AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

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1. SUBJECT CLASSIFICATION

A. PRIMARY: Science and technology — TC00-0000-G352

B. SECONDARY: Applications--Central America

2. TITLE AND SUBTITLE

Alternative energy systems; final report and preliminary report (on the) solar data collection system--solar data acquisition

3. AUTHOR(S)

(101) Solar America, Inc., Albuquerque, N.M.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1979	105p.	ARC 621.47.S684

7. REFERENCE ORGANIZATION NAME AND ADDRESS

SAI

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

(In cooperation with ICAITI and CATIE)

9. ABSTRACT

10. CONTROL NUMBER

PN-AAG-750

11. PRICE OF DOCUMENT

12. DESCRIPTORS

Solar energy
Biomass
Energy
Solar radiation
Data collection
Pyrolysis
Biogas
Wood
Renewable resources
Solar stills
Central America

13. PROJECT NUMBER

14. CONTRACT NUMBER

AID/LAC-C-1339

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

621.47
S684

PN-AAG-955

solar america, inc
SOLAR ENGINEERING AND MANUFACTURING

Re: AID/LAC-C-1339
August 15, 1979

Mr. Harry Ackerman
Director
Regional Office for
Central American Programs
c/o American Embassy
Guatemala City, Guatemala

Dear Mr. Ackerman:

Attached please find our final report on alternative energy sources and our preliminary report on the solar data collection system design as required under contract No. AID/LAC-C-133.9.

This report contains all items as required under the scope of work.

Thank you very much for the many hours you and your staff labored with us in the development of the project paper, of which, only a small part is reflected in our report.

Good luck on this exciting project.

Sincerely yours,

David E. Chavez

Enclosure: as stated.

2620 San Mateo N.E. • Albuquerque, N.M. 87110 (505) 883-0959

SOLAR ENGINEERING AND MANUFACTURING

solar america, inc

F I N A L R E P O R T

ALTERNATIVE ENERGY SYSTEMS

&

P R E L I M I N A R Y R E P O R T

SOLAR DATA COLLECTION SYSTEM
(SOLAR DATA ACQUISITION)

CONTRACT No. A.I.D./L.A.C.-C-1339

2620 San Mateo N.E. • Albuquerque, N.M. 87110 (505) 883-0959

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I. PROJECT SUMMARY

A. Background

Deforestation in Central America appears to be proceeding very rapidly, mainly because of the demand and consumption of fuelwood at both the domestic and industrial levels. ROCAP, the AID Regional Mission for Central America, has proposed a three-pronged assistance program that would do the following:

a) Explore fast-growing tree and shrub varieties that would serve as fuelwood substitutes, and

b) Develop a program which would effectively increase fuelwood efficiency, and

c) Investigate alternative energy sources for fuelwood for both domestic and small industry application.

This project is being designed in cooperation with ICAITI, the Central American Institute for Industrial Technical Research, and CATIE, the Tropical Agriculture Center for Research and Teaching.

B. Solar America, Inc. - Scope of Work

Solar America, Inc. (SAI) worked with ICAITI and counterpart institutions in the six isthmian countries which included Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama, for the purpose of investigating alternative energy sources for fuelwood at both the domestic and small industry levels.

SAI assisted ROCAP in project design for development of the Project Paper, and identified alternative energy sources presently available in Central America, and which would be substituted for domestic and small industry fuelwood uses. SAI identified specific alternative energy technologies and recommended they be field tested under the project, developed the selection criteria for same, determined potential field tests sites, conducted preliminary appraisal relative to economics and feasibility, investigated possible commercial applications and the existence of Central American manufacturing capability. SAI designed an estimated budget for conducting

field tests of the technologies which are to be used in the financial plan of the Project Papers.

A large part of SAI responsibility was the establishment of a Central American Solar Data Collection System. SAI is conducting a survey of all available sources of data on solar radiation regimes in the Central American countries, in the U.S., and in international agencies, and to determine reliability and adequacy of present data coverage. An evaluation is to be made of all related institutions and personnel for the purpose of analyzing existing information networks. Identification will be made of types of solar radiation data consistent with other features of project design, with collection by geographical location. A cost-effective data collection system will be designed to bridge any information gaps and will include recommended hardware, work plan, and cooperating institution responsibilities.

SAI is responsible for submitting required reports as follows:

a) A final report on tasks relating to project design for alternative energy sources to fuelwood substitution, no later than August 15, 1979;

b) A Preliminary Report (draft) on tasks relating to the design of a solar data collection system, no later than August 15, 1979; and

c) A Final Report on the design of the solar data collection system, no later than October 10, 1979

C. Developmental Activities

On July 15, 1979 the first four-member team from Solar America, Inc. (SAI) traveled to Guatemala City, Central America for the purpose of meeting with the involved participants from the ROCAP and ICAITI institutions. This team consisted of both technical and program management members.

Preliminary meetings were held with both ROCAP and ICAITI, individually and collectively, to consider the terms of the contract and to discuss the scope of work and activity, to the mutual understanding of all parties involved in the program planning. Both ROCAP and ICAITI apprised the SAI team of the deforestation problem in Central America,by country

and by region, supported with available surveys and report documents. Fuelwood consumption and utilization practices were presented to thoroughly acquaint the team members with the various economic, ecological, and sociological implications of the present status. All Central America literature concerning deforestation and fuelwood practices was made accessible to the team for consideration and evaluation.

Concurrent with the preliminary meetings in Guatemala, SAI staff members at the Albuquerque, New Mexico home office were performing technical and other support services while in daily telephone communication with the SAI team in Guatemala. These services consisted of technology application, personnel allocation, management requirements, finance, project feasibility study, and research related to the program.

One of the tasks carried out by the SAI home office was a complete literature search in the U.S. Through the NASA Technology Application Center (TAC) Regional Office in Albuquerque, this team carried out a computer based search of all published literature related to the numerous technologies identified for consideration in the program. The computer print-outs returned approximately 1,000 listings of publications on biogas, biomass, solar energy, pyrolytic energy, hydro energy, wind energy, and similar appropriate technologies. The print-outs were the bibliography of reference materials from which SAI drew information on research and development dealing with various technologies considered during the course of the contract project.

The week of July 16-21, 1979 was taken up with daily ROCAP/ICAITI/SAI meetings as conference groups, and on individual basis. In addition, ROCAP and ICAITI representatives accompanied SAI technical members on two field study trips; (1) the lowlands field study tour, and (2) the highlands field study tour.

The lowlands tour consisted of a round-trip of around 200 miles, to the plantation region near the Pacific Coast. An operating commercial biogas plant was visited where Ing. Mario Penagos demonstrated the utilization of biomass substances for generating methane gas and by-product fertilizer. CEMAT, a Central America research institution, had had previous involvement in this technology. Ing. Penagos demonstrated the use of biogas as a fuel for operating a small pickup motor.

A coffee plantation operation was reviewed, and a visit was made to a typical panela plant, both of which consume fuelwood and produce biomass wastes. The utilization of these wastes, and the energy efficiencies of the operations, were observed on-site in settings which were typical of all the region. The lowlands tour concluded with on-site visits to typical lime, brick, and tile kilns where firtshand examination dramatically illustrated the fuelwood consumption technique in large firewood kiln operations.

The highlands field tour was to the Quezaltenango region, the second-most center of population in Guatemala. Large scale deforested areas were under agricultural cultivation. Corn, other grains, field crops, and cattle grazing pastures were observed covering countryside and mountains which previously had been conifer and other tree forests. The agricultural activities seemed to have no limit. Cropping was seen to extend up the side of steep mountains of around 45°angles with respect to level surface. Some dozen, or so, native Indian communities were transited on this tour. Charcoal manufacture and consumption, wood cutting and hauling (domestic), wood vending, and general domestic fuelwood use was observed on-site in these settings. The Choqui Experimental Research Station was visited north of Quezaltenango where the supervisor gave an informative presentation on appropriate technology application in practice in that region. At this site the demonstrations included the Lorena stove and modified models, the savonius wind generator, solar hot water collection, solar food dryers, and domestic biogas generation, all of which were on-line and operational.

The two field study tours were of great assistance in graphically illustrating the seriousness of the deforestation problem, and its relationship to the domestic family and small industry fuelwood consumers. The on-site investigations gave valuable insite into typical fuelwood use, around which the contract activities center, and for which the project demonstrations and activities were designed and implemented.

D. Project Design Summary

The combined interactivity of ROCAP, ICAITI, and SAI in the preliminary investigations led to defining the parameters of the project and, subsequently, to the project design. The management program, technology identification, and the

implementation plan were adjusted and modified daily, as the project was brought in focus. All the possible technological applications were considered and discussed, but only those felt to be appropriate and applicable were further considered for incorporation into the project plan. It was at this point that the manpower allocation, equipment and materials, and project overhead were introduced so that a financial management plan could be derived.

A solar data collection/analysis system was planned as a part of the project. Because of the time element, only very brief field investigation was carried out. Detailed on-site visitations are planned for each of the countries for the purpose of determining what historic data is available, the species of meteorological instruments in use, and the overall reliability. Of major interest will be that data pertaining to solar radiation, for it may have some direct bearing on design criteria for many of the actual demonstrations.

SAI staff members in New Mexico have been contacting universities and research institutions in the U.S., and elsewhere, who are actively involved in solar, wind hydro, pyrolytic, and combustion technologies. The potential role of these institutions is in future training programs, program development, and on-going technological activities within the project.

E. Evaluation of the Fuelwood Conserving Alternative Energy Technologies

1. Introduction

In attempting to evaluate the broad spectrum of alternative energy technologies that are applicable to the goals of this project one must first decide what the target groups are for this technology.

Some estimates are available to account for the total fuelwood consumption in Central America and what percentage is used by the various sectors of the economy. Our studies indicate a general agreement that the four groups identified below are the primary consumers of firewood as an energy source.

- Low income urban households
- Low income rural households
- Small urban industries that consume fuelwood
- Small rural industries that consume fuelwood

This is not to say that the energy needs of these sectors of the economy are the only cause of deforestation in Central America; other causes, like clearing the land for agricultural uses, are contributing factors whose significance has not been definitively evaluated.

These target groups, of course, have the option of converting to fossil fuel for their energy needs, but there are many forces that eliminate this option. The major one is cost; the micro-economies of these households and industries are such that additional expense for fossil fuel and new fuel burning equipment would be devastating. Add to this the fact that none of the Central American nations are oil exporting countries, meaning that further imports would adversely affect their foreign exchange, and it is clear that the use of alternative sources of energy is an attractive option.

It should be noted here that the bias of this analysis is towards the so-called "Appropriate Technologies" and

against what are called the "High Tech" alternative energy technologies. Some of the characteristics of appropriate technology are that it is cheap, labor intensive, non-exploitive of depletable resources, compatible with local culture and functional in a non-centralist context. These attributes of appropriate technology make it particularly applicable to these target groups primarily, because its dependence on local resources and labor intensive systems put it within the economic grasp of low-income households and industries.

2. Criteria for Technology Evaluation

The questions that must be favorably answered before a specific technology may be recommended are the following:

- Is the resource available in sufficient quantities to make its usage attractive in the target area?

  The implications of this question vary greatly from one alternative technology to the next. An example is solar energy which can be distributed in fairly equal amounts throughout any given climatic zone. In comparison to this is wind and biomass energy, whose availability is very site specific. In the case of biomass, the local availability of the resource is of great significance, often making the difference between a demonstration that is a net energy gainer and one that is not.

- Is the system that uses this resource technologically feasible in Central American application?

  Here one would want to know if the required equipment is presently being manufactured, whether the raw materials that make up the device can be found in Central America, and if, over the entire life cycle of the mechanism, the process is a net energy gainer.

- Is the particular technology affordable to the target group?

  This is probably most difficult to answer in that questions of government subsidy and incentive, the availability of lending capital, and personal spending habits must be addressed. Further complications arise in trying to predict life-cycle costs for technologies for which little historical cost data is available. An attempt will be made to answer this question in general terms.

- Is the technology socially acceptable amongst the target group?

  This again is a very difficult question to answer and is made more difficult by the relative scarcity of historical evidence. This question will be briefly addressed in this report, although a conclusive answer will not be given.

- What are the environmental impacts of the particular technology?

  It is beyond the scope of this report to give definite evaluations of the environmental effects of each of the technologies. It should be noted, however, that all the systems suggested are relatively benign, environmentally speaking, and serious adverse impacts are not anticipated for any of them unless otherwise noted.

- Can the proposed demonstration project be easily repeated by the individual members of the target group?

  Here one would want to know how easily the technical information may be disseminated and whether the degree of technical sophistication required to operate such a device is simple enough for the target group.

3. Technology Evaluation

The format used in this evaluation is as follows:

First, the energy resource is identified and evaluated as to its availability in Central America.

Second, the technologies needed to exploit this resource are evaluated with respect to the six criteria enumerated above.

a. Biomass

1) Source Evaluation

Due to the plentiful solar and rainfall resources of the Central American Isthmus biomass is one of the greatest energy sources available to the people of the region. Indeed, the native population instinctively recognizes,this and the inefficient and unplanned use of this resource has lead to its recent depletion. Therefore, our task here is to identify ways to make the conversion of biomass to energy more efficient.

2) Technology Evaluation

a) Direct Combustion of Biomass

Here one would use the presently under-utilized vegetable biomass resources such as the agricultural wastes of coffee, rice, and panela production, commercial wastes such as sawdust and food market refuse, and the presently unharvested biomass sources such as weeds and whatever forestry slash is presently not harvested.

These wastes would be pulverized,if necessary, for ease in handling and combustion, dried, and sold to the members of the target groups. In the commercial applications a blower and hopper arrangement could be utilized,and for household use a number of proven stove designs are available.

These two technologies are recommended because they have proven to be uncomplicated, inexpensive

and effective in applications around the world. They should pose few major problems in social acceptance, because they are not a radical change from the fuelwood combustors presently used.

b) Anaerobic Digestion of Organic Waste

In this process waste from farm animals, agricultural wastes, and possibly human wastes are gathered and fed to the digestor vessel. The yield is methane, similar to natural gas, and fertilizer which is richer than the raw manure. The biogas produced may then be piped or hauled to the end use site and burned in any device that can burn natural gas.

This process has proven very feasible in literally tens of thousands of applications around the world. In fact, Mr. Mario Penagos, a world renowned expert in biogas, has been building successful digestors of all sizes in Guatemala for over 20 years.

Anaerobic digestion requires a moderate initial investment and some technical sophistication to operate the device. In spite of this, Ing. Penagos' success has convinced us that demonstration should be undertaken on both the household and small industrial level.

c) Charcoal Production and Pyrolysis

Charcoal kilns and pyrolysis units both burn wood in an oxygen starved atmosphere, preventing the combustion from going to completion. The end product in charcoal kilns is only charcoal while, in the pyrolytic converters, charcoal is produced along with flammable gases and liquids. Both processes are actually net loosers of energy whose advantage lay in the more usable products that they yield.

Portable charcoal kilns are recommended for demonstration largely because they are an improvement in efficiency over the present "pit kiln" method. They are of moderate expense and of a low level of technical sophistication in operating procedure. Social acceptability should not be a great problem because they are nothing more than a modification to the current charcoal producing process.

Pyrolysis units entail a rather large initial expense,and a fair degree of technical sophistication,in their operation. Technically,the process is well proven, most notably in Europe during the Second World War. There are some environmental problems stemming from the toxicity of the liquid fuel produced,but this has been dealt with in the past and is solvable.

Recognizing all these problems we still recommend a demonstration of these units on the basis of their tremendous improvements in efficiency. We do, however, feel that the only level on which these problems can be successfully solved is on the small industrial level.

d) Production of Gaseous and Liquid Fuels from Agricultural Products

There are numerous chemical methods for producing ethanol, methanol, hydrogen, and synthetic fuel oil from agricultural products,as well as from any cellulose-rich biomass waste.

These technologies are virtually unknown in Central America as an energy source and, with the exception of ethanol production from farm products, their feasibility is largely unproven. The production of ethanol from starch-rich agricultural products is probably one of the world's most common technologies on levels ranging from backyard beer production to commercial distilleries. It is also, as are all biomass processing schemes, an energy looser whose value lies in the fact that it produces a high quality transportation fuel. In addition, the process has the liability of consuming crops or land that could provide food for human consumption.

Finally, there are on-going activities in Central America to develop alcohol fuel,so that demonstration is not recommended.

e) Aquaculture

Numerous schemes have been proposed for producing algae in ponds and then converting the algae to some usable form of fuel. Our investigations have revealed no successful applications of these proposals, and thus we feel demonstration would be inappropriate.

b. Solar Energy

1) Source Evaluation

Although Central America, as a region, is not a world leader in solar energy potential, our preliminary evaluation of the solar radiation data available shows that the trend is toward a respectable area average of 400 gram calories/square centimeter/day. As is typical in the tropics, many areas are characterized by annual dry and rainy season cycles with diurnal cycles in the rainy season of morning sun followed by afternoon rain. On this basis, we feel it is safe to recommend direct use of solar energy as a viable alternative to fuelwood consumption.

2) Technology Evaluation

a) Solar Dryers

Solar dryers can be anything from the simple elegance of clear plastic sheets draped over well-stacked firewood to a large array of air heating flat plate collectors. The technology involved has been successfully demonstrated around the world with a fair share of demonstrations currently going on in Central America.

