BIOGAS POTENTIAL IN THE REPUBLIC OF PANAMA by M.D. Erdman, Paper Number: CBER —X-113

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ABSTRACT

A technological assessment of biogas production potential and the impacts of this technology were undertaken in the Republic of Panama. The assessment data were collected from various National government agencies, during interviews, and from site observations during a two-week period. An estimated 34.1 to 132.3, 11.3, 103.1 to 181.4, and 20.5 to 34.5 x $108m^3$ of biogas could be produced annually from readily collectable animal, aquatic, agro-industrial, and community wastes.

Respectively, this biogas could provide 3.1 to 8.71 x 10^2 MJ of energy, equivalent to 61.5 to 172.8% of the electrical energy supplied nationwide in 1979. Plant biomass and other organic residues could also be anaerobically fermented to produce biogas. Despite the potential for biogas production, limited effort and resources have been devoted to this alternative energy production process in Panama.

Three studies and three projects were proposed to evaluate and stimulate biogas production and use. The proposed study or project, with the estimated time (years) requirement, numbers of staff members, and cost requirement (dollars) were as follows:

- Resource and energy study: 1.0 years, 2.0 staff members, $36,700
- Biodegradability study: 1.5 years, 1.0 staff members, $41,620
- Design and material study: 0.33 years, 3.0 staff members, $21,800
- Residential biogas project: 3.0 years, 11.0 staff members, $996,380
- Cooperative and community biogas project: 3.0 years, 5.0 staff members, $784,630

- Industrial and governmental biogas project: 2.0 years, 2.0 staff members, $109,000

Biogas production and use could impact the residential sector where 46% of the population does not connect to the electrical grid, cooperatives and small communities with biomass resources, and industrial and governmental sectors producing sufficient organic matter waste by-products during normal operation.

INTRODUCTION

Electricity production in the Republic of Panama is under the authority of the Institute de Recursos Hidraulicos y Electrification (IRHE). In 1979, IRHE produced a total of $1.4x10^8$ million watt-hours of electricity, obtained from petroleum (55%) and hydro (45%) sources. Due to increasing costs of petroleum fuels and high capital investment costs for hydro-generating systems, alternative energy resources are being investigated.

Biogas, a mixture composed primarily of methane and carbon dioxide, is produced during the anaerobic fermentation of organic matter. The anaerobic fermentation process is currently viewed as a three-stage process. During the first stage, the ferment

Active bacteria hydrolyze complex carbohydrates, proteins, and lipids and metabolize these simpler compounds to fatty acids, hydrogen, and carbon dioxide. During the second stage, the acetogenic bacteria metabolize the simpler fatty acids and produce acetate, carbon dioxide, and hydrogen.

During the third stage, which is strictly anaerobic, methanogenic bacteria metabolize the products of the first two stages (primarily acetate, carbon dioxide, and hydrogen) to produce a gaseous mixture of methane and carbon dioxide, commonly called biogas. The advantages of biogas production and use include: the fermentation substrate can originate locally; the fuel can be used in a variety of ways (i.e., cooking, lighting, refrigeration, electricity production); the fermentation equipment can be fabricated from locally available materials and labor skills; and the energy source can be stored. The pollution potential of discarded organic matter can also be greatly reduced, and many pathogenic microorganisms can be destroyed during the anaerobic fermentation.

Biogas production has been conducted using batch, continuous, plug flow, anaerobic filtration, contact processes, and multistage fermentation techniques. These fermentations have also been evaluated under low and high solids loading rates, at various fermentation temperatures and pH levels.

A brief review of the various approaches used during the anaerobic fermentation process is presented below. Batch Fermentations: In batch fermentation, organic matter and inoculum are added to the fermenter. The fermenter is then sealed to exclude oxygen and the fermentation is allowed to proceed until the substrate supply is depleted or biogas production decreases or stops. The fermenter contents are then removed and the process repeated. Batch fermentations have the advantage of requiring small labor inputs; however, this advantage is offset by a long lag period and discontinuous biogas production.

