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REPUBLIC OF PANAMA

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SEPTEMBER 1982

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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SEPTEMBER 1982

ENTER FOR ENERGY AND ENVIRONMENT RESEARCH

University of Puerto Rico

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Potential Energy Saving by Using Solar

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Welding at Escuela de Artes y Oficios in

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INTRODUCTION

Energy is a basic resource needed to develop the economies of countries such as the Republic of Panamá successfully. The availability of energy in

different forms is

essential for most of the industrial and service activities, and the cost of delivered energy can be a critical factor in determining the economic competitiveness of industries and Services and the ability of the general public to raise its standard of living.

The following are the principal products that are manufactured in the Republic of Panamá: matches, candies, crackers, ceramics, tiles, cement, cigarettes, dairy products, alcoholic beverages, soft drinks, canned fish, canned food, canned juices, flour, refined sugar, refined oil products, aluminum, and plastic products. The industrial sector requires energy for mining, manufacturing, transportation, air conditioning, agricultural production, and food Processing and preservation. The agricultural industries

include the raising of pigs, poultry and cattle. Providing energy for activities such as the above is a major problem facing all of the developing countries.

Like most developing countries, the Republic of Panamá is undergoing @ rapid transition from an agrarian to an urban society. The Republic of Panamá consists of nine Provinces which are Bocas del Toro, Coclé, Colón, Chiriquí,

Darién, Herrera, Los Santos, Panamá, and Veraguas and @ non

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provincial areas known as Comarcas de San Klis (see Fig. 1)

About 46 percent of the population is concentrated in the urban areas; almost half of this urban population lives in Panama City. The population density varies from 40 to 70 persons per square kilometer in Colon and Panamá, respectively. The urban metropolises have very active commerce

and service industries. Yet the major exports, agricultural produce, sugar, rice and coffee, are produced mostly in the

interior provinces of the Republic of Panamá: Chiriquí,

Sociedad General de Veraguas, Darién. Therefore, the long term

goal of the energy plan for the Republic of Panamá is to increase the country's economic growth by improving the

energy consumption patterns and the energy distribution

by diversifying the energy sources.

Because the Republic of Panamá depends totally on imported oil to sustain its economic activities, the sharp increases in oil prices present a major problem. By 1978 the cost of oil imports was equal to 73 percent of the total export earnings. For this reason, under financing from the World Bank in 1981, the Instituto de Recursos Hidráulicos y Electrificación (IRHE), e.g. Electric Power Authority of Panamá, assisted by the Center for Energy and Environment Research (CEER) of the University of Puerto Rico and the Institute of Energy Conversion of the University of Delaware, started work on a plan to use alternative energy sources to replace conventional fuels.

The development of alternative energy technologies:

however, cannot proceed in isolation from the existing

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Patterns of energy use. Pons for uiternative technutogios

and energy conservation sheul

be integrated into the exist=

ing patterns of energy use in the various sectors of the

Panamanian economy by taking into consideration the type of energy being used (see Tables 1 and 11). Energy planning must be integrated with the overall economic plan. Future energy requirements must be interconnected with future energy economic activity such as industrial output and Personal expenditures for energy consuming devices and fuels. Consequently, the

assessment of the potential use of

energy in the Republic should be viewed as

one part of an integrated energy;

2, SOLAR ENERGY ASSESSMENT PROGRAM

In recent years many countries have undertaken energy

assessment studies which have included the use of altern

tive energy sources. The objectives of the Panamanian

energy program were:

~ to reduce dependence on imported fossil fuels (oil, coal, liquid gas, etc.), and thus limit the impact of

world energy prices on the social and economic

Development plans of the Republic of Panama;

~ to encourage the use of decentralized, renewable

resource technologies; and

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ubtic of Punami energy options

fossil fuel or nuclear power.

A limited number of different applications of solar

in the industrial, commercial and cultural

tors of the Panam

nian economy were selected for

consideration.

ite visits to fourteen plants including

meat pecking, food processing, garment manufacturing,

refreshment bottling, tobacco drying and coffee drying

plants as well as to a brewery, a hotel/restaurant, a

hospital

& school cafeteria, a sugar mill, » rice mill, and

refinery were conducted in the four provinces of Coclé, Herrera, Veraguas and Chiriquí. The selection was made from the many types of industry and plants in the Republic of Panamá listed in Table 11. Various solar energy applications such as water heating, hot air generation, solar assisted cooling, water pumping and other already demonstrated technologies were considered. The time and resources available limited the scope of the assessment, which should be viewed as a first step toward subsequent alternative energy planning and demonstration activities in the Republic of Panamá. This study, which is limited to solar thermal and photovoltaic systems, presents the potential for solar energy use based on only a limited number of possible applications and on the data collected during two subsequent visits of the assessment team in March and June 1981. (19,4)

It is anticipated that a detailed economic analysis and

the policy studies which lie outside the limits of this

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project will be a natural extension of the present program.

an analysis of advanced solar technologies such as e

ral

tower power units, stand-alone photovoltaic stations, salt-

gradient ponds for electricity generation and high tempera-

ture process heat production would req

the study of the

availability of technology, the economics involved, and the industrial acceptance of a new energy source in the Republic. Moreover, the availability of manpower and materials for manufacturing, installing, operating and maintaining solar systems, the budget limitations, and the

timetable of implementation would have to be determined.

by developing solar energy resources for manufacturing commodities in the Republic of Panama, the foreign exchange component of the balance of payments problem could be reduced. Important social and economic benefits could also result from the establishing of an industrial base on solar energy technologies which could create jobs and products for internal and external markets. Several solar technologies have already been developed to the point where the Republic of Panama could initiate a solar development plan which could be implemented in a reasonable period of time with a modest capital requirement. The factors stated above could provide the incentive for the Republic of Panama to consider supporting a program for the widespread use of solar energy in appropriate applications.