Extensive demonstration of solar drying technologies is recommended to replace fuelwood use in certain agricultural processes such as grain drying; to lessen fuelwood consumption in industrial processes, such as brick production, by providing energy for pre-heating, and by making the biomass combustion process more efficient by thorough drying of the material.

It is clear that with a technology as diverse as this, the managing agency should find little difficulty in tailoring the demonstration to the economic status and technical sophistication of the target group. Demonstrations around the world have generally encountered little resistance to their development for social reasons, and little is anticipated in Central America. On this basis we recommend the demonstration of solar dryers.

b) Solar Water Heaters

Solar water heaters are mature

technology with 75 years of manufacturing history and literally millions of installations worldwide. They are similar to solar dryers in the diversity of types available. Their fuel conserving use in Central America is recommended for the small marketplaces and restaurants of Central America where wood is presently used to heat water. They could also be demonstrated in rural clinics and other structures where hot tap water is required.

Because the principle upon which they operate is so elementary, little technical prowess is needed to operate them. They can easily be designed so that they are of low to moderate cost; a price that could easily be borne by the institutions cited above. Again, little problem with social acceptability is foreseen. This technology is recommended for demonstration.

c) Solar Stills

Similar to the solar technologies already discussed, solar stills are a well known technology of which there are many working designs and successful installations. Usually the still is composed of a shallow reservoir covered with a transparent material. This material not only prevents heat loss but also acts as a condensing surface for the vaporized liquid. The materials required are of small expense,and the complexity in operating such an installation is slight. This technology is recommended for demonstration in the sea salt and panela industries.

There have been some problems encountered in the social acceptance of salt produced from open air evaporators in Central America. It is our feeling that emphasizing the difference between evaporators and solar stills will help counteract this objection.

d) Solar Furnaces for Pottery Production

Unlike the preceeding technologies, solar furnaces for firing pottery have not seen wide spread application, and as far as has been determined, they have not been demonstrated in Central America at all. While the technology is reported to work well, its economic feasibility

has not been conclusively proven. As presently envisioned, the cost should be low to moderate and the technical complexity low. Little information is available as to the social acceptability of the process or its product. A single demonstration is recommended for this relatively unproven technology so that better judgment may be made as to applicability in Central America.

e) Photovoltaic Cells

This invention, which has the unique ability to produce electricity directly from sunlight, has yet to prove to be a cost-effective energy producer in the industrialized nations. In addition, it has virtually no possible application as a fuelwood conserving technology in Central America and has thus been rejected.

f) Solar Space Heating

Although all of Central America lies within 15° of the equator there is need for space heating in some areas during the cooler parts of the year. This requirement is small with respect to overall energy consumption and the energy to fulfill this requirement is often the by-product heat of the cooking stove.

Passive solar space heating (systems that require no fans or pumps) such as attached greenhouses, trombe walls and buildings with large amounts of glass oriented towards the sun have begun to prove cost effective in the United States. The active systems, those employing solar collectors and various types of pumps, have not gained the widespread acceptance that the passive systems have due, largely, to their greater initial cost. In both cases heating one's home with solar energy requires some considerable expense.

In view of the size of the demand and the expense involved, solar space heating is not recommended for demonstration.

c. Wind Energy

1) Source Evaluation

At the present time, the amount of wind

energy available to the people of Central America has not been conclusively determined. While there are a fair number of wind speed recording instruments deployed around the region, our investigations turned up no accurate maps showing wind energy intensity. The raw data that has been examined shows a trend towards low average wind speeds at the reporting stations sites; however, it must be pointed out that wind energy intensity is an extremely site specific property so that this trend does not rule its use. Mountain and coastal regions are reknowned for numerous isolated high-wind potential sites. Central America, possessing both of these geographical features, may well have numerous high potential sites. Prospecting for these sites is a costly and time consuming business and one in which accuracy is vital. Therefore, any serious attempt at transferring this technology must first be preceded by this type of study.

2) Technology Evaluation

Almost all wind energy conversion systems produce shaft horsepower as their output. There have been proposals for transforming the wind energy to electricity by other means but to date they remain unproven. This shaft output has little potential for replacing fuelwood consumption but could be used to replace fossil fuel consumption in the production of electricity.

The equipment required to produce electricity from the wind generally costs from $1500 to $2500 per installed kilowatt of capacity. Producing these machines is a complex manufacturing process and their life time is frequently shortened by catastrophic failure.

Operation of wind generators is not a technically sophisticated job, although routine overhauls most certainly are. To the best of our knowledge the feasibility of wind generators is unproven in actual demonstration in Central America.

Because of the high cost and unproven resource availability, and because the end product of wind generators is more readily available from another renewable resources (this will be seen in the following section),

wind energy conversion systems are not recommended for demonstration.

d. Hydro Energy

1) Source Evaluation

Due to its extremely large amounts of annual rainfall and mountainous topography, hydro power is one of the greatest resources of the Central American Isthmus.

2) Technology Evaluation

From the outset it should be stated that all hydro power projects other than the "mini-hydro" systems are beyond the scope of this paper. The technology and site selection for these larger projects have been farily well studied in Central America and are the responsibility of the local government organizations.

The technology for capturing the energy at the numerous "mini-hydro" sites is well proven in Central America. The Costa Rican Institute of Technology has manufacturing and extensive testing facilities as a consequence of that country's long term commitment to exploiting this resource. The success of their program to date should answer most questions as to the feasibility, cost effectiveness and social acceptability of this technology in Central America.

Negative environmental impacts have often been associated with hydropower development mainly stemming from the dams the large installations require. To counteract this problem we would recommend following the Costa Rican practice which, in the interest of economy, employs no dams.

Due to the high degree of development in Central America we do not recommend that demonstrations be done at this time. In our estimation the next logical step is a thorough cataloging and evaluation of the "mini-hydro" sites in Central America coupled with a detailed analysis of the technologies to exploit them.

e. Geothermal Energy

1) Source Evaluation

A number of studies have been conducted on the seemingly immense geothermal potential of the Central American Isthmus. These studies have been principally focussed on Nicaragua although it is felt that El Salvador and Guatemala, and to a lesser extent the rest of the region, have potential as well.

2) Technology Evaluation

Capturing geothermal energy for the production of electricity and heat is a fairly well proven technology. It unfortunately can be rather expensive for two reasons: first,the corrosiveness of the brines extracted, and second,the risk and expense in drilling. If one adds to this the fact that geothermal energy is already under investigation by a number of public and private organizations in Central America,and the fact that it has little potential for replacing fuelwood, the conclusion that it not be demonstrated is easily arrived at.

Summary

The recommendations of this evaluation for alternative energy technologies to replace fuelwood consumption are summarized in Figure 1. A more detailed description of those technologies recommended for demonstration and/or further study follow in the subsequent sections of this report.

FIGURE 1: SUMMARY OF TECHNOLOGY RECOMMENDATIONS

Source and Technology	Resource Availability (high, medium, low)	Technical feasibility (well proven, slightly proven, unproven	Cost (high, medium, low)	Social Acceptability (proven, probable, unknown)	Negative Environmental Impacts (high, medium, low)	Appropriate Level of Technical Sophistication (Appropriate, Inappropriate)	Recommendation (Demonstrate, Study, Do not demonstrate)
A. Biomass							
1. Direct Combustion	High	Well proven	Low	Probable	Low	Appropriate	Demonstrate
2. Anerobic Digestion	High	Well proven	Medium to low	Proven	Low	Appropriate	Demonstrate
3. Charcoal Kilns	High	Well proven	Medium to low	Proven	Low	Appropriate	Demonstrate
4. Pyrolysis Units	High	Slightly proven	Medium to high	Probable	Medium to high	Appropriate	Demonstrate
5. Alcohol & other fuels	Medium to low	Slightly proven	High	Probable	Medium	Inappropriate	Do not demonstrate
6. Aquaculture	?	Unproven	?	Unknown	?	?	Do not demonstrate
B. Solar							
1. Solar Dryers	Medium to high	Well proven	Low	Probable	Low	Appropriate	Demonstrate
2. Solar Water Heaters	Medium to high	Well proven	Medium to low	Probable	Low	Appropriate	Demonstrate
3. Solar Stills	Medium to high	Well proven	Low	Probable	Low	Appropriate	Demonstrate
4. Solar Furnaces	Medium to high	Slightly proven	Medium	Unknown	Low	Appropriate	Demonstrate
5. Photovoltaic cells	Medium to high	Proven	High	Unknown	Low	Inappropriate	Do not demonstrate
6. Solar space heating	Medium to high	Proven	Medium to high	Unknown	Low	Appropriate	Do not demonstrate
C. Wind Energy (All Technologies)	?	Proven	Medium to high	Unknown	Low	Appropriate	Do not demonstrate
D. Mini-Hydro (All technologies)	High	Proven	Medium	Proven	Low	Appropriate	Study
E. Geothermal (all technologies	High	Slightly proven	High	Unknown	Medium to high	Inappropriate	Do not demonstrate

II. TECHNICAL AND ECONOMIC ANALYSIS OF RECOMMENDED TECHNOLOGIES

Introduction

Contained in this section are the detailed technical descriptions of the technologies recommended for demonstration, and a brief sketch of the economic parameters of these technologies. A short discussion of the level of technical sophistication and likelihood of acceptance among the target group is also presented.

A. BIOMASS ENERGY

1. Direct Combustion of Biomass

Numerous waste materials of organic origin exist throughout Central America. Some, such as rice hulls, corn-stalks, and coffee husks, are by-products of agricultural activities, while others, including sawdust, timber slash, and wood wastes are forest by-products from timber type operations. This variety of material wastes is broadly defined as "biomass".

Biomass wastes are sometimes burned for heat energy applications, both domestically and commercially. At other times they go to waste, rotting in the field. In any case, the burning process is not one of optimum efficiency due to the method of operation.

Aggregate size and consistency are important considerations in determining fuel-to-air ratios for incineration efficiency, from small domestic stoves to large commercial ones. Rice hulls and coffee husks are quite uniform, while corn stalks and wood wastes vary widely in fragment size and shape. It is therefore important to examine methods of classifying aggregate size through some mechanical means in order to reduce biomass materials to the desirable form for efficient consumption and resultant heat production.

Domestic Application:

For domestic use the biomass utilization applies mainly to home cooking processes. At this level present fuel consumption efficiencies are very low, in the range of 10%, according to several studies that have been made by national and regional institutions. This indicates a need for investigating other stove types and applications in which to more effectively do fuel extraction from biomass materials.

Among the domestic activities are planned several types of stove demonstrations, including the Lorena and others, having much greater heat conversion efficiencies. Some of the stoves are specifically for burning rice hulls, some for coffee husks, and others for saw-dust or other wastes. The rice hull stove, for example, has had wide

use in Bali where it not only has demonstrated high efficiency and applicability, but the women have found it more convenient and comfortable, especially with regard to smoke control and protective care for their eyes. This stove is fashioned from a small scrap drum, from 2 to 10 gallons in size. A hole is cut in the top, just smaller than the cooking pot to be used, and three small spacers are placed around the opening to space the pot so that flame and heat can pass under and around the side of the pot. At the bottom, in front, a second hole is cut at about the same size as at the top. The rice hulls are compressed into the"stove", packed so as to completely fill the volume except for a central vertical chimney shaft a few inches in diameter, and forming an "L" to the front bottom opening. A slender stick is lighted, inserted into the bottom hole, and the rice hulls inflame as natural drafting action of air starts upward. The usually difficult burning rice hulls burn vigorously, gradually burning out the center of the chimney shaft, until all the rice material is consumed. The burning rate is controlled by the position of the cooking pot over the top opening where it serves as a damper in controlling both the flame and air velocity, subsequently the heat production.

Other stove types operate in unique, but simple, ways in efficiently burning the design wastes.

Industrial Application:

On the industrial scale the apparatus is somewhat more complicated, due to the purpose and application for each installation. Lime kilns, brick ovens, and other incinerating devices are presently consuming vast quantities of fuelwood, and it is especially in these areas that biomass waste utilization is higly applicable. The introduction of fuel into these kilns and ovens is different than for domestic applications, for these units maintain high temperatures for whole days, whereas domestic units operate an hour at a time, or less.

One biomass blower is planned for industrial application. This apparatus will be mechanically powered to accept waste material in a hopper and to deliver it to the furnace through a blowing action. This dispersement is for the purpose of placing the fuel in the fire zone, on demand and in a manner, which is not possible through manual opera-

tion. Sawdust, wood chips, corn stalks, timber slash, and other available wastes will be thoroughly examined for utilization in the industrial applications.

The use of a mechanical blower in the kilns necessitates careful aggregate sizing to insure uniform fuel feeding and burning rate. Without uniformity of aggregate the fuel/air ratio would be varying constantly, and the heat supply and efficiency would not be in constant control. The need for some means of reducing certain wastes to uniform sizes (such as wood waste and scrap, corn stalks, slash, etc... becomes evident. It is suggested that ICAITI might possibly procure a commercial wood chipper capable of chopping typical woody wastes into small "hogged chips" whereby they could be properly handled and fuel-fed into the fireboxes. It is also a possibility that a cooperative effort by several local kiln operators might be feasible in the purchase of such an apparatus which, in the long run, could be cost-effective in their use and consumption of random consistency biowastes.

Costs:

The costs for biomass fuel burning devices varies from very minimal $0-10 domestic stove units to industrial adaptations and/or configurations requiring mechanical blowers. The blower costs may be as low as $100 for a small firebox unit to as much as $500 for a hopper-conveyer feeding unit for use in a larger firebox application. The size and specifications for the blower will be determined by the selected operation-site and will take into consideration the biowaste availability and product being manufactured.

Summary:

In summary, biomass waste conversion to heat energy, for both domestic and industrial application, is highly appropriate for all regions of Central America. Biowastes occur in every section of the region, and their optimum utilization in energy consuming fireboxes will have a direct effect upon reducing fuelwood consumption through substitution of waste matter for fuel. It will also have the directly coupled effect of reducing the operator's costs for the procurement of fuelwood through massive biomass waste substitution.

Description: Sawdust Burner-Adaptation for use in brick kiln. The model assumes the kiln is converted to burn a combination of 25% fuelwood, 75% chipped sawmill wastes and/or sawdust. The fuelwood is to be used for firing up; the wood waste is for continued burning.

Performance: Same as conventional brick oven

Cost: For blower and adaptation, est. $800

Calculations: (comparison)

	(a) Conventional	(b) Modified
Fuelwood per burn	$2\ m^3 \times \$8/m^3 = \$16$	$2\ m^3 \times 25\% = 0.5\ m^3 \times \$8/\ m^3 = \$4$
Wood waste substitute	- 0 - = $0	$2\ m^3 \times 75\% = 1.5\ m^3 \times \$4/\ m^3 = \$6$
Fuel materials cost =	$16 (conv.)	$10 (mod.)

Advantages: The operator spends less time loading wood into the kiln, offset by feeding the hopper-blower, but less time is required to split and cut wood to desirable sizes. Kiln temperature is in control, it is simple to add heat energy and to drop heat energy during burn. The wood waste figure is costed for chipped wood, so total cost per burn (5,000 bricks) indicates a saving of money for operator ($6 per burn).

Fuelwood Impact: For this model kiln there would be a 75% saving in fuelwood consumption, and a 75% utilization of waste (biomass) material. Allowing 100 burns per year, x 1.5 m^3 fuelwood saving per burn, gives 150 m^3 annual savings per kiln.

2. Anaerobic Digestion of Biomass

Biogas is a mixture of methane and carbon dioxide produced by the anaerobic digestion of organic wastes such as animal and human excrement, crop wastes, and slaughterhouse wastes. The two major products produced in a biogas plant are biogas and sludge. The sludge is an excellent fertilizer and of great benefit for food production.

The goal of the demonstration projects over the five-year project period is to design (using existing technology) and demonstrate domestic and small industry biogas systems to directly replace fuelwood uses. The domestic biogas units will be one to three cubic meter size plants which use the waste from two to four large animals (cows or horses), or the equivalent,in other organic waste materials. The larger community,or small industry,digesters will be constructed according to the fuelwood replacement demand and the organic material availability.

The initial costs to produce the biogas prototypes, or demonstration units, will be high. After the initial developmental costs are eliminated it is possible to develop the production capability and assembly techniques to produce biogas units affordable to the rural poor.

There are two general kinds of biogas production processes: (1) batch feeding, and (2) continuous feed. In batch feeding the digester is filled with organic material and produces gas for a period of time. When the digester has completed its anaerobic process the sludge must be removed and the digester recharged. The continuous feed system requires daily attention and daily addition of organic materials. Even though this system requires more attention it produces methane gas on a year-round basis, while the batch system will experience gas production delays every time a new batch is started. On the other hand, the batch digester and system is easier to construct, cheaper, and requires little attention between feedings. It is evident that both systems must be constructed, prototyped, tested, and demonstrated to determine the most appropriate system for Central America.

There are no real "off-the-shelf" biogas digesters produced in the United States, but the technology is well known

throughout the world, especially in India, Korea, and China. Those plants constructed in the United States are custom-made and expensive. The Indian biogas plants and the Chinese models are less expensive, and possibly simpler, in design. Guatemala has biogas plants in operation, since 1960, designed and constructed by Ing. Mario Penagos, considered one of the world's leading authorities on biogas design and production.

