"SOLAR ENERGY AS AN ALTERNATIVE ENERGY ASSESSMENT OF SOLAR ENERGY SOURCES IN THE REPUBLIC OF PANAMA, Caribbean Sea, Colombia, SEPTEMBER 1982 CENTER FOR ENERGY AND ENVIRONMENT RESEARCH.

SOLAR ENERGY AS AN ALTERNATIVE SOURCE FOR THE REPUBLIC OF PANAMA, Caribbean Sea, SEPTEMBER 1982 CENTER FOR ENERGY AND ENVIRONMENT RESEARCH, University of Puerto Rico, ENERGY COLOMBIA.

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INTRODUCTION:

Energy is a basic resource needed to develop the economies of countries such as the Republic of Panama."

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 Panama: 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 developing countries. Like most developing countries, the Republic of Panama is undergoing a rapid transition from an agrarian to an urban society. The Republic of Panama consists of nine provinces which are Bocas del Toro, Cocle, Colon, Chiriqui, Darien, Herrera, Los Santos, Panama, and Veraguas and a non-provincial area known as Comarca de San Blas (see Fig. 1). About 46 percent of the population is concentrated in 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 Panama, 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 Panama: Chiriqui, Los Santos, Bocas del Toro, Veraguas, Darien. Therefore, the long-term goal of the energy plan for the Republic of Panama is to increase the

Country's economic growth by improving the energy consumption patterns and the energy distribution while diversifying the energy sources. Because the Republic of Panama depends entirely 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 Hídricos y Electrificación (IRHE), also known as the Electric Power Authority of Panama, 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 patterns of energy use.

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Patterns of energy use. Plans for alternative technologies and energy conservation should be integrated into the existing 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 2). Energy planning must be integrated with the overall economic

Plan. Future energy requirements must be interconnected with future 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 system.

2. SOLAR ENERGY ASSESSMENT PROGRAM

In recent years, many countries have undertaken energy assessment studies which have included the use of alternative 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.

The Republic of Panama energy options include fossil fuel or nuclear power. A limited number of different applications of solar in the industrial, commercial and agricultural sectors of the Panamanian economy were selected for consideration. Site visits to fourteen plants including meat packing, 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, a rice mill, and refinery were conducted in the four provinces of Cocle, Herrera, Veraguas and Chiriqui.

The selection was made from the many types of industry and plants in the Republic of Panama 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 Panama.

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 scenarios.

Possible applications are based on the data collected during two subsequent visits of the assessment team in March and June 1981. It is anticipated that a detailed economic analysis and the policy studies, which lie outside the limits of this project, will be a natural extension of the present program. An analysis of advanced solar technologies such as solar tower power units, stand-alone photovoltaic stations, salt-gradient ponds for electricity generation, and high-temperature process heat production would require 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 favorably influence the economy in the Republic of Panama. Such applications include water heating and electric power generation for isolated rural areas. The number of economically attractive long-term options will increase as the cost.

If solar cooling and 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

In order to implement the cost-effective use of solar energy in the Republic of Panama, a solar database network is necessary. However, this alone is not sufficient to develop solar energy applications. There must also be research and testing facilities available for assessment of components and systems performance evaluation, equipped with the proper instrumentation.

The year-round availability of solar energy in the tropics is favourable when compared with areas in the northern and southern zones. Insolation measurements at any 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 surface. The local variance in the amount of air pollution also affects the amount of insolation that penetrates through the atmosphere to ground level.

The solar data recorded on a daily basis for the life of Panama have been measured and compiled according to available global insolation on a horizontal plane. This is the predominant method of measurement and reporting worldwide. The availability of diffuse data is rather sparse as only recently has an interest been developed and corresponding effort been made to measure and record diffuse solar radiation.

In the Republic of Panama, several years of solar data are available as daily totals for stations at David, Tocumen, Los Santos and Antén. Data are also available from the Panama 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 humidity 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.