Some solar technologies are sufficiently developed so that their selection for near-term applications could favor

ably influence the economy in the Republic of Panamá. Such

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applications include water heating

and electric power generation

creation for isolated rural areas. The number of economically

attractive long-term options will increase as the cost

of solar cooling and of process heat generation are reduced

as a result of research and development programs in the

United States, Europe, Australia and Japan and as larger

scale commercial manufacturing capabilities are introduced.

2. SOLAR ENERGY RESOURCE BASE

The Republic of Panamá is located in the Western Hemisphere between the 6° and 10° latitudes and between the longitudes of 77° and 83°,

The Pacific Ocean borders on the south and the Caribbean Sea on the north; consequently, the weather in the narrow Isthmus of Panama is dependent on oceanic conditions to a large extent. The climate in the Republic of Panamá is tropical with almost uniform temperatures a year. In the coastal areas temperatures range from 23°C to 27°C (73°F to 81°F). Nights are generally cool, and in the highlands the temperatures range from 12°C to 18°C (52°F to 65°F). There are two seasons, rainy and dry. The rainy season lasts from April to December. The Republic of Panamá averages 165 cm (65 inches) of rain annually in the Pacific area and 305 cm (120 inches) in the Caribbean area. Cloudiness, fog and mist are the main meteorological factors which

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cause the diffusion of direct solar insolation in the

Repub lie.

In order to achieve the gre:

st benefitet

cost ratio,

solar energy systems

will have to be designed according to

the solar radiats

availeble and secording to other local

climatological characteristics. To design and evaluate the performance of simple solar systems such as solar water heaters, solar dryers, and solar stills, the following information is needed:

+ Global solar radiation

= Dry-bulb temperature

humidity ratio

~ Wet-bulb temperature

- Wind speed and direction.

To size and operate more complex solar systems for industrial process heat, air conditioning and power generation, the direct component of the global solar radiation measurement is also required in addition to the above data.

A solar radiation data base which provides accurate information for decisions about solar designs is needed in order to implement the cost-effective use of solar energy in the Republic of Panamá. A solar data base network, however, is not sufficient to develop solar energy applications.

Research and testing facilities for assessment of components and for systems performance evaluation must also be available and equipped with the proper instrumentation.

The year-round availability of solar energy in the tropics is favorable when compared with areas in the northern

and southern zones, Insolation measurements at a

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u

particular location on the earth's surface, however, are highly variable. The variations (at the same latitude) from

one location to another are caused primarily by differences

in local climatic conditions which cause the dispersion or reflection of the insolation incident on the earth's sur-

rounding atmosphere. Local variance in the amount of air

pollution also has an effect on the amount of insolation that penetrates through the atmosphere to ground level at any particular location.

The solar Guta recorded on a daily basis for the

lie of Panamá have been measured

6 compiled according

ailable global insolation on a horizontal plane.

This is the predominant method of measurement and reporting worldwide. The availability of diffuse data is rather sparse since only lately has an interest developed and corresponding effort been made to measure and record diffuse solar radiation. In the Republic of Panamá several years of solar data are available as daily totals for stations at

David, Tocumen, Los Santos and Antén, Data are also available

able from the Panamá Canal Commission for several stations in the Canal Zone. The solar insolation measuring equipment and instruments at sites such as Tocumen Station and the Canal Zone undergo conditions of extreme rainfall and humid-

ity almost all year long. The type of instruments used and

the frequency of their calibration greatly affect the reliability of the data provided, especially at these sites.

Actinometers are being used at most stations. These

solar instruments which are of the mechanical-bimetallic-

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12

drum recording type, are commonly in remote stations

where electrical power is not available. Installed in the

vorly 1870's, these instruments have not been calibrated during their)itetimes in the field. Actonometers are designed os class HIT instruments in the World Meteorological

Organization elussification system in which class I is the

highest quaiity rating. The recording chart which is driven mechanically by @ spring must be first read and then manually interpolated to obtain the daily total values. The ccoursey of the dito from this instrument cen vary widely

en the cere with which it is maf

ined and

brute; the accuracy of even @ well-maintained instru-

ment could va

from + 20 to = 50 percent.

At least five years of data is required to establish
the solar radiation climate patterns at @ given location.

Some of the data required to determine the solar energy
resource base of the Republic of Panama already exist and
are presented in Tables III, and IV.

Table TIL shows the daily average values of the 1975

Global solar insolation on a horizontal plane. ?Table 1V

shows @ compilation of the monthly average of the daily

global insolation, year by year, for the following stations:

David (1972 to 1979), Los Santos (1973 to 1978), Anton (1971 to 1976), and Tocumen (1971 to 1974). A comprehensive summary and mapping of the solar energy resource of the Republic of Panamá does not exist and the accuracy of the existing data is questionable due to many possible sources

of error. The solar data collected so far have to be

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Validated ind expunded to meusire ?iffuce, direct and global

solar radiation to

determine in detail the potential of

solar energy.

OF SOLAR ENERGY IMPLEMENTATION

The most realistic scenario for the near future assumes

that government and international in

stitutions promote the

pie

lead implementation of re

wable energy

the Republic of

© be done through a combination of sub-

rest laws and regulations, Such action is

in view of the beneficial foreign exchange, industrial

lopment and employment market which can be associated

With the impiomentation of alternative energy technologies.

?The further development of these alternative energy sources
can be governed by private copital investment and market
forces.

The solar nergy implementation program could be
composed of two phases

Phase I - Installation snd operation of
Gemonstration/test systems, and

Phase I1- Large scale menufacture and application
programs.

The Phase 1 would consist of a limited number of

installations which would be used to:

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- Funiliarize Ponomanian teehnies) and energy

personnel with the tevinology options

eval tabi

~ tee petential gpplications ané install

sent) size systems to gain operating experience

nder Fawinonian condi tions;

- Indicate which systems are the best choice for

wineturing and use in the Republic of

Pansi

> Identify institutional and social issues whieh

would significantly

influence the choice of

locations; end

~ Set up an institutional network to direct the technical and administrative aspects of the

various components of the program.