ICAITI, with outside consultant assistance, will select the most appropriate designs from which to build prototypes in Guatemala City. After the prototypes are tested and possibly redesigned, ICAITI will demonstrate and gather acceptance data at ten rural homes (domestic fuelwood replacement) throughout Central America, and three small industry plants in Honduras, Guatemala and in Costa Rica. All projects are to replace previous fuelwood uses. The small industry plants are to replace fuelwood burning at a brick kiln, a market place, and for coffee drying.

Typical Biogas Process

The animal waste and organic materials are mixed with hot water as a ratio of 3 parts volatile solids to 17 parts water to create a uniform slurry. The slurry is then filtered to remove solids and grit, then placed in the digester. The digester chamber is either steel or concrete, and it should be insulated to maintain a constant internal temperature of around 95°F (35°C). At times it is best to provide hot water through piping, or through a hot water jacket, to aid in temperature control. This water can be heated with a simple burner and thermostat control, using biogas from the digester.

The slurry is introduced into the bottom of the digester and rises to the top, coming in contact with the bacteria to produce methane and carbon dioxide. Care must be taken to insure an air tight chamber to prevent the mixture of oxygen and methane. This is generally accomplished by designing the telescoping digester roof to increase, or decrease, with digester volume.

The biogas is stored in an expandable-volume container with a water seal. A properly designed container should provide sufficient pressure to enable on-line use of the gas.

During the design stage of the project ICAITI will test and redesign burners appropriate for biogas combustion. Existing combustion systems that use natural gas or liquid fuels can be easily modified to use biogas. Care must be exercised to assure that the combustion systems, or burners, are low in cost and can be easily retrofitted.

Operation and Maintenance Requirements

Biogas digester operation requires care in raw material feeding and ingredient ratios, strict temperature control, and proper acidity control. If the strictly established procedures are not followed, the entire system must be cleaned out and the process started anew.

Additionally, large amounts of raw materials must be available at all times. The daily operation and maintenance activities require care,but are not difficult and do not require high skills levels.

One of the prime considerations in design and adaptability to the area will be to construct, or fabricate, the biogas units with local materials and available local labor. The proposed biogas prototype will first be designed, fabricated, then tested at the ICAITI facilities in Guatemala City. Subsequent demonstration units will be built at the demonstration sites, or where local labor is available.

It is estimated that the cost of the domestic units will be $2,000 each, and the larger community or small industry digesters will cost $20,000 each. Subsequent production types will be built at much lower costs than the demonstrators. It is reasonable to estimate that the domestic units that follow, built for use by 2-5 families utilizing the wastes from 3 cows (or equivalent), will have a materials cost of around 150-250 dollars each. Later small industry digesters will cost much less per unit size, and they will vary in design and configuration, depending upon individual applications.

Outside technical assistance for the planned project is estimated at $34,800. Total direct project costs, excluding salaries and wages, is $114,800.

3. Simple Charcoal Production and Pyrolytic Conversion of Wood

Introduction

The destructive distillation of wood by heating it in an oxygen-starved environment is one of the oldest chemical processes known to man. Presently, this process is used widely in Central America to produce charcoal, and the "pit kiln" method employed does not differ greatly from man's earliest attempts.

Described below is a recommendation for the demonstration of improved types of simple charcoal producing kilns and pyrolysis units that, in addition to charcoal, yield combustible gasses and liquids.

Improved Charcoal Kilns

Charcoal is a familiar and widely used product among the people of Central America. It is produced, by and large, by individual enterprenours at the forest site where the tree has been felled. The process used is the "pit kiln" method, wherein the wood is stacked in an unlined hole and then completely enclosed with sod, or some other readily available, non-combustible material. Small openings are provided to allow oxygen to enter and the combustion products to leave. Proper control of the draft is critical to the efficiency of the process, and in the "pit kiln" method it may only be learned by experience. The process must be monitored continously and can take longer than one week, depending on moisture content of the wood.

Obviously, the production of charcoal is an energy consumer. This consumption is justified by two reasons: First there is a demand for the product stemming from its smokeless flame which is valued in indoor cooking; secondly, containing almost no moisture, it is lighter than wood per unit of energy delivered and is thus more economically transported.

Definite information as to the efficiency of the contemporary "pit kiln" process in Central America has not been found. There are. however, reports on the efficiency of similar methods used in the United States. Forty bushels (1.6 M^3 or approx. 363 Kg.) can be produced by an experienced operator from one cord (128 $ft.^3$ or 3.62 M^3) of stacked hard-

wood. 1/ The yields of present-day processors in Central America may, or may not, be equivalent to this figure, but it is in any case usable as an optimal efficiency for the "pit kiln" process.

In improving the yield of simple charcoal producing kilns two types of kilns are traditionally used, masonry kilns and sheet steel kilns. The masonry kilns are obviously not portable, so the wood must be brought to them. This requirement of hauling the wood partially offsets the advantage of the decreased transportation costs of charcoal production and thus, in our estimation, they should not be considered.

The sheet steel kilns are usually of smaller capacity and are meant to be portable. They are usually conical or rectangular in shape and typically enclose a volume of 3 M^3. The cost of producing these devices has been estimated at $700 (American), and they can be expected to last approximately five years. 2/ Specific designs are available in the United States.

The principal parameter controlling the charcoal yield of these modern enclosed kilns is the average temperature at which the wood is held during the destructive distillation process. The optimum temperature for the production of an acceptable quality charcoal, within a reasonable time limit, is 400°C. (752°F). For the most part this is the industry standard and yields48 bushels (1.9M^3 or approx. 431 Kg.) per stacked cord (3.62 M^3) of hard wood. This means that an improvement in charcoal production of 1.6 M^3 to 1.9 M^3, or approximately 20%, could be expected in changing from the "pit kiln" method to the modern sheet steel kiln. While there are a number of assumptions and approximations made in this estimation the trend does lead to the conclusion that further investigation and demonstration is warranted.

The social impacts of the introduction of this technology are seen as minimal merely because it is a very slight change from the existing practice. Additional adverse envi-

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1/ Forest Products Laboratory; The Production of Charcoal in the Ordinary Pit Kiln; Forest Products Laboratory Mimeo K466; 1932.

2/ Olson, A.R. & Hicock, H.W.; A Portable Charcoal Kiln; Connecticut Agricultural Experiment Station Bulletin 448; 1941

ronmental impacts are also estimated as being minimal for the same reason.

It is therefore recommended that, in order to determine their cost effectiveness, two different sized sheet steel kilns be demonstrated.

Pyrolysis Units

Pyrolytic destructive distillation units are an improvement on the basic charcoal kiln in that the partially combusted gasses that normally escape are captured, and some of them are condensed to liquid so that they may be put to a useful purpose. The gas that the process yields, known as "producer gas", consists mainly of non-combustible carbon dioxide, along with flamable carbon monoxide, hydrogen, methane and some heavier hydrocarbons. The heating value of this gas is approximately 300 BTU/ft.^{3} (2670 Kcal./M^3) and 7,000 to 8,000 ft.^{3} (198 to 226 M^3) of producer gas is normally recovered from one cord (3.6M^3) of stacked, dry hard wood. The heating value of the oil is approximately 6,250 Kcal/Kg.

Pyrolytic Technology is not new, as its principal period of development and exploitation occurred during the Second World War in the fuel-starved European countries. There are numerous industrial size designs that are presently in operation throughout the world. Smaller scale plants that powered automobiles were developed during the war but the design details of these devices are not readily available at the present time.

Georgia Institute of Technology has developed and constructed two pyrolytic combustion units in recent years under a contract with USAID. These units consume approximately 1 1/2 tons of rice hulls per day and were designed for application in the developing nations. While their success has not been overwhelming, the plants are operating at the present time. Some of the difficulties have been attributed to the isolated third world locations of the prototypes,and problems in developing an inexpensive briquetting technology for the powdered charcoal that the device produces. In spite of these drawbacks it is felt that a pyrolytic device, based on the Georgia Tech. design, should be demonstrated in Central America. The reasoning behind this recommendation is that the technology, although not perfected, is certainly historically proven and, in

addition, it is a great improvement in efficiency over simple charcoal kilns.

One could easily imagine a panela plant installation where dry pulverized bagasse were used as the fuel, the gas and liquid were used to fire the panela production, and additional revenue would be generated by the sale of the briquetted charcoal. Certainly many other applications are conceivable.

There are some environmental questions that must be addressed in the application of pyrolytic conversion. The principal problem is that there are a few toxic substances present in trace amounts in the oil. These would have to be handled with the usual precautions, and to be sure that the precautions are observed it is felt that the demonstration unit should be no smaller than the small industry size.

The appropriateness of this technology in Central American society is also in some question. These units are of medium technological sophistication and cost. Once again, for these reasons, it must be concluded that the only practical application is on the small industry level.

In conclusion, it is our recommendation that a demonstration be made of pyrolytic conversion based on its historical success and promise of increased efficiency. This demonstration will help to answer the questions of environmental degradation and cost effectiveness in the Central American application.

ECONOMIC ANALYSIS OF SHEET STEEL CHARCOAL KILNS

Capital Investment:	Q1,000.00
Expected Output:	5000 Kg/Month
Improvement in Efficiency:	20%
Incremental Benefit of Kiln:	1000 Kg/mo.
Wholesale Value of Hardwood Charcoal:	Q0.11/kg.
Projected Payback Period:	9.1 Months

It should be noted that the above estimates are extremely conservative. Some estimates are that efficiencies may be more than doubled (greater than 100% improvement).

This analysis assumes that the labor involved in producing a kilogram of charcoal with a sheet kiln is equal to the labor required with the pit kiln method. This is also a conservative assumption.

ECONOMIC ANALYSIS OF PYROLYSIS UNITS

Capital Cost:	Q20,000
Annual Labor, Management and Maintenance Costs:	Q25,000

Expected Annual Output of Unit:

Powdered Charcoal - 270 Metric Tons

Pyrolytic Oil - 215 Metric Tons

Expected Annual Value of Product:

Charcoal - 270 Metric Tons/yr. = 594,000 Lb/yr.

594,000 Lb/yr. x Q0.03/Lb. = Q17,820

Pyrolytic Oil $215 \frac{\text{Metric tons}}{\text{yr.}} = 473{,}000$ Lb/yr.

$473{,}000 \frac{\text{Lb}}{\text{Yr.}} \times 12{,}500 \frac{\text{BTU}}{\text{Lb.}} = 5{,}912 \frac{\text{MBTU}}{\text{Yr.}}$

$5{,}912 \frac{\text{MBTU}}{\text{Yr.}} \times \frac{\text{Q}4.90}{\text{MBTU}} = \text{Q}28{,}969/\text{yr.}$

The above analysis is based on the projected cost figures based on the feasibility estimates used by Georgia Institute of Technology for their design of a Pyrolytic Converter that has since been built in Ghana. It assumes that following:

1) The plant operates 16 hours a day, 300 days/year

2) The raw material is available close to the plant site and, other than the cost of hauling it, is free.

3) The unit consumes 3.6 Metric Tons (dry weight) of pulverized biomass per day.

4) The powdered charcoal will wholesale for Q0.03/lb. (This is less than Q0.05/lb. for chunks because it is in a less usable form).

5) The pyrolytic oil will wholesale for the same price per unit of energy as petroleum fuels.

B. SOLAR ENERGY

1. Solar Drying

Wood Drying: Fuelwood drying ("curing") is an established practice not only in Central America but all over the world. Freshly cut ("green") fuelwood contains a high percentage of water content which makes it more difficult to ignite and burn. The large amount of water present requires a sizeable amount of the combustion energy of the wood in converting the water to vapor, thereby reducing the net amount of available heat energy. It has long been recognized that dry wood generates more heat energy than its equivalent in moist wood. The dry wood also is capable of faster burning, and it produces a cleaner flame with less smoke.

Several techniques are used to dry wood. One technique is that of outdoor "ricking", or stacking, in such a manner as to allow air circulation throughout the stack. This manner is not without flaw, for morning dew, or rain, may actually have the effect of holding the moisture content higher than would be desired.

Another technique is that of stacking the wood in a building such as a storage shed. This has the advantage of keeping weather away from the fuelwood, but the drying process is somewhat slow and the shed is tying up space that could better be used for another purpose.

A more expensive system for wood drying is sometimes used in Central America whereby a wood shed is heated with diesel or an equivalent fuel. The fuelwood is of a high quality and is also quite costly, placing it outside the range of affordability for the average to poor people. Fossil fuel cost, and availability, is looking more bleak each year, making alternate drying techniques worth consideration.

Solar drying of wood is accomplished in a shed structure by the action of solar heat gain thru a solar-passive roof (at this latitude), and the resultant convective action whereby drier air from outside enters from below, passes thru the stacked wood picking up moisture, then exits near the top, thus carrying away water vapor. The solar wood dryer

can be any one of numerous configurations, and the size can vary from small home types to large commercial ones. The structure need not be expensive or sophisticated, for it need only to support a plastic or fiberglass roof surrounded by fixed and/or movable wall sections, depending upon the operator application.

The solar dryer is apparently the most cost effective of all wood drying methods. There is no energy cost for the operation, and there is relatively little cost for maintenance over a ten-year period. The only cost is that of the investment which, for a 10 m^2 structure, would cost about $400. During the dry season, when sunshine is abundant, the dryer could process more than double the quantity of wood as would be possible in the open air. During the rainy season, when sunshine is present only for a part of each day, the solar dryer could process many times the quantity of wood as would be possible in the open air, for the dryer also serves the purpose of shielding the wood from the daily rains.

In summary, the solar wood dryer is highly appropriate, is not presently in use in Central America, and its widespread utilization would reduce the quantity of fuelwood burning thru the production of dry wood which yields a larger net heat energy in stoves, ovens, kilns, and evaporators. The solar wood dryer is also applicable to the whole spectrum of fuelwood consumers, from the small family unit, to the large industrial operator.

Panela Drying: The panela industry is widespread throughout Central America, with dispersement mostly in the lowlands in each of the countries. The sugar produced in this operation is one of the major exports which returns money to the farmer and to the country.

In practice, the sugar cane is harvested in the field and transported to the panela plant where the liquid fraction is pressed out of the cane stalk, leaving only the fibrous, stringy residue as waste. The liquid fraction is slowly cooked in vats above the brick furnace until it thickens into a viscous brown syrup which is poured into wooden molds to harden into panela "bricks".

The cooking furnaces burn wood, stalk residue, or any material available which can do the cooking job. In its immediate condition the stalk residue is too wet to be of use

as fuel for the furnace. In some cases this material is piled near the plant where it gradually decomposes. In other cases it is piled nearby, allowed to dry for a day or so, then it is added to the furnace to supplement wood as fuel. It is apparent that the stalk residue utilizes a good part of its available heat energy to drive away the remaining moisture content and therefore is not able to deliver the highest amount of net heat energy to the furnace.

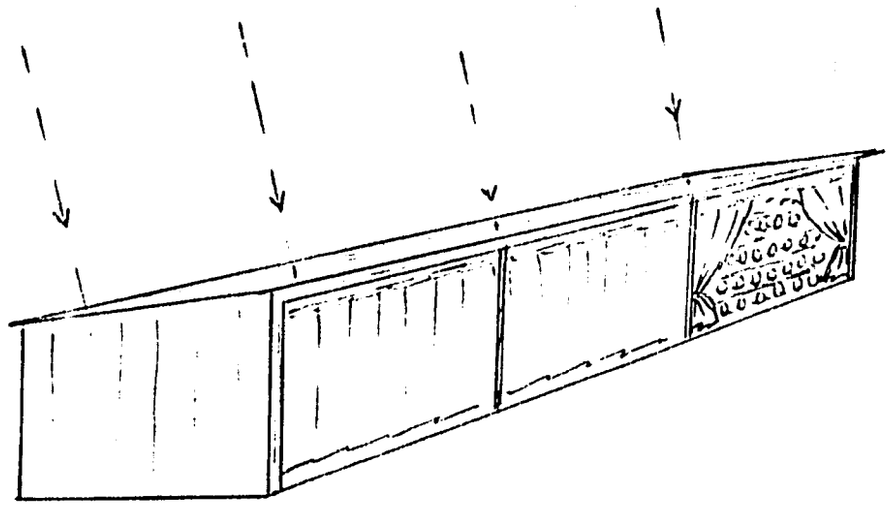
The solar dryer for stalk residue drying would be highly beneficial to the panela operator. An elongated solar dryer with good frontal access would allow for cyclic drying, rather than for batch drying, so that the operator could both introduce and withdraw materials on a daily basis.

The panela solar dryer would be very cost effective over a period of five years and beyond. The cost to build a dryer of 20 m^2 would be about $800. During the dry season it would be capable of drying more than double the amount of open air drying. During the rainy season it would be capable of processing all the stalk waste, whereas the open air processing during this period is almost impossible. At this time there is the double benefit of partially sunny days plus the protection of the residue from the daily rains.