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"Difficult, direct, and global solar radiation makes it challenging to determine the potential of solar energy in detail. For solar energy implementation, the most realistic scenario for the near future assumes that government and international institutions promote the widespread implementation of renewable energy in the Republic. This can be achieved through a combination of subsidies, loans, and regulations. Such action is taken in view of the beneficial foreign exchange, industrial development, and employment market which can be associated with the implementation of alternative energy technologies.

The further development of these alternative energy sources can be governed by private capital investment and market forces. The solar energy implementation program could be composed of two phases. Phase I - Installation and operation of demonstration/test systems, and Phase II - Large scale manufacturing and application programs. Phase I would consist of a limited number of installations used for various purposes, including:

- Familiarizing Panamanian technicians and energy personnel with the technology options available.
- Testing potential applications and installation of small-scale systems to gain operating experience under Panamanian conditions.
- Identifying which systems are the best choice for manufacturing and use in the Republic of Panama.
- Identifying institutional and social issues which could significantly influence the choice of locations.
- Setting up an institutional network to direct the technical and administrative aspects of 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 less developed ones."

Republic of Panama. The demonstration projects for Phase I should satisfy the following criteria:

- Technology must be relevant;

- In general, projects should not be site-specific;
- Projects should have wide applicability;
- Technology should be feasible and available;
- Demonstration should increase the knowledge of technology and provide responses to a set of specific questions;
- Investment in the project should be within a budget range 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 Panama. During 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; for example, 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;

- 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 Panama for solar energy conversion and for conventional refrigeration.

Regarding solar standards, COPANIT is mainly concerned about capabilities to do testing, about the availability of manpower, and about insufficient resources.

Capabilities for developing standards for new industries are essential. A competent institution such as the Instituto de Recursos Hidráulicos y Electrificación (GIRHE) or a professional engineering organization could collaborate with COPANIT to develop solar standards in the Republic of Panama. 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 international funds for programs in Panama are the World Bank, Organization of American States, United States Agency for International Development, Overseas Private Investment Corporation, Canadian Development Funds, and European Common Market Development Funds. Such resources could be used to develop local manufacturing capabilities for alternative energy systems/equipment, and to use the available human resources and know-how through training and technology transfer. An educational program for managerial, professional and non-professional individuals should be developed and implemented to make different groups aware of the energy situation. The news media (newspapers, TV), pamphlets, educational films, interviews, seminars, conferences and workshops could be employed to direct the attention of the general public towards understanding the importance of energy issues. Workshops for the general public should make people aware of the status of solar technology, the role it can play in the Republic of Panama and the benefits it can bring to the people and the country. Individuals 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 economic aspects 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.

4. SOLAR TECHNOLOGY OPTIONS

Solar energy could be used for heating water for commercial, domestic, agricultural, 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.

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 agricultural processes. Wind turbines and photovoltaic systems could be used for pumping irrigation water; the former are already cost-competitive as replacements for stand-alone diesel units, and the latter may become cost-effective by the end of the 1980's. Photovoltaic cells have economically advantageous at present whenever there is a need for electric power which cannot be supplied with conventional systems or only at high cost. In this category are such applications as traffic signs, buoys, beacons.

Conventional fuels, the operation of small-scale (1 to 150 kW) solar thermal power units has been demonstrated. A number of these units are operating in the United States, Mexico, Africa, and Asia. These systems usually operate in a temperature range from 82°C to 149°C (180°F to 300°F) and convert heat generated by flat plate or parabolic trough collectors into power by means 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 towards lowering their cost, towards the improvement of the power conditioning subsystem, and towards the improvement of efficiency to make the cells competitive with conventional power systems.