For advanced technologies such as photovoltaic power units, the demonstration systems should be installed at a limited number of carefully selected test sites which are under the direct control of trained personnel. The purpose of setting up small demonstration/test projects is to

familiarize persons in various industries, in government and

in the general public with the use of renewable energy technology. This type of demonstration also facilitates the transfer of technology from industrialized countries to the Republic of Panama. The demonstration projects for the Phase I should satisfy the following criteria:

= Technology must be relevant;

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~ In general projects should not be site-specific

- Projects should have

wide applicability;

- Technology should be feasible, available and

= Demonstration ends

increase the knowledge of

technology and provide response to a set of
specific questions;

= Investment in the project should be in a budget

Projects which will not financially preclude other

Demonstrations of similar applications:

~ Maintenance by locally available manpower should be technically feasible.

This phase of the program requires little or no manufacturing capability in the Republic of Panamá.

During the Phase II of the program the following activities should be done:

- Set up local training and manufacturing centers at an early stage of implementation: vocational schools should be involved in this stage.

Other human resources can be used; e.g. car mechanics can be trained to maintain wind machines.

- Make large-scale applications in various sectors of the Panamanian economy possible by arranging international loans and appropriate government incentives;

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Introduce education programs for persons in

industry, agriculture, business, and for the

general public;

Introduce standards, regulations and guidelines

for the thermal performance, installation and

operation of systems.

Because the process of setting up standards, regulations and guidelines is long and tedious, an institutional structure responsible for handling these activities should be

established at an early stage. The Comisión Panameña de

Normas Industriales y Técnicas (COPANIT) is an

advisory body

for standards to the

Ministry of Commerce and Industry.

There are no standards at present in the Republic of Panamá

for solar energy conversion and for conventional refrigeration.

Regarding solar standards COPANIT is mainly concerned

about capabilities to do testing, about availability of equipment

Power, and about insufficient capabilities for developing

standards for new industries. A competent institution such

as the Instituto de Recursos Hídricos y Electrificación

(GIRHE) or a professional engineering organization could work

with COPANIT to develop solar standards in the Republic of

Panamá. These activities should be an integral part of the

Process of developing alternative energy sources in the Republic, Legislative action to create tax incentives for the use of alternative energy sources should accompany the development of solar standards.

Possible sources of inte

etional funds for programs in

Panamé are the World Bank, Organization of American States,

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United States Agency for Internat

1] Development, Overseas

Private Investment Corporation, Canadian Development Funds, and European Common Market Development Funds. Such resources could be used to develop local manufacturing expa-

bin

tee for alternative energy systems/equipment, and to use the available human resources and know-how through training and technology transfer.

An education program for managerial, professional and

nonprofessi

a1 persons should be developed and implemented to make different groups aware of the energy situation. The

newsmedia (newspapers,

©. TV), pamphlets, educational

films, interviews, seminars, conferences and workshops could

be used to direct the attention of the general public toward understanding the importance of energy issues. The workshops for the general public should make people aware of the status of solar technology, the role it can play in the Republic of Panamá and the benefits it can bring to the People and the country. Persons in industry should be informed about the demonstration systems which exist in other countries, the technological readiness of such systems, the government incentives which are available, and the other economical aspects which are pertinent to the use of solar energy in a developing country. The workshops for government officials should cover issues such as the status of solar technology, the feasibility of renewable resources, the integration of such resources into Panama's economy, the financial support required, and the investment strategies

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which can be used, These activities should be a part of the overall political and economic process.

Although a more complete study which would fully ena-

ly8e the fuetors mentioned ubove would be requi

ed to define

entation pi

in detail, the solar application

© cutlined above is suitable for the Republic of

Panamé when one considers the prospects for solar tech-

Rologies, the Panamanian resources, and the energy demands

projections.

4. SOLAR TECHNOLOGY OPTIONS

Solar energy could be used for heating water for

commercial, domestic, egricultural and industrial purposes,

for producing process heat for commercial, agricultural and industrial applications, for assisting air conditioning systems, and for generating electricity by using photovoltaic cells. It is difficult to estimate the economic obstacles that still exist concerning the use of solar Process heat systems, solar assisted air conditioning and Photovoltaic cells. Because of technological readiness and the economies of solar water heating, this type of application has more potential to be used in the Republic of Panama in the near future and, therefore, it should be treated in more detail.

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There are many options available

for utilizing solar

energy resources in the Republic of Panama. A combination

of photovoltaic and solar thermal units could be used for

industrial and agricu

processes. Wind turbines and

photovoltaic

systems could be used for pumping irrigation

water; the former are already cost competitive as replace-

ments for stand-alone diesel units and the latter may become

cost effective by the end of the 1980's. Photovoltaic cells

are economically advantageous at present whenever there is a

need for electrical power which cannot be supplied with con-

ventional systems or only at high cost. In this category

are such applications as: traffic signs, buoys, beacons,

telecommunications, cathodic protection, emergency power supplies, etc. Future decisions regarding which system option is most appropriate will depend on the improvements made during the next five to ten years and on the technical and economical performance of these systems. Various technology options are in different states of development. The implementation programs call for using those technologies which have been proven to be effective and which show the greatest economic benefits. These technologies would include solar water heating and wind turbines. The widespread implementation of the more advanced technologies such as

Photovoltaic cells, solar aided air conditioning, and solar

industrial process heat would be contingent upon a successful demonstration program and on further progress in

improving the performance and lowering costs as a result of

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on going research and development programs in other

In general, the feasibility of any technology or

resource depends on the following factors:

Energy conversion technology must be appropriate to the needs

- Technology should be simple and cost effective:
- Technology should be environmentally acceptable:
- Technology should be compatible with the existing social customs and structure;

Intention demands must be low;

- Private and public institutions should be able to

Promote and maintain the resource;

- Capital requirements must be within the means of the

country's financial resources.