Based upon field investigation it is projected that satisfactory drying of panela residue presently takes five days using the conventional methods. The solar dryer should reduce this time to about one-third, or to two days time, through the action of increased temperatures and air convection within the dryer unit. The unit design would allow for three-day turnover of the stalk fuel increments so that the handling is cycling, holding manpower requirements to a minimum. The design would also incorporate low maintenance components, resulting in annual costs of less than $100, which is negligible in comparison to the present daily cost for fuelwood for one of these operations. Since the fresh cane stalks burn with difficulty, and because the solar-dried stalks burn easily and effectively, it can be assumed that the utilization of the solar dryer would improve furnace efficiency, decrease man-power requirement (due to daily stacking and retrieval of stalk fuel prior to midday rains), and would therefore be cost-effective for the operator.

In summary, solar drying for panela operations is highly appropriate, it is not presently in use in Central

America, and its acceptance and utilization would reduce the consumption of fuelwood through the production of greater quantities of renewable substitute fuel having a higher net heat content than is presently available.



Description:	Solar Drying Shed (kiln), 60' x 12' x 8' ht	
Performance:	At 1,000,000 BTU daily input, at 50% efficiency of energy transfer to drying chamber, utilizing 500,000 BTU/day x 360 days/year	
Cost:	Materials to construct (production model) = $1200	
Calculations:	Fuelwood cost (green) =	$1.20/carga(0.2 m^3)
	Calculated BTU content =	700,000± BTU/carga
	Calculated volume of fuelwood per filling shed =	20 m^3 = 100 cargas
	Drying time, outdoor stacking, green wood =	5 months
	Drying time, solar drying shed =	2 months (est.)
	Factor = $\frac{5 \text{ months}}{2 \text{ months}}$ =	2.5X

$$\text{BTU gain} = \begin{array}{r} -800{,}000 \text{ BTU (dry)} \\ \underline{700{,}000 \text{ BTU (green)}} \\ 100{,}000 \text{ BTU} \end{array}$$

$$\text{\%age gain} = \frac{100{,}000 \text{ BTU gain}}{700{,}000 \text{ BTU green}} = 14\% \text{ per fill}$$

$$\text{\%age energy gain} = 14\% \text{ gain per fill} \; \underline{\times\ 2.5 \text{ factor}} = 35\% \text{ projected fuelwood energy gain}$$

On the basis of the above model solar drying shed (kiln) it is projected that there would be a net gain in fuelwood efficiency of 35% (±). This is an indication that fuelwood dryers could be effective in reducing fuelwood consumption through the production of more efficiently burning fuelwood. The green wood gives greater difficulty in burning, burns with more smoke and noxious vapors, and generally yields a lesser degree of effective heat energy to its target than does dry wood.

2. Solar Water Heating

All hot water generated in Central America is from either a fuelwood, fossil fuel or electrical energy source, except for localized, naturally occuring hot water at geothermal sites. The fossil fuel heated water is usually by propane, diesel, or equivalent, and is usually limited to the urban areas. Fuelwood heating of water is practically universal in the rural regions where the majority of the poor are distributed.

Domestic hot water among the poor is considered almost as a luxury. It is usually produced in small quantities as a by-product of cooking where excess, or waste, heat is scavenged from the cooking fire. These people prefer more than this minimal quantity, but the cost of firewood, in money or in time, depletes from the family income, thereby placing hot water in the category of luxury.

Rural hospitals exist in the form of satellite "clinics" throughout Central America. These clinics necessarily use hot water, and the energy source is usually fossil fuel, except for a few rural villages where fuelwood is used for this purpose. All fossil fuels in Central America are imported, as there is no source in the six-country region. (A small oil field does exist in remote northern Guatemala, but the majority of crude is consumed by cement factories nearby).

Geothermal heat sources are scattered around Central America, but the sites are very localized. It appears that hot water could be generated from such sources, but this application would not be appropriate, mainly due to isolation of specific available sites, and additionally because of high costs in developing the technology.

Other sources of heat energy exist within the region in the form of crop wastes or slash materials. However, the general fuelwood shortage has rendered these waste materials useful in other energy applications, so they are beyond consideration as energy sources except for isolated cases.

Solar heating of water is accomplished through the action of sunlight upon, and the subsequent capture of heat energy in, any water containment apparatus. A blackened drum of water becomes a low efficiency solar water heater capable of warming a quantity of water several degrees above

the ambient. There is a wide variety of sophistication which spans the spectrum, reaching the highly efficient systems consisting of insulated storage tanks which circulate water through metal tube-and-plate conduits housed in glass top collector boxes. These efficient solar collector systems are capable of delivering hot water at a rate of around 2 gallons per day, raised 60 F°,for each square foot of solar collector area.

The solar water heating devices range in cost from about $100 for a primitive homebuilt type with water drum storage, up to about $1000 for a similar size, fancy commercial unit. Numerous designs and types are found within this cost range.

Solar hot water is an appropriate technology for all of Central America, and especially in the rural regions. The low technology systems are very applicable for they can be constructed on site using materials which are usually available in-country. These rural type systems can be designed around the principle of thermal syphon whereby the solar heat input is responsible for gravitational circulation of water between tank and collector, thereby eliminating any need for electrical pumping energy.

The rural clinics could benefit greatly from the solar hot water. Manpower previously engaged in collecting fuelwood, or monies previously spent for fossil fuel and/or electrical energy, would be reduced by around 80-90%, freeing monies for other services.

The rural poor could receive many benefits from solar water heating. The hot water would no longer be a luxury, but it would be available daily as a standard item, greatly increasing domestic comfort, cleanliness, and even health conditions. Solar hot water for cooking, cleaning, and washing would greatly benefit the rural poor, and there should definitely be a reduction in domestic fuelwood consumption due to that fraction of energy which presently is being used for heating water for those tasks.

Assume a rural hospital consisting of a 5-bed clinic which processes 25 outpatients daily. Allowing 10 gallons hot water each for the 30 total patients for daily water consumption for all uses (cleansing, bathing, laundry, processing) would give a total of 300 gallons of hot water demand per day. Using the normal ratio of 1 square foot collector

area for each gallon of water indicates a need for at least 300 square feet of collector matched to the 300 gallons of storage tank capacity. The solar collection could be a configuration of 10 collectors, each of 4' x 8' dimensions, giving 320 square feet of collector. These units would be modularly arranged on the roof and tilted southward a few degrees to shed water and to intercept the sun more directly over the year. The collector array would be connected in series with the hot water storage tank which would supply the water for continous clinic utilizaiton. This system would normally be expected to be able to deliver 300 gallons of hot water daily at temperatures in the range of 160°F.

The cost of the described model system would be approximately $15 per square foot (collector) for the complete installation, or about $5,000, when considering the typical pre-manufactured components available off-shelf. Total installed costs could vary above or below this figure, depending upon the amount of fabrication of components planned for each site.

In summary, solar water heating is an appropriate technology for all of Central America. In the urban areas it can reduce or eliminate fossil fuel consumption, while at the same time cutting the consumer cost drastically. In the rural setting it can reduce the consumption of fuelwood while at the same time improving the quality, and possibly quantity, of life. Climatic conditions at particular sites (i.e., %-age of cloud cover, seasonal influence, etc...) can be allowed for in matching the capacity of the collection system to the clinic's demand, so that the 80-90% of demand can be met through the solar input. During the minimal periods when the sun does not shine, the clinic can resort to the back-up system on temporary basis, resulting in a total hot water production cost on the order of 10-20% of the previous operational cost.

ECONOMIC ANALYSIS OF SOLAR WATER HEATERS

Capital Investment: Q5,000

Average Daily Thermal Energy Delivered:

$$300 \frac{gal}{day} \times 8.3 \frac{lb.}{gal.} \times (160F - 60F) \times \frac{1\ BTU}{lb - F^\circ}$$

$$= 249{,}000 \frac{BTU}{Day}$$

The expense for diesel fuel that has been avoided:

$$.249 \frac{MBTU}{Day} \times \frac{Q4.90}{MBTU} \quad X\ .85\ (efficiency) = Q1.44/day$$

The expense for bottled propane that has been avoided:

$$.249 \frac{MBTU}{Day} \times \frac{Q8.40}{MBTU} \quad X\ .85\ (efficiency) = Q2.46/day$$

This is obviously not a very quick payback; however, it should be pointed out that this price is heavily subsidized in many of the Central American countries by gasoline prices on the order of Q1.50/gal. In addition, price increases are anticipated for all fossil fuels, making it likely that the pay back period will be shorter.

3. Solar Stills

The utilization of solar energy for distillation of aqueous substances is not presently practiced in Central America. In all sections of the countries good to high grade water is directly available from springs, small rivers, or from shallow-wells. So there is not a need for water distilleries for the purpose of producing quality water except for isolated examples.

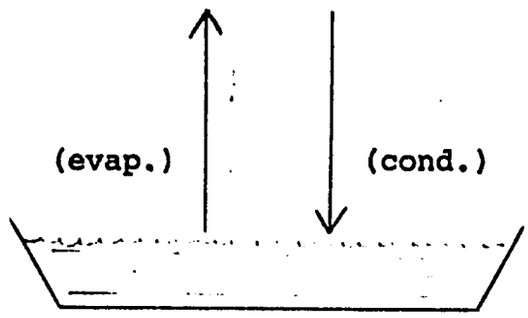
Water evaporation is, however, a process which is on-going in Central America. The end product is salt, rather than water. In Honduras, salt production is a viable industry at numerous sites along the Atlantic coast. The Bay of Nicoy in Costa Rica is a quantity salt producer, as are several sites scattered along the coastal regions of most of the Central American countries.

In general, tidal basins (usually within a bay) are formed at a site where high tide will fill the individual ponds with sea water to a depth of several inches. They then allow the sun to evaporate the water. Upon evaporation the salt crystallizes in a layer which can be skimmed and collected. The fuelwood burning process is that of boiling the salt water with fuelwood heat to remove the water, leaving the salt at the bottom of the container.

Many local buyers specify their preference in the "cooked" salt, and not the "raw" salt. This method of salt production consumes large quantities of fuelwood, and it is only natural that the forests are being depleted in the areas near salt producers.

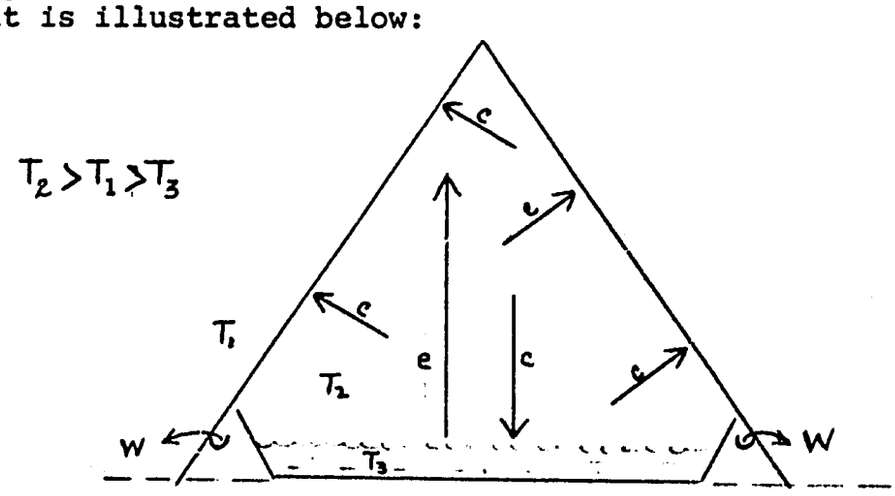
Other methods are available for increasing salt productivity. Fossil fuel heat generation may be in use, but its cost and availability will rapidly eliminate its use from future consideration. Geothermal heat generation would be highly desirable, and even preferable, in some cases except for its being so site specific. Solar distilling is the most appropriate alternative remaining, both from the standpoint of investment cost, and maintenance and operational costs. In practice, the solar still consists of a transparent type tent enclosure over an aqueous medium. At a given temperature an equilibrium establishes whereby the rate of evaporation and the rate of condensation become equal as illustrated

below:



The above unit is totally enclosed, so there is no net change in humidity or aqueous volume.

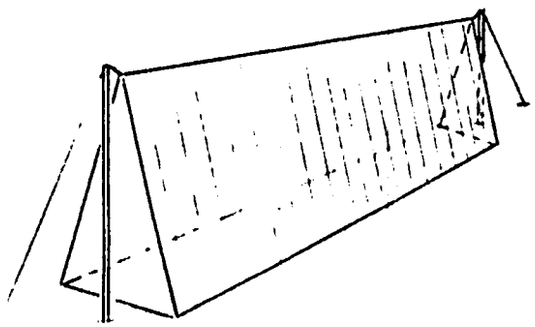
However, sunlight enters the enclosure, raising the ambient temperature, which has the effect of increasing the rate of evaporation of water. The resultant effect is that of increasing the rate of condensation on the inside walls of the enclosure due to the microlaminar temperature remaining very near to that of exterior ambient temperature which is well below that of the inside. The result is illustrated below:



Condensate water collects on the tent walls, trickles downward, and collects in the gutters where it is removed (W"). The net result is that water eventually is removed through evaporative process, leaving only the salt residue in the basin. The water is of high quality and can be collected for domestic consumption or commercialized.

The cost of building production solar stills is low. The materials and labor for a still of $100m^2$

will run in the range of $200 to $1000, depending upon sophistication. The less expensive primitive type consists of two poles supporting a cable, over which is draped a durable plastic film in the form of an "A" tent. This enclosure is closed at both ends, and the aqueous medium is held in a shallow pond inside. The configuration can be narrow to moderate in width, and of any length to suit the operator. An ideal layout for a commercial salt evaporator would be that of numerous modules, each of 20 feet in width by 100-200 feet in length. If distilled water collection is of no concern, the condensate could simply be allowed to trickle to floor level where it is absorbed back into the ground outside of the evaporator pond.



Assume a model solar still having dimensions of 30' wide X 100' long, constructed as described above. Two poles, each 12' in height, are erected at the center of each end. A galvanized aircraft cable, 1/4" X 125' long, runs between the tips of the poles, then downward and outward to distal points of anchoring so that the cable is taut and secure. A single,quality, clear, polyethylene plastic film, 40' X 130' dimensions, is draped across the cable and spread outwards to form the "A" configuration giving a ground level width of just over 30'. The sides are staked securely, and earth is placed on top of the surplus edge to further secure the sides. The excess front and rear end flaps serve as curtain openings for ease of access. The floor area is scraped level, a plastic sheet of 30' X 100' dimensions is put in place and the sides are formed up to about 12" to form the pond. One foot margin at each side is sufficient for running off the condensate water to the outside. This

is a simple, but effective, solar still with material cost of about $400.

During operation the salt water is directed into the pond until a depth of 6-8" is achieved. The curtain ends are closed during the daytime so that the sunlight enters, trapping the heat energy inside, and raising the temperature to a good margin above the outside ambient (to about 120°F or more). The rate of evaporation increases sizeably at this temperature, and the condensation occurs rapidly on the inside surface of the tent enclosure due to the temperature drop across the film between inside and outside ambient. The condensate trickles to the bottom of the tent wall where it is either collected, or allowed to dissipate into the ground. At night-time the curtains are pulled open (if desired) to allow the flow of air to pick up and remove water vapor. No energy input is required from the operator except for manpower. It would be reasonable to expect that 6" of water would be removed through evaporation during a three-day period, giving a total volume of 1500 ft^3 of water. This quantity would yield around 10 lbs. of salt/ft^3, or a total of around 15,000 lbs. of salt every 3 days, and 30,000 lbs/week. At a minimal return of $.025/lb the gross return would be around $750 per week for the single still, and $1,500 per week for an operator with two stills. Allowing $500/week for labor, operational, and selling costs, the operator would net around $1,000 per week for a healthy income. Refer to the table which follows.

A study performed by Andrew Sisson, a ROCAP contractor during July, 1979 documented numerous data on salt operations, with most related to commercial applications around the Bay of Nicoya in Costa Rica. His investigations revealed the existence of 9 "salinas" (salt producing operations) in the village of Corozal, 4 in Lepanto, and 7 in Jicaral. It was found that firewood consumption has fallen sharply in the last two years due to new technology invented by Nicolas Cheuré in Colorada, Guanacaste, who has also done work with biogas.

This newly introduced technology consists of scraping out pond areas to form "quadrangles" which are 300' x 25' x 9" in depth. A plastic liner is laid in place, and salt water is introduced to a depth of 2". The water evaporates over a 3-7 day period, leaving about 10,000 lbs. of salt residue. This "raw" salt brings

about 10 colones ($2.50) per 100 lbs., or about $250 per cycle. Each operator using this system owns several quadrangles. Refer to the table for summary of "quadrangle" salt production.

Previously, all salt in this region was recovered through the salinas using fuelwood to heat the salt water in large "pailas" (cooking pans). Each "paila", consuming a cartload of firewood, produces 450 lbs. of salt from 12 hours cooking time. 200 cartloads are used each year to cook 90,000 lbs. of salt per each "paila". A typical operator owns 8 "pailas" and consumes 1600 cartloads per year while producing 720,000 lbs. of salt. Present market price of the "cooked" salt is about 60 colones ($7.50) per 100 lbs. and fuelwood costs around 55 colones ($7.00) per cartload. Refer to the following table for summary of salt production from "salinas".

In summary, the application of solar distilling to Central America is appropriate. The technology is simple and inexpensive, and the maintenance and operating costs should be minimal, returning good benefits to the operator through high quality salt production, while at the same time reducing fuelwood consumption and the accompanying costs in manpower. The fuelwood costs alone, for a typical salt operator processing a similar quantity of salt weekly, would run about $400, according to surveys of salt operations on the Bay of Nicoya in Costa Rica. With firewood becoming scarce, and expensive, the solar still appears to be the best possible alternative to pursue.