The use of air conditioning in the Republic of Panama 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 if the economic aspects of these applications could be improved. Solar refrigeration can often use the same basic technologies required for solar air conditioning. Solar generation advances the commercial activities related to agricultural produce and food. From the energy storage point of view, the economics of solar

Refrigeration is 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 options. 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 cases, 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. The 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 components which do not require specialized technology and manufacturing capabilities will be made in the country where the systems are installed. In the case of the Republic of Panama, such components would include towers for wind turbine units, collector array support structures, flat-plate solar collectors, and some fiberglass shell parabolic trough collectors. Entire systems for solar ponds, both shallow and salt gradient, could be made in the Republic. Although photovoltaic modules can be manufactured in the Republic of Panama, 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 Panama 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 exchangers, and prime movers coupled to water pumps. Conventional manufacturing techniques are used in assembling them.

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And they are made of the most common construction materials. For the most part, these systems could be manufactured in the Republic of Panama, thus providing an additional incentive for their widespread use. The economies of solar thermal power systems are influenced 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, a high rate of diffusion of the global radiation available in the Republic of Panama 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 applications.

Electric Power Generation. The type of systems implemented will, of course, depend 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 through 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 can be in the form of chilled water rather than batteries.

If solar-powered cooling proves to be reliable and efficient, its adoption could result in substantial fuel and operating cost savings for a wide range of public and private users in the Republic of Panama. Although the technical feasibility of solar thermal power production is well established, the long-term reliability, low cost and technical performance required to justify widespread implementation of solar thermal/electrical power conversion have not been demonstrated. More demonstration and development programs are needed to identify the best system options for various applications in the Republic of Honduras.

The high humidity and the corrosive environment of the oceans will also influence the type 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 expensive.

Diesel engines are used in the Republic of Ami for water pumping, at the La Vieto sugar mill in Santiago for example, and for power generation in remotely located plants, at the Setton 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 Panami and, therefore, it is also difficult to judge the extent to which standalone solar energy systems can be used to displace diesel fuel there. Holistic systems are an aspect of the Panamanian government's plans 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 Panamé, Los Santos, Colén, 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. 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 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 mainly depends on how much power conditioning is required and on the cost of the solar cell panels. Photovoltaic systems will be 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 units, a 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 recommended for the Republic of Panama. Today's advances in photovoltaic cells, however, have been considerably easier to foresee and achieve than those required to make photovoltaic systems competitive with utilities in the future. At present, a 20-Watt (no energy storage) module costs about $150-200 depending on quantity and the type of cells and 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 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 be an important factor since such applications tend to be centered in areas of high population 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. Utility Interface A.

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 m^2 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 240m^2 of collector panel; spacing requirements to avoid shading are taken into account.

38 The optimization of the overall power generation and distribution system is an important part of the solar power utility interface and should be analyzed during the demonstration phase. This optimization depends on factors such as electric power demand characteristics, cost of storage alternatives, mix of conventional generating facilities, 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 (pumped hydro), the solar electricity generation systems function primarily as fuel savers and the requirements for conventional generator capacity are not significantly modified.

From the technical and economical points of view, a 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 Panama. The IRHE.

Expressed a 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 (1980 prices).

To encourage energy conservation through financial incentives and through the use of alternative energy systems for electricity 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 kWh. The large users pay according to the load factor and peak power energy use. Load Factor = kWh/8760 hrs x. This electricity rate structure was established in 1977. Persons interviewed in the Panamanian commercial/industry sector voice the opinion that the IRHE rate structure does not encourage energy conservation and hinders Panamanian national interest since a commercial/industrial customer using a lower number of electricity hours at the capacity will have to pay higher rates.

4.3. Solar Water Heating System

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 the solar water heating industry and applications.

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 addition to heating water for households and schools, water heating

The following text will be possible for institutional and commercial buildings such as hospitals and hotels, as well as for industrial processes needed in textile and food processing industries, the beverage making industry, and the coffee and tobacco industries. New 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 areas seems to indicate that institutional and commercial 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 based on 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, this would result in an energy saving of 2.44 x 10^4 m^2-yr (2.15 x 10^8 Btu/yr) or 4.9 x 10^29 m^2 (4.32 x 10^30 Btu/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 x 10^3 GJ (1.67 x 10^6 Btu). This corresponds to the saving of 4561 liters (1205 gallons) of diesel fuel or fuel oil No. 2 for a single solar domestic water heating system during its twenty year lifetime. For the applications listed in Table 11, the overall saving in water heating will vary from 2.2 x 10^4 GJ/yr (2.0 x 10^7 Btu/yr) for 10 percent of solar energy contribution to 1.7 x 10^4 GJ/yr (1.6 x 10^7 Btu/yr) for 50 percent of solar energy contribution, which corresponds to the savings of 1.1 x 10^4 liters of diesel fuel during 20 years.