The early installation of demonstration systems will involve purchasing most of the components outside of the Republic of Panama. But a significant advantage of solar technology for developing countries which have an existing industry and infrastructure base is that later on a large scale demonstration program can use fabrication and manpower resources available in the country. Solar systems could be installed on a large scale in residential, institutional and commercial buildings and in industrial plants which would result in reductions in the use of conventional fuels.

The operation of small scale (1 to 150 kW) solar

thermal power units has been demonstrated. A number of

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units are operating in the United States, Mexico, Africa and

Asin, These systems usually operate in a temperature range from 82°C to 149°C (18°F to 300°F) and convert heat gener-

plate or parabolic trough collectors into power

mean of organic Rankine cycle engines. The most common application for these power units has been for pumping water.

Photovoltaic power units, which convert solar energy to

electricity with no moving parts, are used throughout the

world to supply small amounts of power to users located in remote areas which are not serviced by a utility grid. The effective performance of these systems has been demonstrated and efforts are now directed primarily toward lowering their cost, toward the improvement of the power conditioning subsystem, and toward the improvement of efficiency to make the cells competitive with conventional power systems.

The use of air conditioning in the Republic of Panamá is concentrated mainly in urban centers. As living standards improve and the electricity grid reaches more areas, the use of air conditioning is expected to spread to the rural regions of the country. Solar energy can be used to operate air conditioning systems, including those using absorption cycles which require heat, and conventional vapor compression cycles which use electrical or mechanical energy. The technical feasibility of solar air conditioning has been sufficiently demonstrated so that the near term introduction of solar air conditioning is judged to be a workable option for applications in the period of 1985-1990

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if the economical aspects of these appli

ations could be improved.

Solar refrigeration can often use the same basic tech-

nologies required for solar air conditioning. Solar
generation advance the commercial activities related
to agricultural produce and food. From the energy

storage point of view the economics of solar refrigeration
are more favorable since the storage can be in the form of
cold or frozen produce,

A variety of systems with different requirements for

manpower, finances and materials could be used to introduce

technology option. Solar related energy systems
are fabricated primarily from basic construction materials
such as steel, copper, wood, plastic, fiberglass, cement,
glass and aluminum, The amount of these materials needed
will depend on the projected use of solar energy as an
alternative energy source in the Republic of Panama.

In some e:

8 the combination of materials required,

could be modified to take advantage of resources in the Republic of Panama. For example, aluminum could be substituted for steel, plastic pipes for steel pipes, and fiberglass and wood for metal. Creation of new employment markets will be indirectly associated with solar applications in the Republic because some of the basic materials used in the fabrication of subsystems will be manufactured within the country. It can generally be assumed that com-

ponents which do not require specialized technology and

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manufacturing capabilities will be made in the country where

the systems are installed. In the case of the Republic of

Panamá such components would include towers for wind t

turbine

units, collector array support st

structures, flat-plate solar

collectors

and some fiberglass shell parabolic trough col-

lectors. Entire systems for solar ponds, both shallow and

salt-gr

ent, could be made in the Republic. Although photovoltaic modules can be manufactured in the Republic of Panamá, sophisticated components for subsystems such as inverters, photovoltaic cells and blades for large wind turbines will have to be purchased abroad. Before making decisions about manufacturing or importing materials and subsystems, an analysis of the industrial capabilities of the Republic of Panamá in relation to the program of solar development needs to be made. Table V presents the cost of some materials in the Republic which would be used in solar applications.

4.1 Solar Thermal Power Systems

A number of solar thermal power systems are in various stages of development. It is expected that by the 1990's the ongoing development and demonstration program in various countries will lead to the commercial availability on the world market of solar thermal systems having a wide power range. A wide variety of solar thermal power systems for pumping irrigation water are already available. These systems consist of thermal collectors, reflectors, heat ex-

changers and prime movers coupled to water pumps. Conven-

tional manufacturing techniques are used in assembling them,

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und they are made of the vosnion construction materia !s men
tioned provinusty. For the mort part these systems evuld be
manufactured in the Republic of Panami, thus provicing an
additonal incentive for their widespread use.

The economies of solar thermsi power systems is influ

enced by their cost and the thermal performance of the solar collector and the prime mover subsystems. Most of the concentrating collectors considered for solar thermal power

generation and several of the photovoltaic concentrator systems

require highly concentrated direct solar radiation.

Therefore, at high

rate of diffusion of the global radiation

available in the Republic of Panamá will reduce the effectiveness

of these types of solar power systems.

Most solar applications which are appropriate for solar

thermal power systems can be served by photovoltaic power units. In the future these two technology options could be used for applications including water pumping, air conditioning and refrigeration, village electrification, and eventually for large scale, grid-connected electric power Generation. The kinds of systems implemented will depend, of course, on the progress made in lowering the cost and on the reliability and durability of the different systems in field operations.

Air conditioning and refrigeration can be provided by solar energy by means of mechanical power, electricity generation or the direct generation of thermal energy. Some cooling applications have an advantage over more generalized electric power applications since the storage requirements

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can be in the form of chilled water rather than batteries.

If solar powered cooling proves to be reliable and

micel, its adoption could result in substantial fuel and

operating cost savings for a wide range of public and pri-

te users in

Republic of Panamá.

Although the technical feasibility of solar thermal

Power production is well established, the long-term reli-

ability, low cost and technical performance required to

justify widespread implementation of solar thermal/elec-

trical power conversion have not been demonstrated. More

Demonstration and development programs are required to

identify

the best system options for various applications in the Republic of Yonurd. The high humidity and the corrosive environment of the oceans will also influence the kinds of systems selected for demonstrations.