SUMMARY OF SALT PRODUCTION SYSTEMS IN CENTRAL AMERICA

TYPE OPERATION	CAPITAL INVESTMENT	CAPITAL LIFE	YEARLY COST	MAN-HR COST/WEEK	FUELWOOD COST/WEEK	OTHER COST/WK	GROSS RETURN/WK	NET RETURN/WK
"8 Pailas"* (cooking operation) *a paila boiler pot is 8' X 6', & about 9" deep	$300/p X 8p $2400	10 yrs.	$250	50 hrs X 2 men 100 man-hr X 4$ ea. $400	64 cart± X 6.5$ $400(±)	est. $100	450 lb X 8p 3600 lb X 6 day 21,600/wk X .07/lb $1500(±)	$600/Week
"5 Quandrangle"* (open evaporators) *a quandrangle is a pond with 300' X 25' X 2" dimensions	$150/q X 5q $750	5 yrs	$150	30 hrs X 2 men 60 man-hr X 4$ ea. $240	- 0 -	est. $150	4000 lb X 5q 20,000 lb X 2/wk 40,000 lb X .02/lb $1,000(±)	$600/Wk
"2 Solar Still"* Projection *a still design of 30' X 100' X 12' in height	$500/s X 2s $1000	5 yrs	$150	30 hrs X 2 men 60 man-hr X 4$ ea. $240	- 0 -	est. $150	15000 lb X 2s 30000 lb X 2 cyc 60000 lb X .025/lb $1,500(±)	$1,100 /Wk

4. Solar Furnaces

Solar furnaces are relative newcomers to the field of solar energy, so there has been no introduction into Central America, except for a few novel solar cooker kits. Solar furnaces are found in a variety of configurations and sizes, and their applications are numerous. The solar cooker is the simplest of the bunch, consisting of a parabolic dish-type reflector which catches the suns rays and concentrates them at the focal point where cooking is achieved. These units are usually about four feet in diameter, resting on an adjustable stand of about two feet in height, costing upward from $80.

A host of concentrating type solar reflectors fills the gap from the small solar cooker, and culminating with the "Tower of Power" heliostat furnace at Sandia Laboratories in New Mexico, U.S.A. The heliostat furnace consists of some one hundred individual large reflecting parabolas geared to deliver, in synchrony, the massive quantity of solar energy from several acres of incidence to a single point high atop a concrete structure. The result is almost instant melting of a ton of steel. One application of this energy is to generate steam to deliver turbo-electric energy to electric grids.

In principle, the quantity of solar energy which strikes one square foot of surface area can be reflected to some point of focus where extreme temperatures can be generated. There is no increase in energy through this concentrating technique, only an increase in temperature with the corresponding decrease in target area, with the total energy unchanged. Whenever extreme temperatures are desired the concentrating collector should be considered.

In the case of ceramic kilns, where high temperatures in excess of 1000F are required, the concentrating solar collector principle is highly applicable. Assuming a small kiln (which handles pottery) that may require an internal temperature of 1200°F for three hours, while consuming 20,000 BTU/Hr (3 Hrs. x 20,000 BTU = 60,000 BTU consumed), a theoretical concentrating solar reflector can be designed. One with dimensions of 10 feet x 10 feet will give a surface of 100 square feet in area which, upon receiving an average of 2000 BTU per/day/square foot would be equal to 200,000 BTU for an average day's incident solar radiation (2000 BTU x 100 ft^2 = 200,000 BTU/day). Assuming 90% reflectivity the daily

quantity of solar energy delivered to the kiln would be 180,000 BTU/day = 180,000 BTU/day). Allowing kiln radiative losses at 40% (i.e. 60% utilization of the energy) the kiln would utilize 108,000 BTU/day (.60 x 180,000 BTU/day = 108,000 BTU/day). Since the kiln requires 60,000 BTU over three hours duration, it is apparent that the described concentrator is near the appropriate size, for the maximum solar radiation is available during mid-day, and 60,000 BTU would be available over a three hour period.

Presently, the ceramic kilns are operated with either fuelwood or fossil fuel. Fuelwood is almost universally used in the rural areas all over Central America. The conversion of the kilns to solar energy would reduce the consumption of fuelwood and fossil fuels. This would have the double advantage of reducing energy costs for kiln operations, and of increasing the convenience of the operator.

Based upon the described solar furnace, the base cost of a manually operated system would range between $1,000 and $5,000 depending upon sophistication. Based upon volume of use, and upon negligible maintenance costs over a ten year period, the system appears to be cost effective, especially in view of the dwindling fuelwood and fossil fuel supplies.

It is apparent that the solar furnace is an appropriate technology for use in all Central America. The availability of sunlight year-round does not vary considerably due to the almost constant twelve-hour day lengths, and all of Central America falls within a solar applicable zone.

Description: Experimental solar kiln, concentrating reflector-type, w/100 ft^2 collector area, w/1 ft^2 receiver area

Performance: at 1600 BTU/ft^2 daily input, at 50% efficienc of energy transfer to kiln chamber, utilizinc 80,000 BTU daily, 25 days/month x 12 months

Cost: Equipment and materials (production model) $1,000 (est.)

Calculations: Fuelwood cost, presently $1.60/carga (0.2 m^3)

Calculated BTU content = 800,000 BTU/carga
then BTU cost = $2.00/1,000,000 BTU

Solar kiln, producing 80,000 BTU/day
x 25 days/month x 12 months/year = 24,000,00(
BTU/year

24,000,000 BTU/year x $2.00/1,000,000 BTU =
$48.00/year fuelwood savings

Advantages: Kiln operation is clean, controlled, uniform, predictable energy, ease of operation

Fuelwood Impact: Fuelwood use is totally eliminated

This model unit would be an introductory experimental model through which less expensive units could be designed, and possibly manufactured in Central America. It would serve as a demonstration unit through which other concentrator-type solar furnaces could be adapted for use.

C. SMALL SCALE HYDRO

Small scale hydro refers to the extraction of energy from a mass of water in motion, and transforming that energy into electrical or mechanical energy. This discussion treats that part related to "microhydro" and "minihydro" energy applications, and the end product deals with electrical generation for domestic or small village consumption.

All of the Central America countries have two things in common which make them very attractive for small hydroelectric generation: (1) there is an abundance of small streams which run year-round, and (2) there is a great deal of vertical terrain exaggeration. The streams of water, and the vertical drop, are the two factors which determine hydropotential.

Large scale generating stations require dams to accumulate a head of water which falls through several hundred feet to deliver large quantities of kinetic energy to turbines which drive the generators. Small scale hydroelectric generation differs from regular hydroelectric generation in that (1) a large dam is not required, and (2) the large vertical drop (head) of water is not required. In addition, the quantity of electrical energy generation is much less. Regular hydroelectric generation usually delivers electrical energy in "megawatts" (thousands of kilowatts) whereas microhydro and minihydro stations usually deliver up to "hundreds of kilowatts".

A typical microhydro generation station might consist of a simple lowhead turbine design, powered by 1/2 ft^3 of water per second, with the water delivered through a 4" PVC plastic pipe originating at a pond upstream some 500 feet distant and +80 feet in elevation. The river would not be diverted, and the water would go back into the stream below the generator level following its use. The electrical generating potential from this station would be of the order of 4 KW. A minihydro generation station would operate similarly, except the flow rate would be greater, and the electrical generation would be in the range of 20 to 100 KW, or more.

Regular hydroelectric generating technology ordinarily is found in sections of a country where rivers and streams feed a large arterial river which, in turn, fills a reservoir held by a dam. The dam is usually several hundred feet in height in order to maintain the large head of water

necessary to power the turbine generators. This technology is applicable to large areas of contiguous land mass. The major problem encountered with these systems is not the technology, but the high cost of dam construction and transmission lines to remote areas. There are many small rivers and streams, most of which are very short (i.e., 100 miles or less), and are located in these isolated areas which do not have electrical power. The small scale hydros are highly applicable to these areas.

The recommended study on small scale hydro should consist of two elements: (1) A study should be made to determine the applicability of "cascading" numbers of minihydros along the courses of appropriate rivers and streams for electrical power generation and their potential national grid interface, and (2) an in-depth survey and study should be made of the remote population distributions, their individual accessibilities to nearby rivers and streams, and their potential acceptance and utilization of electricity at the domestic and small community level, from both microhydro and minihydro production.

Small scale hydroelectric generation should be cost-effective for implementation in Central American countries. Considering that the total installation costs would run around $6,000 for a 5 KW microhydro station, and up to $50,000 for a 100 KW minihydro station, the capital cost/KW is quite low. Maintenance and cost of operation for the stations is lower than for any other type of electrical generation. This is due to their not consuming fuels, and their simplicity of operation with minimal manpower requirement. Microhydro and minihydro electric generation is an appropriate technology which should be pursued in Central America.

III PRELIMINARY EVALUATION OF SOLAR DATA BASE AND RECOMMENDATIONS

Introduction

Solar energy, which is among the alternative energy sources recommended for reducing fuelwood consumption, is one of the more abundant renewable resources in Central America. An accurate base of solar radiation is a prerequisite for the widespread application of solar energy technologies.

This report contains the preliminary results of a survey and evaluation of the Central American solar radiation data base, and makes preliminary recommendations for upgrading that data base and data collection network to a high quality.

A. Preliminary results of the survey of existing radiation data & instrumentation

In visiting Guatemala, Honduras and Costa Rica it has been determined that a large amount of solar radiation information exists. There are, however, a number of significant problems with this data base. Our preliminary analysis of the solar radiation data available, and the instrumentation that generated it, has convinced us that a meaningful development of solar energy in Central America will require a more accurate data base.

In the three countries visited it was found that the current data base is the product of measuring instruments installed in the early 1970's. These instruments are of two types, actinometers and heliometers and typically a weather station will have one of each. Indications are that the situation is similar in El Salvador and Nicaragua.

The heliometer is a simple, light-sensitive on-off switch that records the total hours of bright sunshine per day. This information can be of some value in the design of solar energy collection devices but the information that can be deduced by knowing the hours of bright sunshine is only approximate. In addition there is the question as to what degree of illumination distinguishes bright sunshine from partial overcast. In general, the data generated by the heliometer is of limited value in solar energy applications.

The actinometer is an instrument designed to measure the instantaneous solar radiation incident upon a horizontal surface from the entire sky dome. All of the instruments examined were manufactured by the now defunct German firm, Feuss. These instruments rely on the differential expansion of two bimetallic strips, one white and one black, for the sensing of solar radiation. These differential expansions move a pen that indicates the amount of solar radiation on a spring driven strip chart. These charts must be manually integrated to obtain daily or hourly totals.

This type of instrument has seen wide usage throughout the world. Unfortunately the accuracy of the data that the actionometer yields can vary greatly depending on the care with which it is maintained and calibrated. A particular well cared for instrument will have accuracies varying from ± 20% to ± 50%. This lack of reliability is due to the following problems:

1) The calibration constant is a function of ambient temperature and wind velocity.

2) These instruments are non-linear and calibration is a function of solar elevation and azimuth.

3) The mechanical movement of the bimetalic strips often causes flaking of the white and black paints and thus a change in calibration.

4) The instrument is not sealed and conditions of high humidity can cause deterioration of the painted surfaces and corrosion, hence change in calibration.

Because of these problems actinometers are not relied upon today by those who are seriously planning solar energy programs. Despite this, the data base that these instruments have produced may be better than none at all, as will be explained later in this section.

In addition to the doubtful accurancy of the instruments there is some question as to the methods used in compiling the information they have generated. To date not enough investigation has been done to determine if this has had an additional negative impact on the quality of the data base.

This survey has revealed that the Honduran based Committee on Regional Hydraulic Resources (CRRH) has, in cooperation with other groups, proposed a regional weather data acquisition network to compile and improve solar radiation data. Contact with this group is planned and their activities should be coordinated with those proposed for ICAITI.

B. Types of solar radiation data needed

The types of information needed in solar energy design may be broadly classified into two areas - that needed for simple systems and that needed for complex systems. Having established these two broad categories one must next inquire as to what degree of accuracy is necessary. The American scientific community has set the goal of + 2% and it is our feeling that a similar goal be set for any new network established in Central America. This goal is obtainable with the systems described below:

Simple solar data acquisition systems

In order to design and evaluate the performance of simple solar systems such as

non-tracking water heaters, solar dryers and solar stills the following information is required:

1) Total hemispheric solar radiation
2) Air temperature
3) Relative humidity
4) Wind velocity

The device typically used in modern weather stations to record total hemispheric solar radiation is Pyranometer. A Pyranometer more accurately records the same information as an Actinometer because it works on a more dependable principle. Thermocouples are employed in the Pyranometer which produce a direct current voltage proportional to the incident radiation. The correction for solar altitude and azimuth is also more reliable than in the Actinometer.

The instruments presently employed in the Central American countries for temperature humidity and wind velocity appear to be of reasonable accuracy and would provide information of sufficient quality for simple solar energy systems.

Complex solar data acquisition systems

In predicting the performance of concentrating collectors, heating and cooling systems in large buildings, and for computer modeling of any solar system it is necessary to know the energy incident on a surface perpendicular to the sun's rays on an hourly basis. The device used to take this measurement is called a Pyroheliometer. To get hourly data the usual practice is to employ a small integrating computer that records the information on magnetic tapes. A complete complex system weather station would then consist of the Pyroheliometer and the electronic devices needed to process and record the data as well as the instruments described in the previous section.

The temperature, humidity and wind device in place in the Central American countries are neither accurate enough nor do they produce information in the proper format for the design of complex solar energy systems. Thus, in order to obtain meaningful data for the more complex systems, it would most likely be necessary to replace entire weather stations as well as install Pyronometers and Pyroheliometers.

C. Recommendation for a solar radiation network

1) Management and administration

The most important factor in any weather network is management and administration. It is recommended that at least one professional level

person be employed as overseer of the system and that he be assistedby a technician employed on a half-time basis.

2) Installation

It is recommended that the installation of all these devices be supervised by an American consulting concern specializing in solar data acquisition. It is felt that is necessary because of the lack of experience of the Central American in meteorological organizations with Pyranometers. In addition the manner in which a Pyronometer is installed at a specific site can have a great effect on the quality of the data it yields and thus it should be supervised by an experienced individual. Finally this consultant will be needed to establish uniform compiling procedures to insure that the data is of uniform quality. This is a time consuming job and it is felt that 65 man-days are necessary.

3) Calibration

It is recommended that all instruments be calibrated initially at six-month intervals for the first two years andthen annually or as experience dictates.

It will be necessary to establish a central calibration facility to provide high quality service to the deployed instruments. This facility may be managed by the professional described above and run by his technician - assistant. The equipment needed at the facility will consist of an Absolute Pyroheliometer, Oscilliscope, digital voltmeter and other related instruments. The cost of establishing this facility will be approximately $ 29,000 including shipping the instruments twice annually to the central station.

It is possible to ship the instruments back to the United States for calibration but this would imply additional expense and delay. In addition having one Pyroheliometer operating in Central America will make it possible to generate more accurate mathematical transformations for predicting the solar radiation incident on an arbitrarily oriented surface.

To minimize network down time it is recommended that 20% more instruments be purchase then are actually installed in the field to act as replacements in case of malfunction and as loaners at calibration time.

4) Instrumentation

It is recommended that twelve solar radiation field stations be purchased consisting of the following:

1) Pyronometer $ 1,000

2)	Multipoint strip Chart Recorder	$	4,000
3)	Equipment Racks & Instrument Moutings	$	500
4)	Power Supply Modification (to provide auxiliary power at electrified sites and primary power at isolated sites)	$	1,000

This instrument package is designed as a reterofit to the existing weather stations to provide accurate radiation data for the design of simple solar energy systems. A more complex instrumentation package including a Pyroheliometer is not recommended due to the budgetary constraints of the project. In addition deployment of this less complex system will provide valuable experience to the meteorological organizations with modern radiation measuring equipment and also establish a network infrastructure so that more complex instruments may be deployed at a later date.

The advantages of locating this package at the existing weather station locations are the following:

1) Personnel are already available for the daily maintenace routines.

2) By comparing the outputs of the Actionmeter and Pyranometer for one year it may be possible to produce mathematical expressions that can be used to correct the error in the historical data of the Actionmeter. As a consequence instead of having to wait five year to get reliable picture of the local solar radiation climate it may be possible to get a slightly less accurate picture within 1 1/2 years of installation.

The computer programs needed for this rehabilitation are well proven in the United States and it is recommended that a consulting firm specializing in this field be employed in this attempt. These programs statistically analyze the simultaneous data of the two instruments to generate the correcting equations. The cost of this service for the twelve stations is approximately $ 15,000.

In the decision to recommend twelve stations a number of factors had to be considered. The primary consideration was the budgetary allotment for hardware but also considered were questions of the cloudiness zones of the region, the present locations of the actionometer weather stations and the population distribution.

To date the computer generated average cloudiness maps that are available from NASA have not been thoroughly analyzed. As a consequence selecting the proper weather station sites may not be done yet. This will be included in the second phase of this project.