The usage of solar systems has spanned many years. The rate at which solar water heaters are installed, and consequently the potential energy savings, will largely depend on the actions 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 Panama will hinge on the development of economical and appropriate solar hot water systems. It is expected that the following types of solar hot water systems may be suitable for different applications in the Republic:

- Active systems
- Thermosyphon systems
- Refillable systems

Active systems will likely be most suitable in commercial buildings such as hospitals, hotels, restaurants, laundries, schools, and apartment buildings where electricity, running water, and storage space are available.

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

Refillable systems, where the collector and the storage are combined, constitute a simple, low-cost application of solar energy. Although they may not be suitable in situations where refilling is considered an inconvenience, the low cost of these systems makes them a reasonable option for low-income families in rural areas.

No significant technical constraints or human resources limitations exist regarding the production of solar water heating units in the Republic of Panama. 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 current industrial infrastructure and can enhance industrial development.

The requirements for labor, especially technical labor for the assembly and installation, are within the Panamanian capabilities. Although the benefits of solar water heating are significant,

The text appears to be fragmented and has several errors. Here is a corrected version:

"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 government and international aid to develop such systems can overcome the capital cost obstacles. The foreign exchange losses and the desire to improve the standard of living of the Panamanian people should create a favorable political climate for solar water heating. Solar water heaters will primarily reduce the amount of energy required to heat water for bathing and laundering. In view of the above factors, a demonstration of solar hot water heating using flat-plate collectors was the technology selected by the IRHE for all geographical areas of the Republic of Panama and since it could be integrated into the present manufacturing infrastructure. A photovoltaic power unit demonstration/test project was also a selected technology because of its long-term potential and the good prospects for module manufacturing in the Republic.

The economies of solar water heaters will be the 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 a solar collector panel, a structure for collector mounting, a storage tank, piping, and pumps and controllers.

The labor cost related to the..."

The economics of solar water heating systems, if manufactured in the Republic of Panama, are shown in Table VII. Available financing programs, tax credits, or other financial means must be created to deal with the high initial cost of solar systems. Stimulating 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 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 Panama, which has an electricity rate of \$0.08-\$0.12/kWh, a solar system with a collector size of 3.6 m^2 and 40% conversion efficiency would produce a monthly saving between \$17 to \$26. The solar-produced heat cost will be \$8 to \$18 per 10^9 Joules (9.48 x 10^9 Btu) for the installed cost of solar domestic water heating systems in the range of \$150/m^2 to \$200/m^2 (\$14/ft^2 to \$18/ft^2).

This solar heat cost includes manufacturing of the systems in the Republic of Panama, 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 a 6 percent interest rate on the loan funds.

Figure 3. Monthly Solar Hot Water Savings

It's clear that the system cost per square meter has a significant influence.

On the cost of the solar-generated heat, its reduction could accelerate the market penetration of 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 greatly improve. 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. However, cost reductions 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 Panama, 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 water heaters.

Such a solar program would create rural development, energy savings, favorable foreign exchange rates, the availability of capital, resource utilization and development. 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, market resistance, capital availability problems, and the lack of government and

International loan commitments would significantly inhibit the market penetration of solar water heaters. The benefits to foreign exchange and job creation 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 market penetration. Without such an initiative, the current "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 extent to which the manufacturing/marketing/installation/maintenance infrastructure develops to support the solar industry will be an important factor in achieving market acceptance. If the systems are appropriate, reliable, and economical, are marketed and financed effectively, and are installed and maintained properly, the industry and market penetration can be expected to develop rapidly and overcome the existing constraints. In the case of solar water heaters, the rate of implementation can be estimated using the payback period versus 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 a luxury and not a necessity, potential purchasers of solar water heaters may prefer other consumer items such as radios and television sets. Because no data exists 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, a 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.