The cost of power from a solar thermal power unit is a

function of variables such as the \$

initial cost, the annual

Power output, the operation and maintenance costs, the interest on loans and the depreciation rates. The cost of Power usually decreases with an increase in a system's capacity. The cost of solar generated power is still significantly higher than power generated by large central utilities. Small diesel units, however, are often used for Pumping water and power generation in remote areas with a cost of \$0.14-\$0.18/kWh for diesel units of 10 kW power capacity. This cost can be much higher in areas where the maintenance of systems is poor and the diesel fuel supply is

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expensive. Diesel engines are used in the Republic of

Guatemala for water pumping, at the La Vieja

sugar mill in

Santiago for example, and for power generation in remotely

located plants, at the Seton coffee drying plant in

Chiricy

for example. It is difficult to estimate the capacity of the diesel pumps and generators installed in the

Republic

of Panama and, therefore, it is also difficult to judge the extent to which stand alone solar energy systems

can be used to displace diesel fuel there.

Electric Systems

Another aspect of the Panamanian government's

programs to improve living standards in rural areas and to develop sparsely populated areas. In many cases this process requires providing electric power for residential, agricultural and commercial applications. At present, about 46 percent of Panamanian families are without electricity. In 1978, IRHE provided electrical service to a total of 220,000 customers. The distribution of residential, commercial and industrial users was 90.1, 9.5 and 0.4 percent respectively. The number of residential users were greatest in Panamá, Los Santos, Colón, and Herrera provinces and represented 76, 55, 53 and 49 percent of the total number of families within these provinces. Table VI shows the electrical power use in the Republic of Panamá.(6) Photovoltaic power units are well suited for providing power in remote areas where extending the utility grid or operating diesel engines/generators is particularly costly or

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impractical. The implementation of this option will depend

on the cost of photovoltaic

generated electricity compared

to the cost of operating diesel generators. The cost of a

Photovoltaic system depends mainly on how much energy

@ power conditioning 5s required and on the cost of the solar cell panels.

Photovoltaic systems will be the most attractive if no grid is available. It is highly probable that in power

units under 100 kWh/day batteries will be used, in larger

@ Diesel generator will back-up the photovoltaic System. Due to a large component of the diffuse solar radiation « flat-panel type photovoltaic cells will be re-

commended for the Republic of Panamá. Today:

's advances in

photovoltaic cells, however, have been considerably easier to foresee and achieve than those that will be required to make photovoltaic systems competitive with utilities in the future. At present @ 20-Watt (no energy storage) module

costs about \$150-200 depending on quantity and the type of cells used would save approximately \$4 per year in electricity in the Republic of Panama. It is expected, however, that high efficiency photovoltaic cells will be made from relatively low-cost materials within a decade.

Several applications of photovoltaic demonstration units which use small systems, however, could be used locally to drive irrigation pumps and refrigeration units or to provide small amounts of power for use in villages. These systems would have to be located near the loads being served. For these applications land use requirements could

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be an important factor since such applications tend to be centered in areas of high population

on or extensive agricultural activities.* For larger applications of village electrification and residential use (assuming 2-1 kWh/day

per dwelling

the land and grid interfacing requirements

would have to be evaluated in more detail during the Phase

Most regions of the Republic of Panama are sparsely

populated. Therefore, sufficient land areas are available

for larger scale photovoltaic or solar thermal units that

would tie in with the utility grid which is relatively

extensively developed in urban areas.

ity Interface

A large demonstration program of solar energy use should include the option of utility interfaced photovoltaic Power. The displacement of a significant amount of electric Generation capacity by photovoltaic power units will affect utility operations because the output of the solar power units will be highly variable and will depend on sunshine availability, The widespread use of photovoltaics will therefore require a study of the utility interface and of the impact of the use of photovoltaics on the optimum mix of conventional power systems, on the need for energy storage, and on the utility rate structure,

About 10 m² of collector panel area is required per peak kW of output capacity. The resultant land use required for a 10 hp pumping system would be about 240m² of collector panel; spacing requirements to avoid shading are taken into account .

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The optimization of the overall power generation and

distribution system is an important part of the solution!

* power

utility interface and should be analyzed during the

conceptual phase. This optimization depends on factors

has elements

sie power demand characteristics, cost of

storage w/alternatives, mix of conventional generating ractli-
tes, and solar/wind resource dependability. If no storage
is built into either the solar power units themselves
(batteries, thermal storage, compressed air) or into the

overall utility system (pu

ped hydro), the solar electricity

Generation systems function primarily us fuel savers and the

Requirements for conventional generator capacity «

not

significantly modified. From the technical and economical
points of view, @ few hours of energy storage to smooth out

the clouds impact on electricity generation by solar energy may be recommended in the case of large, utility integrated solar power stations.

The solar generated electricity could be integrated into the country's distribution grid if the solar-electric plants capacity will not exceed up to 15 percent of existing capacity of electric plants in the Republic of Panamá. The IRHE expressed # willingness to buy solar-electric power at the rate of \$0.065/kWh.* In the case of solar electricity generation at an isolated site, this rate could be increased to \$0.085/kWh* according to IRHE, In addition, IRE agreed that the present electric rate structure should be studied

?An Industrial customer pays approximately \$0.08-\$0.12/KWh (1880 prices)

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to encourage energy conservation through financial incentives and through the use of alternative energy systems

f

elect

ity generation.

?The IME uses five different electricity rates: one

for the residential sector, one for public lighting, and
three for commercial/industrial users. Customers are
divided into small electricity users - below 5 kW, medium

users - 6 to 29 kW, and large users - over 30 kW

Small and

medium users are charged only for the electricity use in

hours, The large users pay according to the load factor and

Penk power energy use; Lose Factor = khhrs/8760 hrs x

This electricity rate structure was established in

1977, Persons interviewed in the Panamanian commerce/
Industry sector voice the opinion that the IRHE rate struc
ture does not encourage energy conservation and hinders
Panamanian national interest since # commercial/industrial

customer using s lower number of electricity hours at the

capacity will have to pay higher rates.