Our preliminary analysis of the present Actinometer locations relative to the population centers of Guatemala, Honduras, El Salvador and Nicaragua indicate that twelve installations are sufficient to establish the solar radiation climate of these countries. Panama and Costa Rica have been excluded because other programs have been planned to update their networks.

D. Conclusion

This report has analyzed the solar radiation data available in the Central American countries and concluded that the data base is unreliable and inadequate for the widespread exploitation of solar energy.

A high quality network has been recommended that will produce a reasonably accurate picture of the region's radiation climate within 1 1/2 years of deployment a a scientifically acceptable picture within five years.

IV. MANAGEMENT AND ORGANIZATIONAL DESCRIPTION

Introduction

This section explains the results of Solar America's efforts in establishing an organizational design for this project. Also included is the the training program required to achieve the necessary level of expertise for this project among ICIATI personnel.

IV. MANAGEMENT AND ORGANIZATIONAL RECOMMENDATIONS

A. ORGANIZATIONAL STRUCTURE

The organization for the ICAITI element of the project (see organizational chart, Figure 2) will be as follows:

ICAITI Director: The top managerial responsibility for all ICAITI projects is at the director level. About 5% of his time will be devoted to this project. The present Director is Lic. Francisco Aguirre.

ICAITI Deputy Director and Technical-Industrial Services Division Head: The major managerial decisions and direct project operations will be coordinated between this position and the Assistant Technical Industrial Services Division Head. About 20% of the Deputy Director's time will be devoted to this project. The present Deputy Director and Division Head is Ing. Ludwig Ingram.

Project Manager - ICAITI Assistant Technical-Industrial Services Division Head: The Technical Industrial Services Assistant Head will be the overall project manager. Program planning, implementation, operation and administration will be at this level. He will have line responsibility over the three project teams and all staff assigned to the project. He will also be the principal communication link with the CATIE project element Manager and the ROCAP Project Manager, and will be responsible for coordinating outside technical assistance. About 60% of his time is expected to be devoted to this project. The present Technical-Industrial Services Division Assistant Head is Ing. Justin Whipple, Mechanical Engineer.

Project Operations Manager: The project operations manager will report to the project manager but will be responsible for the day to day operation of the project, and coordination with the national counterparts and volunteer groups involved in the project in the specific countries. This is a newly created full-time ICAITI position for project implementation.

Technology Dissemination Assistant: The technology dissemination assistant will be responsible for field coordination and evaluation of the demonstrations to be carried out in the different countries. This person will provide the sociological input and will work closely with the technical teams from design and selection of the equipment to be demonstrated and tested, through evaluation of acceptability in the

ICAITI PROJECT ORGANIZATIONAL CHART

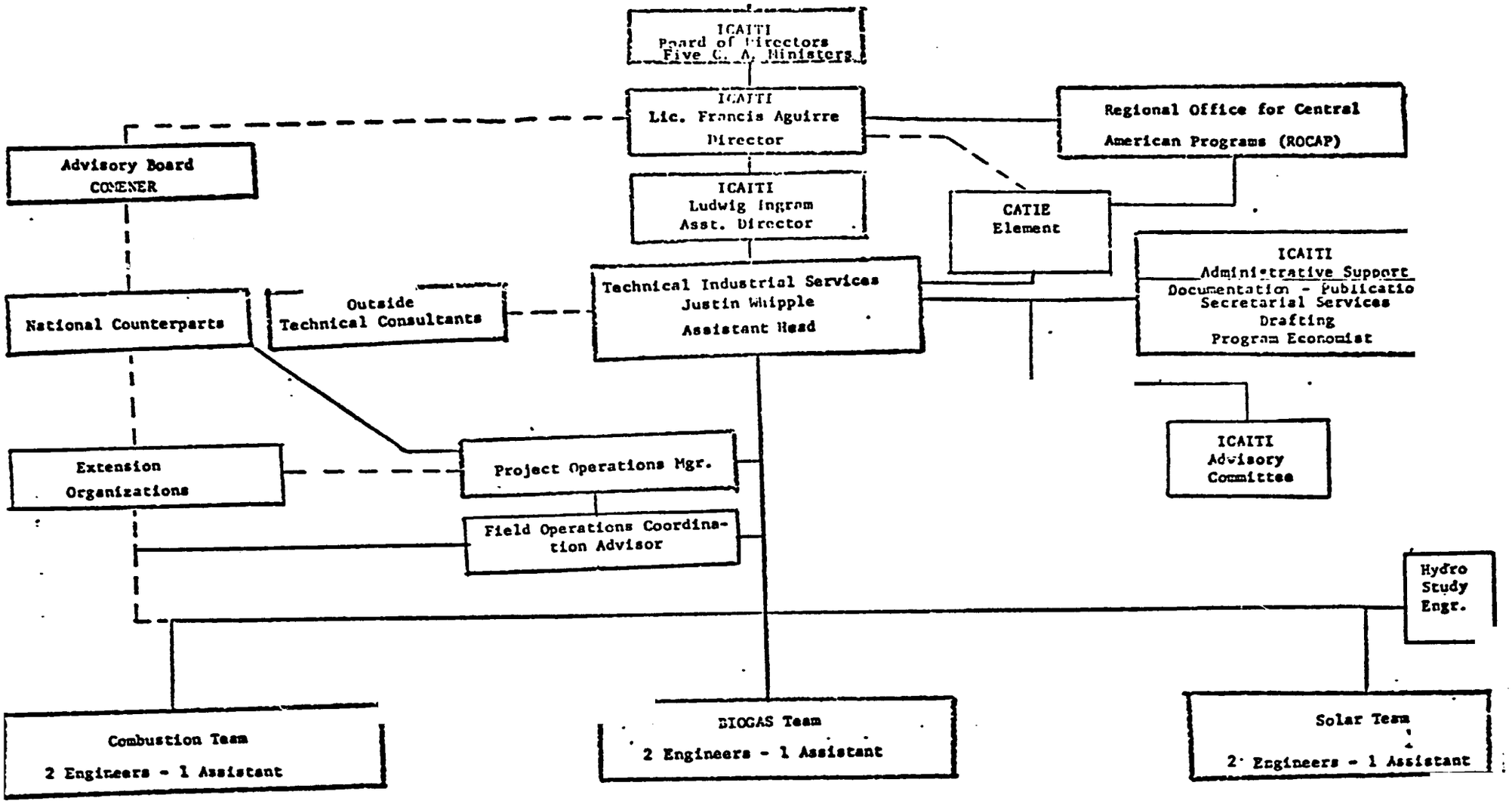


Figure 2

field and dissemination coordination specifically in the three critical areas.

Technical Teams: Each technical team will consist of a chief engineer, one or two additional engineers, and an engineering assistant. Each team will be assigned a specific technical area and will conduct investigations, develop/design, construct, test, and demonstrate their technology as programmed. The teams will provide continued technical assistance to counterparts in the expected counterpart dissemination.

The teams and their principal activities are:

i. Fuelwood Efficiency Team - 2 Engineers and 1 Assistant.

   This team will work on technical aspects of domestic and industrial efficiencies testing, adaptation, demonstrations, and evaluation. A reduction to one engineer and assistant is planned by the end of the second year of the project.

ii. Appropriate Technology Team - 2 Engineers and one Assistant.

   This team will work on the technical aspects of biomass, biogas, and pyrolysis (and charcoal making) including adaptation of designs, testing, demonstrations, and evaluation.

iii. Solar, Hydro, and Solar Data Collection Team - 3 Engineers and one assistant.

   This team will work on the technical aspects of solar plans, designs, demonstrations, and evaluation, development of national solar data collection systems, and assistance to the national governments in evaluating the potential of mini and micro hydroelectric generation and possible local manufacture of such equipment.

ICAITI Advisory Committee: ICAITI has organized an internal Advisory Committee. This committee is chaired by the project manager and has, as members, the heads of each of the major ICAITI divisions. Their function is to review progress and advise on program management and project implementa-

COMENER: This is a regional energy program development organization. It is being organized at the ministerial level and will become the Central America energy policy coordinators for the region. At present, the organization is in the organizational stage and is not expected to have a major input in the program. However, ICAITI will maintain contact with COMENER as this organization plans energy development strategies and policies.

National Cooperators and In-Country Organizations:

Throughout the five year project period, various national and international counterpart organizations will collaborate with ICAITI in carrying out the project tasks. Their effort is expected to cover the following:

- Continuous liaison for information and planning
- Work directly with ICAITI line personnel in field investigations
- Provide assistance in the selection of specific sites for demonstration units, and obtain official permits as required
- Take direct responsibility, with ICAITI's technical supervision, for the construction and operation of all demonstration units
- Joint sponsoring, with ICAITI, of regional seminars
- Provide personnel, and pay all costs for their participation in regional seminars, and in ICAITI workshop sessions
- Undertake wide scale dissemination of proven new technologies after completing the demonstration projects

The following institutions, capable of participating in some or all of the above tasks, have been considered for this collaboration:

Guatemala: University of San Carlos, Peace Corps, VITA, United Nations Central American Energy Program, Mesoamerican Center of Appropriate Technology Studies (CEMAT); Choquí Experimental Station, Solar Energy Association of Guatemala,

Instituto de Fomento Municipal (INFOM), Fundación del Centavo, Desarrollo de la Comunidad, INAFOR, Oficina de Planificación Económica.

El Salvador: University of El Salvador, Catholic University, Rio Lempa Energy Commission (CEL), United Nations Central American Energy Program, CENAP, Peace Corps, VITA, Solar Energy Association of El Salvador, Banco de Fomento Agropecuario, CENTA.

Honduras: Corporación Hondureña de Desarrollo Forestal (COHDEFOR), National University, United Nations Central American Energy Program, Peace Corps, VITA, Centro de Desarrollo Industrial (CDI)

Nicaragua: National University, INVIERNO, Fundación Nacional de Desarrollo (FUNDE), United Nations Central American Energy Program, Peace Corps, VITA

Costa Rica: National University of Costa Rica, University of Costa Rica, National Board of Scientific and Technological Investigation (CONOCIT), Centro de Investigación de Tecnología de Alimentos (CITA), Instituto Costarricense de Electrificación (ICE), United Nations Central American Energy Program, Peace Corps, VITA

Panama: Hydraulic Resource and Electrification Institute (IRHE), Panamanian Institute for Agricultural Research (IDIAP)

Although ICAITI will contact, directly, all of the above organizations, their services for each specific application will be requested through the offices of the national coordinators of the United Nations Central American Energy Programs, who are thoroughly familiar with regional energy problems and with the relative capabilities of the local organizations presently active in this field. The criteria for selection of the field counterparts will be that they are extension oriented, are able to provide personnel to receive training in the technologies or systems to be introduced, assist in construction of the demonstrations, and follow-up in monitoring the demonstrations.

The coordinators in four countries who already have expressed their willingness to cooperate with ICAITI in this project, are the following:

Guatemala	Ing. Jose Luis Terrón C.,	Jefe del Area de Energía of GOG Planning Office
El Salvador	Ing. Eric Casamiquela	Executive Deputy Director of the GOES Electric Institute (CEL)
Honduras	Ing. Jose Angel Bobadilla	Consejo Superior de Planificación Económica
Costa Rica	Ing. Mario Barboza S.	Infrastructure Dept. National Planning and Coordination Division

Depending upon the political situation in Nicaragua, the coordinator in that country may be Ing. Alejandro Guerrero, manager of Planning Systems of National Electric Co. (ENALUF).

ICAITI, through SIECA, will also maintain continuous contact with the national COMENER organization which is expected to participate more directly in the project in the later years, possibly substituting the National Coordinators of the United Nations program.

Since Panama will have an AID financed Renewable Energy Sources,ICAITI will maintain contact with that program, through IRHE, or possibly using the services of the Panamanian collaborator for the United Nations Energy Program, Lic. Beatriz Ordaz de Rodríguez, to arrange a continuous interchange of technological information. It is expected that at least domestic stove demonstrations will be carried out in Panama with counterpart assistance. Also Panamanian organizations will participate in the Regional Seminars under the project.

Peace Corps: ICAITI will have one peace corps volunteer in each country to work with national counterparts in construction of the demonstrations, evaluation, and dissemination in the critical areas.

Outside Consultants: Because of the program's wide range and diverse technologies and their application, funds have been allocated for short-term technical assistance to ICAITI over the life of the project.

Project Staffing

The present staffing of the ICAITI Technical-Industrial Services Division and the Applied Research Division are as follows:

Technical-Industrial Services Division

Justin H. Whipple	Deputy Head, Mechanical Engineer
Oscar Gil Girón	Chemical Engineer
Orlando Posadas V.	Chemical Engineer
Raúl Pingarrón B.	Electro-Mechanical Engr.
José Manuel Recinos	Economist
Luis F. Cifuentes	Economist
Bertha E. Barrios	Economist
Heinz Walter	Textile Engineer/Industrial Economist
Marco Antonio Castañeda	Technician - Draftsman
Estela González	Secretary
María del Carmen Parada	Secretary
Lidia Hrstka de Valladares	Secretary

Applied Research Division

Carlos Rolz	Chemical Engineer
Juan Francisco Menchú	Chemical Engineer
Sheryl de Cabrera	Microbiologist
Roberto de León	Bio-Chemist
Elizabeth de Porres	Food Technologist
Edna Isabel Morales	Bio-Chemist
Ricardo García	Chemical Engineer
Francisco Calzada	Chemical Engineer
Jaime Valladares	Industrial Chemist, PHD
Carlos Porres	Chemical Engineer
María del Carmen de Arriola	Bio-Chemist
Fabiola Micheo	Pharmaceutical Chemist
Oscar Maldonado	Chemical Engineer

Carlos Segura	Technician
Guillermo Pérez	"
Federico Chavarría	"
Carlos Iván Arriola	"
Williams Guillermo Alvarez	"
Gustavo Adolfo Herrera	"
Juan Francisco Alonzo	"
Jesús de María Silva	Laboratory Technician
Rafael Ramírez	" "
Norberto González	" "
Roberto Castañaza	" "
Carlos Eduardo Rodríguez	" "
Carlos Humberto Arias	" "
Edgar Rolando Pineda	" "
German Cecilio López	" "
Cecilio Antonio Coronado	" "
Marie Eugenia Ayala	Secretary
Patricia de León	Secretary

For the proposed project, five existing ICAITI personnel are to be assigned directly to the project and will be AID financed. This includes two full-time Chemical Engineers from the Applied Research Division and one mechanical engineer. The mechanical engineer will be available for the project since his present activities end in October. The two chemical engineers will be replaced in the Applied Research Division, funded from other sources. A Technical-Services Division economist and the draftsman will be partially funded by AID based on the time they are expected to spend on the project.

In addition to the above, the ICAITI proposed project staff will be increased by the following AID financed staff:

Project Operations Manager
Technology Dissemination Assistant
Two Chemical Engineers
Two Mechanical Engineers
Three Engineering Aides
Secretary

B. PROJECT PERSONNEL TRAINING

ICAITI Personnel Training

One of the objectives of this project is to assist ICAITI to further develop their technical capability in fuelwood efficiency, solar energy, biomass, biogas, and other alternative energy sources. ICAITI should train their personnel to carry out the project scope of work and to eventually become the alternative energy technical center in Central America.

S.A.I. recommends that the ICAITI technical personnel training program be divided into short term and long term training. The long term training would provide the ICAITI engineers the opportunity to take post-graduate courses in alternative energy programs at U.S. universities. Upon their return, they would become a major element in ICAITI's technical staff. This long term training would be for one or two years of graduate studies leading to Masters degrees in Solar Energy Engineering, Combustion Engineering, and Alternative Energy Systems. There are several U.S. universities offering degree programs in the above areas who would design study programs as requested by ICAITI.

The short term training would allow the ICAITI technical team members to attend periodic seminars and conferences in their interest area. The short courses would be sponsored by qualified U.S. universities or institutions in combustion, biomass, biogas, solar, and developing alternate energy technologies. Besides the more formal, institutionally sponsored seminars and conferences, it is recommended that the ICAITI engineers visit other demonstration sites for "hands-on training". While in the U.S. and after their more formal training, they should work with the consultants to order the necessary equipment and select the most appropriate designs to take back for their demonstration projects.

There are several universities, training institutions and private groups which offer degree programs and short courses applicable to this project. Some of them are:

Solar Energy

- Solar Energy Institute
  New Mexico State University
  Las Cruces, New Mexico

  Offers undergraduate and graduate degrees in Solar Engineering. Focus is on all solar application. Emphasis on practical, cost effective technology. Offers seminars and workshops on a scheduled basis.

- Colorado Sunworks
  Box 455
  Boulder, Colorado

  Offers periodic workshops in Solar Technology and Solar Design.

- University of Colorado
  Center for Management and Technical Programs
  Boulder, Colorado

  Offers a 3-day course on solar heating systems.

- University of Wisconsin - Extension
  Department of Engineering
  Madison, Wisconsin

  Offers a 5-day course in solar energy for engineers.

Pyrolytic Conversion and Charcoal Production

- Economic Development Laboratory
  Georgia Institute of Technology
  Engineering Experiment Station
  Atlanta, Georgia

  Offers training in areas of applied research and technology.

Biomass Development

- National Center for Appropriate Technology
  Box 3838
  Butte, Montana

A U.S. government sponsored organization offering assistance in small, appropriate technology applications.