The process of fermentation is generally considered impractical for agricultural waste or biomass fermentations due to the high capital costs for the fermenter. Continuous Fermentations. Fermentations of this type are fed on a continual or semi-continual basis. Due to the feeding routine and fermenter capacity, an equal amount of material is generally displaced from the fermenter at the time of feeding. The IRME is currently constructing a fermenter of this type. This fermentative approach has the advantages of continuous operation and relatively constant biogas production. Furthermore, the fermenter capacity can be more closely designed to meet the biogas operating requirements, reducing capital investment costs. In a plug flow fermentation, the waste substrate is periodically added to the fermenter and successively displaced through the system by subsequent substrate additions. Plug flow fermentations have been reported in Germany (11), South Africa (9), England (4), and Puerto Rico (7). High-rate Fermentation. A high-rate fermentation uses agitation and temperature control to ensure that the fermentation proceeds at a stable optimum rate. This approach was initially developed for use in sewage disposal. This fermentation approach is generally recognized as essential for optimizing fermentation rate (14). Potential disadvantages of the high-rate approach include high energy inputs to maintain agitation and temperature, sophisticated control mechanisms, and high capital equipment costs. Since this type of approach has been widely used in human waste treatment plants, much information and technical expertise is available. However, the costs for these services or equipment may be prohibitive. Anaerobic Filtration. In an anaerobic filtration process, the microbial populations attach and colonize on a support structure within the fermenter. The media substrate is then passed over the microorganisms. In this fermentative approach, the microorganisms essentially stay within the fermenter and are not

The text is placed in high-rate or plug flow fermentations. Although this approach has been demonstrated, only wastes with a relatively low biological oxygen demand (BOD) of 200 to 10000 mg/l were considered applicable. The Anaerobic Contact Fermentation process returns settleable solids and microorganisms back to the fermenter for further degradation. This approach allows for rapid fermentation, which decreases the fermenter capacity requirements. The major difficulties with this approach are the poor settling characteristics of various wastes, especially those with trapped gas particles attached, and the low solids requirement in the inlet waste stream.

Multistage Fermentation is designed to isolate and optimize the individual metabolic conditions for the major groups of bacteria involved in the process. Theoretically, this would result in improved fermentative efficiency and reduced capital and operating costs. Pfeffer reports that a multistage fermentation is more efficient than a complex mix system, but if the system is stressed, failure of the multistage system is more rapid. All the preceding fermentation approaches have been successfully demonstrated. The advantages and disadvantages of each approach vary depending upon many variables, such as substrate type and supply, operating parameters, biogas needs, labor, economic and social considerations.

The objectives of this study were to identify geographic areas where biogas production and utilization would interface in the Republic of Panama; identify and evaluate existing biogas technologies; identify studies and resources to develop biogas production potential; develop a national biogas plan and identify a series of projects to be developed within five years to expand the national biogas program.

Methods and Materials: The assessment data was obtained from various national governmental agencies in the cities of Santiago and Panama, during interviews and

The text was observed during site visits over a two-week period, from March 23 to April 3, 1981. An itinerary for the assessment period is presented in Appendix 1 on page 7. Summary reports of the site visits and interviews are presented in Appendix 2.

The current biogas program in the Republic of P was initiated in 1979 by IRHE through an Agency for International Development (AID) grant program. The biogas program was situated within the Alternate Energy and Conservation group of IRHE. The program is directed by an engineer who is presently the only full-time program member, operating with a budget (excluding salary and overhead) of twenty thousand dollars for the two-year program.

IRHE is currently installing a 20-m^3 flexible, horizontal, plug-flow, semi-continuous anaerobic fermenter at a farming cooperative near the city of Santiago. The fermenter is being constructed of hypalon and will use a solar collector operating by thermosyphon for auxiliary heating. Swine waste solids will be manually collected from a concrete-floored farrowing building and diluted with water to approximately 10% total solids. The mixture will then be added to the fermenter daily. The design resembles the Taiwan, Republic of China, red-mud plastic methane converter fitted with a premixing tank commonly found in the Gobar design from India. Materials for the fermenter construction and monitoring are being supplied by IRHE. Land, construction labor, daily operating labor, and monitoring will be performed by the farm cooperative members under the supervision of IRHE.

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A second fermenter is currently being designed by IRHE for installation at another site. Both IRHE fermenters are expected to cost approximately twenty thousand dollars. The Instituto Agropecario Jesus Nazarano (see Appendix 2) has an operating 14-m^3 anaerobic fermenter with 20-m^3 of biogas storage capacity. This fermenter has been in operation since 1979 and the biogas is being used for cooking in the school cafeteria.