4.3. Solar W

ter Heating Syst

The use of solar energy for hot water in the Republic of Panama will depend largely on government policy and International loans. The government's desire to reduce imported oil, to alleviate the balance of payment problem, to improve the living standards in rural areas and to integrate the remote villages into the national life may positively affect the development of solar water heating industry and applications.

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The government's commitment to improve life in the rural areas could suggest a commitment to support the installation of solar water heaters in rural areas. In

In addition to heating water for households and schools, water

heating will be possible for institutional and commercial

buildings such as hospitals and hotels and for industrial

Processes needed in textile and food processing industries,

the refreshment making industry, and the coffee and tobacco

industries, Ne solar systems supply process hot water or

pre-heating boiler feed water in the Republic of Pansmi,

The pattern of market penetration by solar energy in other

es seems to indi

cial applications may increase the use of solar water heaters, in terms of area of collectors and energy savings, by roughly 20 percent over that used for residential applications.

Figure 2 shows the potential energy saving calculated on the base of the information received by the assessment team if solar heated and preheated water were used in various sectors of the Panamanian economy as shown in Table 11.(3) Assuming 40 percent as the conversion efficiency of a solar system and the solar resource data of Table IV, this will result in an energy saving of $2.44 \times 10^9 \text{ kWh/yr}$ ($2.15 \times 10^8 \text{ Btus/yr}$) or $4.9 \times 10^{29} \text{ gms}$ ($4.32 \times 10^8 \text{ Btus/yr}$) in 20 years of a system's lifetime. For a typical solar water heating system which has a collector area of 3.6 m^2 (38.7 ft^2), the energy saving will be $1.76 \times 10^9 \text{ Btus}$ ($1.67 \times 10^8 \text{ Btu}$). This corresponds to the saving of 4561

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Potential Energy Saving by Using

Rep

Fig.

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liters (1205 gallons) of diesel fuel or fuel oil Nr. 2 for a single solar domestic water heating system during its twenty year lifetime.

For the applications listed in Table 11, the overall

savings in water heating will vary from 2.2×10^6

energy

Gsiyr (2.0×10^7 Btulyr) for 10 percent of solar energy

contribution to 1.7×10^6 GJyyr ($.6 \times 10^2$ Btusyr) for 50

Percent of solar energy contribution which corresponds to

the savings of 1.1×10^6 gallons) of diesel fuel during 20

years of the solar systems? use respectively.

The rate at which solar water heaters are installed and consequently the potential energy saving which will result depends on the action taken by the Panamanian government and the assistance of international lending institutions. The effective and widespread implementation of solar water heating in the Republic of Panamá will depend on the development of solar hot water

h are econ

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stems

appropriate. It is expected that the following kinds of solar hot water systems may be suitable for different applications in the Republic:

- Active systems

- Thermosyphon systems

= Refillable systems.

Active systems will be most appropriate in commercial buildings such as hospitals, hotels, restaurants, laundries, Schools and apartment buildings where electricity, running water and a storage place are available.

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Thermosyphon systems are suitable for the rural areas with non-freezing climates and where electricity is not available. These systems do not use pumps and controls. They are also very popular in the urban centers of many countries.

The refillable systems in which the collector and the storage are combined is a simple, low cost application of solar energy. Although they may not be used in situations where the refilling is considered an unacceptable inconvenience, the low cost of these systems make them a reasonable option for low income families in rural areas

No significant technical constraints or human resources

limitation exists concerning the production of solar water heating units in the Republic of Panamá. Most of the components of solar domestic water heating systems can be manufactured in the Republic of Panama. This kind of production can be incorporated into the present industrial infrastructure and can enhance industrial development. The requirements for labor, particularly technical labor for the assembling and installation, are within the Panamanian capabilities. Although the benefits of solar water heating are significant, it is evident that only with the government's commitment to overcome the existing capital cost barrier can solar energy provide a major contribution to the energy economics in the Republic. In a country where capital is in short supply and institutional barriers discourage capital investment in new energy systems, only the

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government and internutions] #id to develop such systems ean

overcome the capital cost cbstacles.

The foreign exchange losses and the desire to improve the standard of living of the Panamanian people should create s favorable politieu! climate for solar water heat-

ing. Soler water heaters will primarily

reduce the azount

of energy required to heat water for bathing ond laundering.

In view of the above factors, a demonstration of solar hot water heating by using flet-plate collectors was the

Vechnology selected by the IRHE for 1

e 1 since it is

© for all geographical areas of the Republic of

Panini and since it could be integrated into the present

manufac

ng infrastructure. A photovoltaic power unit

demonstration/test project was also a selected technology

because of its long term potential und the good perspectives

for module manufacturing in the Republic.

6.31 of Heating

?The economies of solar water heaters will be © primary

determinant of their market acceptability. System economics

will be influenced by the initial installed cost, operating and maintenance costs, financing costs (interest rates), system life (depreciation), cost of conventional energy

system performance (efficiency), and insolation levels. The initial installed cost depends mainly on the material cost and the labor cost. The principal components of an active solar hot water system are @ solar collector panel, a Structure for collector mounting, a storage tank, piping, and pumps and controllers.

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The labor cost related to the economics of solar water heating systems if they were manufactured in the Republic of Panama is shown in Table VII.

Readily available financing programs, tax credits or

other financial means must be

used to deal with the

problem of the high first cost of solar systems. Stimu-

lating the use of heated water, even if solar energy is

used, involves a substantial initial commitment to import

the equipment or at least some of the materials which will

be required. The government and the business sectors should

be made aware of the lifetime cost as opposed to the first

cost of water heating systems in this situation.