Biogas

- Jordan College
  Cedar Springs, Michigan

  Offers seminars, workshops and degree programs in Alternate Energy (in general).

- Biofuels Co.
  Box 609
  Noxon, Montana

  Offers workshops and on-the-job training workshops in biogas production.

- New Alchemy Institute
  Woods Hole, Mass.

- Brace Research Institute
  MacDonald College of McGill University
  Ste. Anne de Bellevue
  Quebec, Canada

  Periodically offers workshops on small scale device and low technology applications.

- New Mexico State University
  Agricultural Engineering Dept.
  Las Cruces, New Mexico

There are, undoubtedly, many other individuals or groups which offer courses or degree programs which would be beneficial to ICAITI during the proposed project.

It is recommended that the ICAITI management work closely with their U.S. technical consultants to determine which institutions offer the most appropriate courses and would provide specially tailored courses upon request. (New Mexico State University is designing an alternative energy workshop and seminar program for a group from Panama).

National Counterpart Training

It is recommended that the national counterpart training be accomplished through three methods:

a. Workshops on theory, technology, applications, and fabrication/construction techniques, for those individuals who will be directly involved with the various demonstration projects; The workshops would be ICAITI sponsored and held after the first prototype(s) have been built and tested.

b. On-the-job training by ICAITI personnel and outside consultants during the construction/installation and testing of the demonstration units; This training is for national counterparts, volunteer personnel, and other individuals within their respective countries. This training will be "hands-on" training where the individuals trained in the workshops will actually construct the demonstration units under the supervision of the ICAITI technical personnel.

c) As each group of demonstrations is completed and demonstrated, regional seminars should be held to present the results and for programming further widespread dissemination by the national counterpart organizations and volunteer groups. At least six regional seminars covering all of the proposed new technologies should be programmed for the 3rd, 4th, and 5th. Visits to demonstration sites will be organized where practical. During these regional seminars plans will be formulated for program continuation after the fifth program year and expanded dissemination.

V. IMPLEMENTATION PLAN FOR THE RECOMMENDED TECHNOLOGIES

Introduction

This section describes the plan for identifying, selecting, constructing, testing, demonstrating and disseminating the technologies that have been recommended.

The organization of this section follows the implementation chart shown in figure 3.

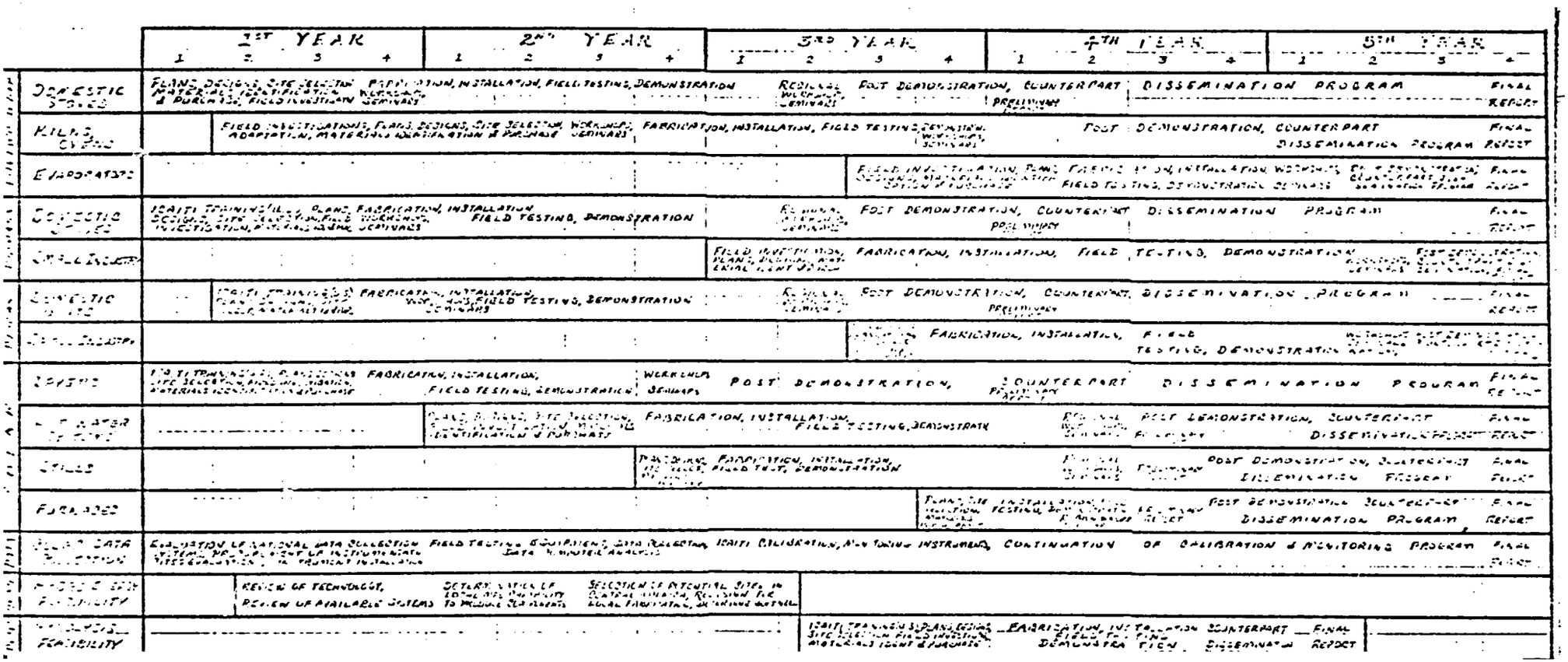


Figure 3: Implementation Chart

A. FUELWOOD EFFICIENCIES

1. Domestic fuelwood efficiency

- ICAITI will design a training program and will hire a contract combustion engineer who will work with ICAITI in the initial planning. This technical team will acquire existing data and designs which are applicable to low-cost domestic stoves for cooking.

Testing phase

- ICAITI will carry out controlled laboratory testing of existing low-cost cooking stoves. Modifications will be made as required to increase the efficiency of individual stoves. The most appropriate low-cost cooking stove from this group will be selected for field testing.

Field testing

- ICAITI will utilize the Peace Corps and/or local counterparts and will carry out a training program in the utilization and operation of the appropriate cooking stoves. The testing will be done under field conditions prior to demonstration.

Final site selection

- ICAITI will make determination of the final site selections for the domestic demonstration units.

Demonstration and testing

- Under ICAITI supervision, the demonstration units will be constructed in the five countries by the Peace Corps and national counterparts. These units will be operated, tested, and continuously evaluated over a 12-month period.

Regional seminars

- ICAITI will hold regional seminars and give demonstrations in the five countries. ICAITI will offer instruction in the preparation and plans for the appropriate cooking stove for each country.

- ICAITI and the dissemination technician will prepare operating manuals to be utilized by the national counterparts.

Dissemination and critical areas testing

- The national counterparts will work with the in-country volunteers for the five countries in carrying out the national dissemination relative to the appropriate cooking stove. Preliminary data and feedback information will be collected by ICAITI.

Preliminary report

- ICAITI will prepare the prliminary report. The report will include a summary of all data and feedback information collected from the field experience within each of the five countries, plus the critical areas. The preliminary report will address such items as user acceptance, user utilization, domestic practicality, and efficiency for fuelwood use and for man-hour involvement by user.

Continued in-country dissemination

- The various volunteer and national dissemination groups will continue to give demonstration presentations in each of the five countries to disperse information relative to the appropriate cooking stoves and related fuelwood efficiency and user utilization.

Update, final report

- ICAITI will prepare a final report on domestic fuelwood efficiency. This report will include the 3rd year preliminary report and also all data and survey information up to this time. All possible feedback from users will be tabulated for inclusion in this report. This final report should address such items as acceptance, utilization, practicability, and fuelwood efficiency for domestic cooking stove application.

2. Industrial fuelwood efficiency

Training, planning

- ICAITI will design and plan a training program which will involve the services of engineers, Peace Corps, and/or national counterparts. This program will relate to fuelwood efficiency as it applies to industrial applications, such as with kilns and ovens. The training will not involve the technical contractor providing on-the-job training and seminars for ICAITI and national counterpart personnel.

Technical field investigations

- ICAITI will go to field sites and make investigations of existing efficiencies and design characteristic of brick kilns, lime kilns, ceramic kilns, bakery ovens, salt evaporators, panela cookers, and other related high heat demand processors. Peace Corps volunteers and/or national counterparts will be involved.

- Technical consultants will give guidance to the ICAITI staff in the analysis of the technical field investigation.

Adaptation and modification

- ICAITI, with guidance from technical consultants, will make adaptation and modification for the purpose of improving the fuelwood efficiency in design for the kilns, ovens, cookers, and other heat-process apparatus.

National training

- ICAITI, with assistance from technical consultants, will provide the instructional program for the national counterparts. This program will prepare the counterparts for the scope of work dealing with the application of fuelwood efficiency designs and techniques appropriate to each heat-process apparatus.

Demonstration and testing

- ICAITI and the national counterparts will adapt five units for fuelwood efficiency demonstration, including (1) one brick kiln in Guatemala, (2) one lime kiln in El Salvador, (3) one village ceramic kiln in Guatemala, (4) one industrial ceramics kiln in Guatemala, and (5) one bakery oven in Nicaragua. The technical consultants will assist in the demonstration and in the testing and evaluation process.

Evaporators

- ICAITI and the national counterparts, assisted by technical consultants, will set up two additional demonstrations in fuelwood industrial efficiency design: (1) one salt evaporator and (2) one panela cooker. This project section will start the third quarter of the third year and will continue to the end of the fifth year.

Dissemination seminars

- ICAITI, with guidance of technical consultants, will hold seminars at the demonstration sites for the purpose of instructing the involved personnel in fuelwood efficiency designs and operating techniques. ICAITI will prepare plans, designs, and operating manuals for in-country field utilization in fuelwood efficiency for appropriate apparatus.

National dissemination

- ICAITI and the in-country volunteers and national counterparts will prepare and implement the dissemination for fuelwood efficiency in kilns and ovens applicable to each country.

National training, salt and panela projects

- ICAITI will establish an instructional program for the purpose of training of the national counterparts in the designs and techniques for increasing fuelwood efficiencies in salt evaporators and panela cookers, concurrently with the preceding national dissemination program with kilns and ovens.

Demonstration and testing

- ICAITI, with assistance of the technical consultants, will set up two demonstrations adapted to existing operations. (1) one panela cooker in Guatemala, and (2) one salt evaporator in Honduras, will each be adapted to utilize the preliminary designs for increased fuelwood efficiency.

Preliminary report, kilns and ovens

- ICAITI will prepare a final report on improvement of fuelwood efficiency related to the kiln and oven demonstration projects. The preliminary report will address cost-effectiveness of modifications, practicability, and user utilization of the efficient designs.

Dissemination seminars

- ICAITI will hold seminars at the salt evaporator and panela cooker sites for the purpose of instructing the involved personnel in fuelwood efficiency designs and techniques. ICAITI will prepare plans and operational manuals for in-country field utilization in related fuelwood efficiency.

Final report

- ICAITI will prepare a final report on the fuelwood efficiency projects. The final report should address such factors as user acceptability, adaptability of designs, cost and time effectiveness, and fuelwood efficiency projections.

B. BIOMASS

Training of ICAITI engineers

- ICAITI engineers, under the guidance of technical consultants, will be placed and instructed by appropriate technical institutions and/or individuals familiar with the technology currently addressed ---biomass conversion for domestic and small industry, and/or village applications.

- ICAITI engineers, upon completion of training and with technical consultants, will plan and design the first domestic prototype biomass conversion unit. This team will identify equipment and materials necessary to construct the first unit.

1. Domestic biomass

Site selection and prototype construction

- ICAITI engineers, with consultants, will locate and purchase equipment and materials for constructing the first domestic biomass conversion unit.

- ICAITI, with the technical consultants, will construct the prototype.

Prototype testing, evaluation, and modification

- ICAITI will test and evaluate the prototype, and make appropriate modification when necessary.

- ICAITI will develop final design for the construction of the additional domestic units. Additionally, ICAITI will develop all training materials.

Identification, seminars, training, for Central American participants

- ICAITI, with national collaborators, will identify sites and participants for the development and implementation of the domestic biomass units.

- Upon completing the site selection, ICAITI will send out a team of technicians to each participating country and construct an initial in-country domestic unit. This construction phase will be used as part of the in-country instruction.

Implementation of demonstration units

- ICAITI and participating countries will construct, evaluate, and demonstrate the domestic units. ICAITI will offer technical assistance to its counterparts, and it will serve as the regional clearing house for all matters pertaining to the project, including the evaluation of the demonstration units.

Training of in-country outreach organizations

- Participating countries, in conjunction with ICAITI will provide seminars and training to the outreach organizations in Central America (i.e., Peace Corps). The outreach organization will be provided with technical assistance as required.

Preliminary report

- ICAITI will prepare a preliminary report on the domestic biomass conversion project. The report should address project effectiveness, practicality, cost, utilization, etc.

2. Industry/village biomass

Site selection and prototype construction

- ICAITI engineers, with technical consultants, will plan and design the first small industrial biomass conversion unit. This team will also identify equipment and materials necessary to construct the unit.

- ICAITI engineers, with the technical consultants, will locate and purchase equipment and materials for constructing the first industrial biomass conversion unit.

- ICAITI, with the technical consultants, will select the appropriate site for the construction of the first prototype.

- ICAITI, with the technical consultants, will construct the prototype.

Prototype testing, evaluation, and modification

- ICAITI will test and evaluate the prototype and make appropriate modification when necessary.

- ICAITI will develop final designs for the construction of 11 additional small industrial and/or village units. Additionally, ICAITI will develop all training materials.

Identification of Central American participants, regional seminar, and training

- ICAITI, with national collaborators, will identify participants and sites for the development and implementation of 11 small industrial and/or village biomass units.

- Upon completing the above, ICAITI will send a team of technicians to at least two (2) participating countries and construct the initial units. Participants from other countries will be invited to participate during the construction phase which will be part of the instructional package.

Implementation of demonstration units

- ICAITI and participating countries will construct, demonstrate, and evaluate the small industrial and/or village biomass conversion units. ICAITI will offer technical assistance to its counterparts in Central America, and it will serve as the regional clearing house for all matters pertaining to the project, including the evaluation of the demonstration sites.

Final report

- ICAITI will prepare a final report on the total biomass conversion project. The report should address project effectiveness, costs, practicality, utilization of units, etc.

C. BIOGAS

Training of ICAITI engineers

- ICAITI engineers, with technical consultant guidance, will be placed and instructed by appropriate U. S. institutions and/or individuals familiar with the technology of biogas conversion for domestic, small industry, or village applications.

- ICAITI engineers, upon completion of U.S. training, and with technical consultants, will plan and design the first domestic prototype biogas conversion unit. Equipment and materials necessary to construct the first unit will also be located.

1. Domestic biogas

Site selection and prototype construction

- ICAITI engineers, with technical consultants, will locate and purchase equipment and materials for the construction of the first domestic biogas conversion unit.

- ICAITI, with the technical consultants, will select the appropriate site for the construction of the first prototype.

- ICAITI, with the technical consultants, will construct the prototype.

Prototype testing, evaluation, and modification

- ICAITI will test and evaluate the prototype and make modifications as required.

- ICAITI will develop final designs for the construction of 10 domestic biogas units. ICAITI will also develop the training materials required.

Identification of Central American participants, seminars, and training

- ICAITI, with national collaborators, will identify participants and demonstration sites for the development and implementation of the domestic biogas conversion units.

- Upon completing the above, ICAITI will host a training seminar and construct at least one domestic biogas conversion unit. Participants from other countries will be invited to participate and then return and construct the units.

NOTE: ICAITI can host seminars in Guatemala City or elsewhere.

Implementation of demonstration units

- ICAITI and participating countries will construct, demonstrate, and evaluate ten domestic biogas units. ICAITI will offer technical assistance to its counterparts and it will serve as the regional clearing house for all matters pertaining to the project, specifically the evaluation and analysis of the demonstrations.

Regional seminars

- Participating countries in conjunction with ICAITI, will identify appropriate outreach organizations interested in the application of the technologies. When identified, the outreach organizations, will be provided with training and technical assistance.

2. Industrial biogas

- ICAITI, with technical consultants will plan and desing the first industrial prototype biogas conversion unit. Equipment and materials, required for the construction of the unit, will be identified.

- ICAITI engineers, with the technical consultants will locate and purchase equipment and materials for constructing the prototype.

- ICAITI, with the technical consultants, will select the appropriate site for the construction of the first unit.

- ICAITI, with the technical consultants, will construct the prototype.

Prototype testing, evaluation and modification

- ICAITI will test and evaluate the prototype and make appropriate modifications when required.

- ICAITI, with the technical consultants, will develop final designs for the construction of three (3) additional industrial and/or village biogas conversion units. Additionally, ICAITI will develop training materials required for the implementation of the project.

Identification of Central American participants, and training workshops

- ICAITI, with the national collaborators, will identify participants for the development and implementation of at least three industrial biogas conversion units.

- Upon completing the selection of the site locations and participants, ICAITI will invite participants to attend a workshop at the site where the prototype is located. ICAITI and the technical consultants will be available to provide technical hands-on technical training.