Digested effluent from the fermenter at the eateries is added to an aquaculture pond, which is harvested annually. The amount of solid waste produced at the farm was greater than the fermenter capacity. Therefore, maximum biogas production potential has not been obtained. A red-mud plastic flexible fermenter has been ordered and is awaiting arrival and installation at the school. The additional fermenter capacity is expected to provide sufficient biogas for all cooking at the school, and the excess will be used in spark-ignited, internal combustion engines. No other biogas plants have been located within the country at the present time, although plans are being considered for biogas plant installation at a municipal slaughterhouse currently under construction.

General Characteristics and Geographic Sites for Biogas Production:
Biogas production, in order to be economical and energy efficient, must be located near substrate resources. The Republic of Panama is politically subdivided into nine major provinces and a non-provincial area known as Comarca de San Blas. Due to the low population and limited accessibility of the San Blas area, little information was available for consideration in this report.

The national economy of Panama is based primarily upon agriculture and services. The principal agricultural commodities are bananas, sugar, rice, and coffee. Secondary agricultural products of importance are meat and animal by-products, vegetables, root crops, and fruits. The data presented in Table 1 lists some general characteristics of the country. The population of Panama is approximately 1.8 million, and 45% of the population reside within the province of Panama. The provinces of Darién and Bocas del Toro have the lowest populations and densities within the nation. The population density varies from 0.4 to 0.7 persons per hectare (HA) in Darién and Panama, respectively. Provincial densities are comparable for low-density areas of Darién and Bocas del Toro, and intermediate areas of Los Santos.

The regions of Veraguas and average density areas of Coclé, Colón, Chiriqui, and Herrera are notable for their agricultural production. The highest production of cattle, swine, and poultry occurs in the areas of Chiriqui, Veraguas, and Panamá, respectively. In contrast, the regions with the lowest animal production are Darién, Bocas del Toro, and Colón.

Chiriqui and Coclé are the largest producers of coffee and rice. The least amount of these commodities is produced in Bocas del Toro and Darién. The greatest banana and sugar cane production, for which the data is not presented here, are found in the areas of Chiriqui and Bocas del Toro, and Coclé and Panamá, respectively.

The electrical power distribution characteristics are presented in Table 2. In 1979, IRHE provided electrical service to a total of 220,058 customers. The distribution of residential, commercial, and industrial users was 90.1%, 9.5%, and 0.4% respectively. The largest numbers of residential customers were in Panamá, Los Santos, Colón, and Herrera provinces. They represented 76%, 55%, 53%, and 49% of the total number of families within these provinces.

Currently, an estimated 46% of the nation's families are without electricity. They could, therefore, be greatly impacted by the biogas technology for non-electrical cooking, lighting, and refrigeration. Although electricity production from biogas is feasible, the capital investment costs and low efficiency preclude this method for the residential sector.

The areas and relative importance of biogas production are greatest in Bocas del Toro, Darién, Veraguas, Coclé, Chiriqui, Colon, Los Santos, and Panama. The residential and commercial energy sources used in Panama are presented in Table 3. Wood provides an estimated 70.4% of the total energy requirement used in the residential and commercial segments within the nation. Electricity and refined gas represent the other major energy sources currently used. In areas without electricity, wood and charcoal, kerosene, and refined gas would increase in importance. The major uses of biogas are presented in Table 4.

Production has been used for cooking, lighting, refrigeration, and more.

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The text on page 3 also appears to be unreadable with a mix of random characters, symbols, and numbers.

The text on page 14 seems to be unreadable as well, with a mix of random characters, symbols, and numbers.

Production also includes steam and electricity. The major uses and relative importance ranking of biogas production in the residential areas of Panama are as follows: cooking > lighting > and refrigeration.

A list of identified and underutilized resources of potential biogas production value, along with estimated annual biogas production potential, are presented in Table 5. Five major sources of organic matter have been identified: animal residues, plant biomass, agro-industrial residues, commercial residues, and residues accumulated as a result of governmental services.

An estimated 34.1 to 132.3, 11.3, 103.1 to 181.4, and 20.5 to 34.5 x 10^6 m^3 of biogas could be produced annually.