Figure 3 shows the monthly savings of a solar hot water

system assuming various electricity rates and the solar

system costs. In the case of the Republic of Panamá, which

has an electricity rate of \$0.08-\$0.12/kwhr, a solar system

with a capacity of 40 P (38.7 kW) having a 40

with a collector size of 3.6 a

Percent conversion efficiency would produce a monthly saving

Between \$17 to \$26. The solar produced heat cost will be \$8

to \$18 per 10° Joules (9.48×10^6 Btu) for the installed

cost of solar domestic water heating systems in the range of

\$150/m² to \$200/m² (\$4/ft² to \$18/ft²). This solar heat

cost includes the manufacturing of the systems in the

Republic of Panamá, a twenty-year life of the solar system,

an operating and maintenance charge of 2 percent of initial

costs, and a government or international loan to subsidize

the systems! introduction on the Panamanian market, and an 6

Percent interest rate on the loan funds. It is clear that

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cost of electric

ENERGY (\$/RWH)

MONTHLY SAVINGS.
OBTAINED FROM
UTILIZATION OF A
SOLAR HOT WATER
SYSTEM. COMPARED
TO AN ELECTRIC
WATER HEATER,

MONTHLY SAVINGS USD

3000 Avenace

3500 SOLAR ENERGY

4000 COLLECTOR PLANE

4300

75000

3800

6000

6300

2200 \$/m²

2% 16 so 40 30 20

Solar WOT WATER- ALL OAY = $\frac{\text{BTU}}{\text{WATT-HRS}}$

SYSTEM EFFICIENCY (1 part DAY=water)

erent ee

Fig. 3. Monthly Solar Hot Water Savings

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the system cost per square meter has a significant influence on the cost of the solar generated heat and its reduction could accelerate the market penetration by solar water

It can be assumed that reductions in costs for solar water heating over the next few decades will be considerably less than those for solar photovoltaic or solar thermal Power plants because the technical and engineering status of the latter systems are expected to improve greatly. Cost reductions on more developed technologies are brought about primarily by savings from volume production of the required equipment and engineering savings in equipment manufacture, installation, operation and maintenance activities. Cost reductions, however, will be limited because a large part of the cost is associated with conventional generators and controls.

4.9.2 Market Penetration

If the government does not strongly support solar water heating in the Republic of Panamá, the market penetration will depend on the economies of solar water heaters as established by the free market. Yet the foreign exchange and the industrial and social benefits of solar water heaters may induce the government to encourage their widespread implementation. In the latter case a broad range of actions is possible ranging from establishing standards to creating financial incentives (low-interest loans, tax

credits, grants) to encourage the installation of solar

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water heaters. Such a solar program would create rural development, energy savings, favorable foreign exchange

rates, the availability

of capital, resource utilization and

Government.

hi

Market penetration will also depend on a number of

variables such as fuel cost and supply, solar systems cost,

market response, capital availability and the income levels of the consumers. The difference between the urban and

rural areas is likely to have less of an effect on the

market penetration of solar water heaters than on the type

of solar systems which are installed. Nevertheless, the

market resistance, the capital availability problems and the

lack of government and international loan commitments would inhibit significantly the market penetration of solar water heaters.

The benefit to the foreign exchange and to the creation

of jobs in relation to solar water heating would justify an additional 30 percent subsidy for water heaters. This would result in a decrease in the payback period and an increase in the market penetration. Without such an initiative, the present "wait and see" attitude of the market will continue since the transition to new fuels or systems usually takes from 30 to 50 years in the absence of any strong incentives.

The nature and the extent to which the manufacturing/

marketing/installation/maintenance infrastructure develops

to support the solar industry will be an important factor in

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achieving market acceptance

If the systems are appropriate?

ate, reliable and economical, are marketed and financed

effectively, and are installed and maintained properly, the industry and the market penetration can be expected to develop rapidly and overcome the constraints that exist. In the case of solar water heaters, the rate of implementation can be estimated using the payback period versus the market penetration. It may be assumed that a six year payback period would result in a 1 percent penetration of new construction. Solar water heater market penetration will also depend on the rate of increase in the standard of living. In rural areas where hot water is @ luxury and not

necessity, potential purchasers of solar water heaters may prefer other consumer items such as radios and television sets. Because no data exist on the hot water use in the various sectors of the Panamanian economy, the exact amount

of the market which can be supplied by solar water heating is hard to determine. Nevertheless, @ policy to encourage market penetration by solar water heaters should also be supported because of environmental considerations. Technology assessment studies prepared for other countries indicate that solar water heating has a net positive environmental impact in developing countries because it reduces the depletion of forests and other biomass resources.

4.3.3

ower Training

Educational institutions such as universities, high

Schools and vocational schools should introduce energy

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subject-matter into their curriculums and use their technical capabilities to initiate manufacturing of alternate energy devices (see Figures 4 and 5). In vocational schools

solar collectors and solar water heaters could be produced and plumbers and contractors could be trained.

The training required for most of the fabrication, installation, and operation of solar systems is far less than that required for most conventional energy conversion facilities. It should not be difficult to train people to

take advantage of the employment oppo:

unities resulting

from a solar implementation program. Solar water heating and certain other solar applications offer significant

foreign exchange advantages. Over 50 percent of the

installed system costs are labor-related and the Panamanian

labor could readily be trained to perform these labor

requirements. In addition, many of the basic materials and

much of the equipment required could be manufactured in the

Republic of Panamá.

?The widespread implementation of the solar applications program will require the training of manpower skilled in management, science and engineering, manufacturing and production, installation and maintenance, and systems operations. One goal of Phase I is to provide a group of experienced personnel who can assist in initiating manpower training centers as part of the Phase II activities.

Many of the solar energy subsystems use components such as support structures, towers, piping/plumbing, and storage

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tonks which are similar in construction to conventional equipment, These subsystems require workers skilled in

sheet metal forming, molding, plumbing, welding, mechanical

assembly, carpent ion, ond

+ Glass handling, site prepa:

concrete pouring as de conventional power systems.