Implementation of demonstration units

- ICAITI and participating countries (3) will construct, evaluate, and demonstrate three industrial and/or village biogas conversion units. ICAITI will offer technical assistance to its counterpart and it will serve as the regional clearing house for all project matters, including the evaluation of the demonstration sites.

Training of in-country outreach organizations

- Participating countries, in conjunction with ICAITI, will provide training to the outreach organizations in each country which could best reach the target audience (industry and village). ICAITI will provide technical assistance to the outreach organizations when required.

Final report

- ICAITI will prepare a final report on the industrial and/or village biogas conversion project. The report should address project effectiveness, practicality, costs, utilization, etc.

D. SOLAR ENERGY

U.S. Training of ICAITI engineers

- ICAITI engineers, under the guidance of the technical consultants, will be placed and instructed by appropriate technical institutions and/or individuals familiar with solar energy technology applications. The training will specifically address solar drying, solar water heating, solar distillations, solar furnaces, solar data gathering and evaluation, and their application to industrial, village and domestic use.

1. Solar dryers

Site selection and prototype construction

- ICAITI engineers, with technical consultants, will plan and design two industrial solar dryers, and will identify equipment and materials necessary to construct the prototypes.

- ICAITI engineers, with technical consultants, will locate and purchase equipment and materials for constructing the two industrial solar dryers.

- ICAITI, with the technical consultants, will select the appropriate sites for the construction of the units.

- ICAITI, with technical consultants' assistance, will construct the industrial solar dryers.

Prototype testing, evaluation, and modification

- ICAITI will test and evaluate both prototypes, and make appropriate modifications when necessary.

- ICAITI will continue to test and evaluate prototypes and make appropriate modifications.

- ICAITI will develop training material to be used to train outreach organizations in Central American countries.

Identification of Central American participants, seminars, and training

- ICAITI, with national collaborators, will identify outreach organizations in each country which have the capacity to reach the specific target audience that would benefit from this activity (i.e., panela industry).

- ICAITI and host country will hold one seminar per site, and invite those outreach organizations as identified per country. Additionally, ICAITI should make available, on-site training to these countries where sites are non-existent.

Training of in-country outreach organizations

- Participating countries, in conjunction with ICAITI, will provide training as discussed in the above.

- ICAITI, and the counterparts in Central America, will make every effort to assure that the technology is transferred to the appropriate target audience.

Final report

- ICAITI will prepare a final report on the Industrial Solar Dryer project. The report should address project effectiveness, practicality, cost, utilization, etc.

2. Solar water heater and solar furnace

Training of ICAITI engineers

- Completed in 1st year

Site selection and prototype construction

- ICAITI engineers, with technical consultants, will plan and/or design three solar water heating systems, and at least one solar furnace. (Pottery kiln).

- ICAITI engineers, with technical consultants, will identify and purchase the equipment necessary to assemble three solar water heaters, and at least one solar furnace.

- ICAITI, with the technical consultants, will select the appropriate sites for the installation of each unit.

- ICAITI, counterparts, and technical consultants, will install three solar water heaters and the solar furnace at the appropriate sites.

Testing, evaluation, and modification

- ICAITI will test and evaluate the prototypes and make appropriate modifications when necessary.

- ICAITI will continue to test and evaluate at demonstration sites, and develop training materials.

Identification of Central American participants, seminars and training

- ICAITI, with national collaborators, will identify outreach organizations in each country with the capability of reaching the specific target audience addressed by this activity (i.e., clinics, schools, etc.)

- ICAITI, and host countries, will hold at least three solar water heating seminars at the sites, and hold at least two solar furnace seminars at the solar furnace sites.

Training of in-country outreach organizations

- ICAITI, and participating countries, will provide technical assistance, training, etc., to those groups in each country that are interested in applying the technologies.

Final report

- ICAITI will prepare a final report on the solar water heater and the solar furnace project. The report should address project effectiveness, practicality, cost, utilization, etc.

3. Solar still

Training of ICAITI engineers

- Completed in 1st year

Site selection and prototype construction

- ICAITI engineers, with technical consultants, will plan and design two solar still units. One for removing moisture in panela production and one for salt production.

- ICAITI engineers, with technical consultants, will identify and purchase the equipment and materials required to construct two solar stills for industrial use.

- ICAITI engineers, with technical consultants, will select the appropriate sites for the construction of each unit.

- ICAITI engineers, with technical consultants, will construct two solar stills for salt and panela production.

Prototype testing, evaluation, and modification

- ICAITI will test and evaluate both prototypes and make appropriate modifications where necessary.

- ICAITI will develop all training materials necessary to disseminate information.

Identification of Central American participants, seminars and training

- ICAITI, with national collaborators, will identify outreach organizations in each country with the capability of reaching the specific target audience addressed by this activity (panela and salt industries).

- ICAITI, and host countries, will hold at least one on-site seminar at each unit, and hold at minimum one seminar on the subject in each country.

Training in in-country outreach organizations

- ICAITI, and participating countries, will provide technical assistance, training, etc., to those groups or industries interested in applying the technologies.

Final report

- ICAITI will prepare a final report on the solar still units. This report should address project effectiveness, practicality, cost, utilization, etc.

E. SOLAR DATA ACQUISITION SYSTEM

Finalization of the network plan

- A consultant will be hired by ICAITI and brought to Central America to accomplish the following:

  (1) Finalize the locations for pyranometer field sites.

  (2) Establish the initial contacts and agreements with meteorological organizations in the host countries.

  (3) Give initial instruction to the ICAITI personnel.

Equipment Procurement

- With the aid of the consultant (s) ICAITI will order the pyranometer station equipment, and calibration equipment.

Equipment Deployment

- ICAITI will again bring the consultant (s) to Central America to accomplish the following:

  (1) Supervise the set-up of the calibration equipment and procedures.

  (2) Supervice the set-up of the 12 pyranometer stations and the procedure to compile the data they generate.

Data Collection

- ICAITI will catalog and store the data generated by the pyranometers, and copies of the data produced by actinometers that are operating next to the pyranometers. It is planned that the network will be operated for the duration of the project.

Historic data rehabilitation

- ICAITI will employ an American consulting firm, to compare the data from the two instruments. This service will rehabilitate the historic data from the actinometer to a higher level of accuracy.

F. SMALL SCALE HYDRO ENERGY FEASIBILITY STUDY

Preliminary

- ICAITI engineers, will be instructed by the appropriate individuals and/or institutions familiar with small scale hydro-electric generation process applicable to small community and village utilization in Central America.

Technology Review

- ICAITI and the technical consultants will review all available previous hydro-electric development involving small-scale application in the "micro-hydro" and "mini-hydro" ranges. A search and review of all available systems and/or technological designs will be conducted for the purpose of making evaluations of those systems which may be most appropriate for Central America. Factors to be investigated include sophistication, cost, efficiency, reliability, and all other items which apply to the cost effectiveness of small scale hydro-electric application for Central America.

Production Analysis

- ICAITI and the technical consultants will make an indepth study and identification of all materials and components which may be used in the fabrication of small scale hydro-electric generation stations. This should be based on the results of the technological review and the types of hydro units deemed to be most appropriate. Sources, availabilities, and costs will be major considerations in the identification process. Local manufacturers and fabricators will be visited for the purpose of making evaluations of in country manufacturing capability. Both individual and collective manufacturing capabilities will be considered in this analysis.

- ICAITI, with the assistance of technical consultants, will make detailed study and establish criteria for the selection of potential sites for small scale hydro-electric generation stations in Central America. This study will include a search of all available literature and documentation on hydro-electric potential combined with extensive field study investigations. The purpose of this study is to identify all potential hydro energy sites, and to prepare a compilation of the sites along with all pertinent energy data.

  From the site data, several small scale hydro stations should be designed so that manufacturing and fabrication costs can be accurately determined for the financial analysis of potential installations. It is assumed that the site data will be extensive and will therefore require a reduction to an appropriate listing of sites most applicable

to the end-users. Included in the reduction listing will be the input from a concurrent study of government needs and the site relationship to present and planned national electric grids.

Final report and presentation of final report

- ICAITI engineers and the technical consultants will prepare a final report of their findings, conclusions, and recommendations.

- A regional seminar should be scheduled to present the final report to all participating countries, regional organizations and international organizations. During this seminar, plans should be formulated for implementation of the report's recommendation.

G. CHARCOAL & PYROLITIC CONVERSION

Training of ICAITI Engineers

- ICAITI engineers, under the guidance of the technical consultants, should be placed and instructed by appropriate technical institutions and/or individuals familiar with pyrolytic conversion units and charcoal kilns for small industry application.

- ICAITI engineers, upon completion of the training and with technical consultants, should design the pyrolytic conversion unit and charcoal kilns.

Site Selection and Prototype Construction

- ICAITI engineers, with technical consultants, should locate and purchase equipment and materials required for the construction of the devices.

- ICAITI, with the technical consultants, should select the appropriate construction sites.

- ICAITI, with the technical consultants, should construct the industrial prototypes.

Prototype Testing, Evaluation, and Modification

- ICAITI should test and evaluate the prototypes and make appropriate modifications when necessary.

- ICAITI should develop training literature and other materials necessary to provide adequate dissemination of the technology to Central America.

Identification of Central American Participants, Seminars and Training

- ICAITI, with the national collaborators, should identify those organizations in Central America who would be interested in pyrolytic conversion and charcoal kilns for industrial or domestic use.

- ICAITI should schedule one regional seminar on the use of pyrolytic conversion for industrial use.

- ICAITI, and the energy consultants, should provide onsite technical assistance, if the interest exists, for actual construction of additional units.

Final report

- ICAITI should prepare a final report on the industrial pyrolytic conversion project. The report should address project effectiveness, practicality, costs, utilization, etc.

VI. ENUMERATION OF FIELD TEST SITE

	Guatemala	Honduras	Nicaragua	El Salvador	Costa Rica	Total Demonstrations
Domestic and Low-Income Village Demonstrations						
Lorena, Fogon, and other efficient Stoves	5	5	5	5	5	25
Other Biomass Domestic Stoves (non-fuelwood users)	12	12	12	12	12	60
Biogas Domestic Stoves	2	2	2	2	2	10
Village WECA (10 KW)	1	1	1	1	1	5
Village Mico-Hydro	1	1	1	1	1	5
Rural Hospital Solar Hot Water Systems	0	0	1	0	1	3
Marketplace Fuelwood Replacement Demonstrations						
Biomass (garbage - hot water)	0	0	0	0	1	1
Biogas (garbage - hot water)	0	1	0	0	0	1
Solar (solar - hot water)	0	0	0	1	0	1
Village Solar Wood Dryer	0	0	1	0	0	1
Domestic - - - - -	21	22	23	23	23	112
Brick, Tile, Lime						
Efficiency Redesigned Wood Burning Brick Kiln (El Tejar)	1	0	0	0	0	1
Efficiency Lime Kiln	0	0	0	1	0	1
Biomass Lime Kiln	1	0	0	0	0	1
Blown Biomass Brick	1	0	0	0	0	1
Stalks, Bagasse Brick	1	0	0	0	0	1
Biogas Brick	1	0	0	0	0	1

	Guatemala	Honduras	Nicaragua	El Salvador	Costa Rica	Total Demonstrati
Solar Wood Dryer	1	0	0	0	0	1
Panela, Bakery, and Salt						
Panela (Biogass Conventional Dryer)	0	0	1	0	0	1
Panela Biomass - Solar Dryer	0	0	1	0	0	1
Panela Solar Still	0	1	0	0	0	1
Salt Evaporator (Redesign)	0	1	0	0	0	1
Salt Solar Still	0	1	0	0	0	1
Bakeries						
Small oven design	0	0	0	1	0	1
Large over design	0	0	0	1	0	1
Biomass	0	0	0	1	0	1
Ceramics						
Village Kiln Design	0	1	0	0	0	1
Industrial Kiln Design	1	0	0	0	0	1
Solar Kiln (Furnace)	0	0	0	0	1	1
Coffee Drying						
Biomass	0	0	0	0	1	1
Biogas	0	0	0	0	1	1
Pyrolytic						
Non Fuelwood Biomass	1	0	0	0	0	1
Industrial/Commercial - - -	8	4	2	4	3	23
TOTAL*	29	26	25	27	26	133

*Domestic & Industrial/Commercial

VII. MANUFACTURING CAPABILITY IN CENTRAL AMERICA

It is planned that all possible technological components will be manufactured, or fabricated, in Central America, with only minimal importation for those cases where local manufacture is not feasible. All demonstration apparatus will be designed for highly applicable and appropriate technology involving low sophistication which is reproducible at the domestic and small industry levels.

Basic surveys were made in Guatemala and Costa Rica, the two countries which cover the industrial spectrum of the six-country region, where metal and wood working shops were found to be in abundance. Two major such manufacturers in Guatemala were "Aceros Prefabricados" and "Aceros Prefabricados de Ramirez", the latter a quite diversified industry. Each of these companies expressed interest in any available contractual enterprises dealing with fabrication of iron and steel components and apparatus. These companies are equipped with machine tools, equipment, and manpower capable of doing metal cutting, shaping, welding, milling, etc...; practically any kind of metal manufacturing that would be demanded for fabrication.

Cost analysis was also requested from these companies, and it was somewhat determined that shopwork costs were well below those in the U.S., probably due in part to the low manpower costs in Central America.

The same general capabilities were found to exist in Cost Rica, but it appeared that the manufacturing costs were a little higher. In San Jose the equipment and machinery was more modern and sophisticated and in one case, controlled by computer input. At Cartago, the Instituto Tecnologia was outfitted with one of the most modern mechanical shops to be found anywhere, including the U.S. Very well maintained equipment included computer-operated milling machines and lathes, drill presses, hydraulic presses, punch presses, 10-foot shear and brake apparatus, and both oxy-acetylene and electric arc welders. Nothing was missing. Students used these facilities for classes during the days, and during the afternoons and evenings they were used to do contract jobs in fabrication and manufacture of all kinds of components and apparatus. These people also expessed an interest in bidding on any appropriate technology equipment fabrication jobs that might be forthcoming.

Local people were also consulted regarding the less urban fabricating capabilities. It was determined that numerous small shops exist in almost every village, throughout the country. These small operators welcome all work which they encounter, and most are very crafty from many years of improvising experiences. It can be considered practical to plan for most component

fabrication to be carried out by small shop operators, or combination of operators, around the smaller towns, whereas larger scale manufacture of quantity hardware can be shifted to the larger towns and cities.

The following table is included to give a cost basis for sample manpower and materials in Guatemala, and applicable to most of Central America, with some modification.

MANPOWER (including benefits)

laborer, unskilled	$ 3.50/day
laborer, skilled	4-7.00/day
laborer, foreman	.7-10.00/day
engineer assistant . . .	10-20.00/day
engineer, various . . .	20-50.00/day

MATERIALS COSTS, SURVEY

1.	wood, structural grade	$200/mbf
2.	wood, 1/2" CD ply	10/sheet
3.	plastic, fiberglass	0.30/ft^2
4.	plastic, pipe, 1" PVC	0.20/ft
5.	steel pipe, 1" galv.	0.60/ft
6.	sheet metal, galv.	0.40/ft^2
7.	cement, portland,	2.70/92-lb
8.	drum, used, 55 gal.	3.00/ea.
9.	sand and/or gravel	6.00/yd^3
10.	iron, re-inforcing	0.25/lb

VIII. ESTIMATED BUDGET FOR FIELD TESTS AND DEMONSTRATIONS

Introduction:

Contained in this section are the estimated direct costs associated with field testing and demonstrating the recommended alternative energy technologies by major sub-groups.

TECHNOLOGIES AND ASSOCIATED COSTS

Technology	ICAITI Personnel	Outside Consultants	Travel & Per Diem	Seminars Workshops	Equipment Materials	TOTAL
1. Domestic Fuelwood Stoves	$114,530	$ 16,200	$ 17,400	$ 10,000	$ 3,600	$ 161,730
2. Ovens & Kilns(eff.)	109,890	23,800	17,400	8,000	12,200	171,290
3. Evaporators (eff.)	65,020	17,000	14,000	5,000	3,100	104,120
4. Charcoal Efficiency	65,680	11,700	10,500	5,000	10,000	102,880
5. Domestic Biomass Stoves	95,830	17,700	17,400	10,000	12,000	152,930
6. Non Domestic Biomass	125,015	16,200	17,400	10,000	40,000	208,615
7. Domestic Biogas	111,215	19,200	17,400	12,000	20,000	179,815
8. Non Domestic Biogas	125,420	24,600	14,000	10,000	60,000	234,020
9. Solar Data Collection	107,040	38,700	13,800	-	91,000	250,540
10. Solar Dryers	111,760	21,500	14,000	8,000	10,000	165,260
11. Solar Hot Water	96,570	21,500	14,000	4,000	15,000	151,070
12. Solar Stills	65,000	9,400	10,000	4,000	4,500	92,900
13. Solar Furnace	47,880	7,900	8,500	4,000	2,000	70,280
14. Pyrolytic Conversion	140,420	20,700	17,400	10,000	20,000	208,520
15. Small Hydro Feasibility Study	75,270	64,100	17,300	10,000	500	167,170
16. New Technologies	-	-	-	-	-	100,000
	$1,456,540	$330,200	$220,500	$110,000	$303,900	$2,521,140