two weeks awareness/ construction courses in village domestic technologies approximately eight courses within three VTFs.

c. Training Materials and Equipment

1. Purchase of training vehicle by GOB

2. Purchase of audio visual/ media training equipment

3. Compiling training material by training unit with non-formal education and short-term consultants.

4. Technical Assistance

a. Two long-term technicians (six person years)
- Renewable Energy Specialist
- Sociologist/Extension Specialist

b. Twenty-five person months of short-term consultancies. Five months will be used to carry out a National Energy Assessment Study.

5. Research and Development on RETs (commodities plus shipping and installing)

   a. wind/hand/advanced pumping system

   b. photovoltaic pumping system

   c. RET health center equipment

   d. Woodlot Management

   e. Pedal-power sorghum dehuller

   f. Exhanol Fuel Feasibility

6. Construction

   Some design and construction of buildings at five sites:

   a. RIIC - four structures

   b. BTC - 1/3 of building

   c. VTF - One structure at each of the three sites

7. Others

   Costs are project local hire staff and support, office equipment, rent, inflation and contingencies.

APPENDIX C

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APPENDIX D

BRET Personnel Roster

Project Coordinators

F. O. Motlhatlhedi, MMRWA	
Richard J. Stanley, ARD	October 1, 1981-August 30, 1982
Carl P. Zietlow, ARD	January 14, 1983-September 26, 1985

Extension Section

Judith A. Oki, ARD Extension Support Supervisor
Mbulawa Mugabe, Extension Coordinator
Charmaine Peacock, Training Coordinator
Walter M. Dube, Metal Stove Promoter
Moemedi Moswete, Gaborone Facilitator
Kehakgametse Bathobasele, Ditshegwane Facilitator
Baikanne Mphyoyakgosi, Shoshong Facilitator
Koofete Tebele, Shoshong Facilitator

Technical Section

Gabaipone Mmasekgoa Masire, Technical Coordinator
Jonathan Hodgkin, ARD Engineer
John T. Shields, Field Supervisor
Modise Motshoge, Wind/Water Technician
James Sentle, Solar/Stove Technician
Baintlafatsi Leteemane, Village Technologist
Toko Kgaswane, Borehole Mechanic

Administration

Ross Tebele, Administrative Coordinator
Sylvia Lekaunyane, Bookkeeper/Stores Controller
Selinah Tokwe, Typist
Michael Mothibi, Driver/Messenger
Dineo Moeketsi, Janitor

U. S. Peace Corps Volunteers

Stewart Bentley, Village Solar/RET Evaluator
Nancy McGrath, Curriculum/Trainer
Lori Merriam, Graphics/Media
Bruce Pierson, Village Technician
Theresa Powers, Village Technologist