Environmental impact in developing countries can be reduced as it lessens the depletion of forests and other biomass resources.

4.3.3 Power Training

Educational institutions such as universities, high schools and vocational schools should incorporate energy-related subject matter into their curriculums. They can also use their technical capabilities to initiate the manufacturing of alternative 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 necessary 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 opportunities 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 Panama. 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.

These subsystems require workers skilled in sheet metal forming, molding, plumbing, welding, mechanical assembly, carpentry, and glass handling. Site preparation and concrete pouring are also necessary skills.

Conventional power systems. A significant part of the manpower 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-related equipment design, manufacture, and installation. For example, engineers will need to be trained in design and sizing solar water units, industrial process heat, and 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 early stage of the program to provide qualified manpower for the implementation of Phase II. Such training should include solar theory, design and layout instructions, system sizing methods, construction techniques and materials, building collectors and systems, and testing, maintaining, repairing, and operating solar units.

In addition to the financial considerations and governmental participation in the program, institutional factors influence the use of solar energy in a country. New products or systems must be introduced in the context of the established customs, social issues, political environment, existing industries, and infrastructures. Solar energy in 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 accurately determine the extent to which solar energy technologies can be employed, a detailed market survey of issues such as technology availability, economies, 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

It is assumed, however, that government incentives cannot be provided unless the basic economics of the solar option are attractive compared to more conventional options. In contrast to the individual decisions involved in the purchase and use of water heaters in industrialized countries, most of the solar power systems in developing countries are purchased and 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 a government-backed loan in the Republic of Panama.

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 II. 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 installations 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 II and in the future. It is anticipated that by the mid-1990s, solar technology demonstrations will be used to indicate the type of technology, engineering, manufacturing, and installation measures which will assure that solar energy systems.

Solar energy is economically competitive when reasonable initial subsidies are provided. It can be projected that solar 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 solar power systems, i.e., batteries, which would adversely affect a system's economies. 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 applications program.

6. CONCLUSIONS

Much of the plants visited in the Republic of Panama could use solar energy in its direct form, or in the form of wind power, or 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 include solar energy use for hot water generation and air conditioning (collector area of up to 1000 m), photovoltaic power units (0.5 to 5 kW), small (5 to 25 kW) and large (100 to 200 kW), wind machines and anaerobic digester systems similar to the 20 m 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 being considered. Future studies should be conducted to determine the direct, diffuse, and total solar components of solar availability in the Republic of Panama. Additionally, how the ratio of direct to diffuse radiation varies at different locations throughout the country should be explored.

The development of an industrial base for solar water heating systems is important due to the current availability of proven technology and the wide range of possible solar applications in the Republic of Panama. Organizational structures are needed to manage the development of a solar water heating industry. Government subsidies and a regulatory policy must be determined. A financing mechanism with affordable interest rates also needs to be established to enable the development of manufacturing and widespread applications of solar energy.

The Republic of Panama should undertake a more systematic program to utilize solar energy. This should be related to long-term integrated energy planning, economic sector planning, resource 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 the short term (Phase 1 and Phase 2).

Photovoltaic powered stand-alone electric systems, industrial process heat generation, and solar-powered air conditioning in the commercial sector have some potential as solar energy applications in the Republic of Panama in the long term. These should be considered as potential candidates for the Phase 2 demonstrations.

Acknowledgment: This work is a part of the master plan for the development of renewable energy resources in the Republic of Panama.

The text was revised as follows:

The project was executed under contract number 31-80-DG for the Republic of Panama, funded by a grant from the United States Agency for International Development. The project management was handled by IRHE, and the technical execution was carried out by the Center for Energy and Environment Research at the University of Puerto Rico, and the Institute of Energy Conversion at the University of Delaware.

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