A significant part of the manpowe:

requirements involve

basic skills similar to those already being provided by the existing manpower training/education infrastructure, special training will be required, however, for many aspects of

the solar

Jated equipment design, manufacture and instal-

Jetion. For exemple, engineers will need to be trained in

design and size solar water units, industrial process heat end photovoltaic power systems, and personnel will need to be trained to maintain wind turbine plants. The proper training of such personnel should take place at an esrly Stage of the program to provide qualified menpower for the implementation of Phase II, Such training should include solar theory, design and layout instructions, system sizing methods, construction techniques and materials, buslding collectors ond systems, and testing, maintaining, repairing and operating solar units.

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In addition to the finaneial considerations and to governmental participation in the program, institut ional factors influence the use of solar energy in # country. New Products or systems must be introduced in the context of the established customs, social issues, political environment, existing industries and infrestructures. Solar energy in

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the Republic of Panama may require some changes in living habits which call for a government or manufacturer sponsored

education program. For example, the use of solar hot water

systems may represent a significant departure from established

habits in water collection, distribution and use.

5. EXPECTED IMPACT OF SOLAR TECHNOLOGIES,

To determine accurately the extent to which solar energy technologies can be employed, a detailed market survey of issues such as technology availability, economics,

public acceptance, and manufacturing capability needs to be done. In all cases, the widespread implementation of solar water heating, process heat generation, cooling and

power systems will require positive action on the part of

the government. It can be assumed, however, that government incentives can not be provided unless the basic economics of

the solar option opp

r attractive when compared to more

conventional options. In contrast to the individual dect-

sions involved in the purchase and use of water heaters in

the industrialized countries, most of the solar power sys~

tems in developing countries are purchased end installed by

government agencies. The large grid-connected systems which

would have a significant impact on the nationwide energy

source will have to be purchased by # government backed-up

loan in the Republic of Panama.

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The implementation rate for solar energy use would depend on the market development for solar systems if the economies of such systems proved favorable in Phase 11. In general, the implementation rate for solar energy applications will be limited by materials, financing and available labor. The economies of internal resources such as labor and materials which would be used in the construction of solar power units would be compared to those of conventional

Power plants. The assumption is that the initial installa-

tions would be non-grid connected so that the relatively high cost of solar energy could be used to supplement or replace the energy produced conventionally by the diesel generators and diesel driven pumps which are costly to operate. Later applications would include installations which could be grid connected when improvements in the economics of solar energy systems would make such systems competitive with larger scale utility generators.

An accelerated solar implementation for power generators implies government action in the form of subsidies,

Standards and regulations to provide the base for the rapid build-up of the manufacturing capability during Phase 11 and in the future. It is anticipated that by the mid-1990's solar technology demonstrations will be used to indicate the type of technology, engineering, manufacturing and installation measures which will assure that solar energy systems are economically competitive when reasonable initial subsidies are provided. It can be projected that solar

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energy in its various forms can supply up to 15 percent of the electric energy needs in the Republic of Panama. Such an increase in electric capacity could be absorbed by the present utility grid without causing any network disruption. Further increases in solar electric generating capacity could significantly influence utility operations and may require substantial additional energy storage capability in pumped storage or when integrated with the solar power systems, i.e. batteries which would adversely affect a system's economics. These factors do not limit the role of solar energy in the Republic of Panama to the 15 percent

range, but they do indicate the issues which need to be

analyzed in the planning of a large scale solar applic

tions program.

6. CONCLUSIONS

ch of the plants v.

sited

in the Republic of Panamá could use solar energy in its
direct form, or in the form of wind power, or in its biomass
form. In some cases a company's interest may be strong
enough to provide matching funds for a solar system pilot
project. Various systems need to be evaluated and the
Demonstration of selected ones carried out. A technology
Demonstration program should be started to field-test some

of the different concepts. Systems that could be tested

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include solar energy use for hot water generation and air conditioning (collector area of up to 1000 m²), photovoltaic Power units (0.5 to 5 kW), small (5 to 25 KW) and large (100 to 200 H_i), Wind machines and anaerobic digester systems similar to the 20 m³ flexible, horizontal, plug-flow, semi-continuous anaerobic fermenter which was installed at a farming cooperative in the town of Santiago.

Almost all the plants visited could reduce their fossil fuel consumption by introducing energy conservation measures. An energy audit should indicate the areas which need improvement. Energy conservation measures should be implemented before the application of alternative energy sources is considered.

Future studies should be made to determine the direct, Diffuse, and total solar components of solar availability in the Republic and how the ratio of direct to diffuse radii

tion varies at different locations throughout the country.

The development of an industrial base for solar water heating systems is important because of the current availability of proven technology and the wide range of possible solar applications in the Republic of Panamá. Organizational structures to manage the development of a solar water heating industry need to be established and government subsidies and a regulation policy determined. A financing mechanism with affordable interest rates must also be established to make possible the development of manufacturing and widespread applications of solar energy. In addition, the

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Republic of Panamá should undertake a more syste

tic pro-

Gram to use solar energy by relating it to long-term inte=

grated energy planning, economic sector planning, resource

aa:

and analytical methods development, and near-term

infrastructure requirements.

The Panamanian government should support indigenous

research on low cost solar technology development, provide

consumer applications, make capital more accessible to

those wishing to install solar systems, and identify and

remove institutional barriers to the use of solar

technologies.

Solar water heating in the residential, commercial, and

industrial sectors has good potential in a short term

(Phase 1 and Phase 11) and photovoltaic powered stand-alone

elect

city sy

toms, industrial process heat generation and

Solar powered air conditioning in the commercial sector have

some pot!

ntial as solar energy applications in the Republic

of Panamá in the long term, and they should be considered as

potential candidates for the Phase 11 demonstrations.

nowledgement

This work is @ part of the master plan for the develop-

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