The text can be corrected as follows:

From readily collectable animal, aquatic, agro-industrial and government collected wastes, respectively, biogas could provide 3.1 to 8.71 x 10^9 MJ of energy. This is equivalent to 61.5 to 172.8% of the electrical energy supplied nationwide in 1979. Plant biomass and other organic residues could also be anaerobically fermented to produce biogas. Animal, plant, and human residues appear to be the greatest potential resource base for the residential sector outside the capital city. Although animal residues are produced in the largest amounts, the usual non-confinement housing of animals throughout the nation greatly limits the amount of waste which is readily collectable. In the capital city, garbage and human residues are the residues of greatest importance. Both renewable resources are under governmental regulation and produced in large amounts.

Although only five major sources of organic matter have been identified, essentially all organic matter could be a potential fermentative substrate for biogas production. Optimization and exploitation of additional microenvironments with suitable resources and energy needs could also enhance biogas energy.

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Production. Recommended Studies to be Undertaken to Fully Assess the Biogas Potential: Resource and Energy Study.

The first step in evaluating the potential for biogas production in Panane would be to make an accurate resource and energy assessment for the entire country. This study would be subdivided into two sections: 1) resource identification, characterization, and supply; and 2) energy requirements.

The major objective of the study would be to identify and quantify all potential resources and energy interface locations within the nation. This information could be obtained through surveys, site visits, and laboratory analysis. A partial list of important physical and chemical parameters to be identified during the study are listed in Appendix 3. Successful collection of this information would document and identify the size, potential, and impact of developing the biogas technology in the country.

The information collected would also assist engineers in matching the biogas plant size to the present and future energy needs of the area. The estimated time, staff, and budget requirements necessary to carry out this study are presented in Appendix 5. It is estimated that two staff members could complete this study within one year with an operating budget of $36,700.

Degradability Study. The primary objective of this study would be to determine the biodegradability rate and biogas production potential for the individual substrate resources previously identified. The biodegradability rates could be determined by any of three approaches: Literature review, in-vitro, and in-vivo assays.

A literature review approach would rapidly reveal previous research efforts for common substrates such as animal wastes, thereby reducing the time, effort, and costs incurred in laboratory evaluations. Uncommon resources or resources with limited published data would require biodegradability assays using the in-vitro fiber analysis procedures (see Appendix 6) and chemical determinations (see Appendix 3). These

Procedures are rapid and can be easily performed in analytical fiber and forage laboratories. The in-vitro approach is advantageous when compared to in-vivo assays because many different resources can be evaluated rapidly (generally within one week) and economically. The disadvantage of this approach is that actual biodegradability is only assumed.

The in-vivo method to evaluate biodegradability of a resource is to conduct controlled, laboratory-scale anaerobic fermentations and determine the chemical changes and the biogas yield. In this approach, the actual biodegradability is determined and the fermentation parameters (i.e., pH, total and volatile solids loading rate, retention time, and temperature) are optimized for each resource type. This type of evaluation provides the necessary information to enable engineers to design a biogas plant when supplemented with the data collected in the resource and energy study. The disadvantages of this approach are the long time requirements and the high equipment and labor costs.

For example, a single substrate could require up to two years to be fully evaluated in a well-equipped laboratory. Due to time and economic restraints, it would appear most advantageous to perform the literature and in-vitro evaluations first, and then conduct the in-vivo analysis only on resources of major importance. The estimated time, staff, and budget requirements necessary to carry out this study are presented in appendix 6. It is estimated that one staff member could complete this study within 1.5 years with an operating budget of $41,620.

Design and Material Study: The primary objective of this study would be to educate, select the optimum biogas design, construction materials, and produce working designs for residential, cooperative, community, and governmental sized biogas plants in Panama.

This relatively short study would essentially demonstrate to the engineering staff the various approaches and materials that have been used.

Throughout the world, the information collected, along with engineering skills and knowledge of the economic, cultural, and social characteristics of the country, would allow for the selection of an optimum system for local use. Economic and social conditions within Panama would tend to reflect the need for the fermenter to be economical and simple to construct, operate, and maintain.

The residential fermenter designed and built in the People's Republic of China and India may be best suited for use in Panama. These fermentation systems are generally constructed from locally available materials and at relatively low cost. Construction is also labor-intensive and would result in increased employment potential for the labor force.

The plants basically contain a masonry-constructed fermenter and a biogas storage system. The biogas produced is used primarily for cooking and lighting. Alternatively, the red-mud flexible line from the Socialist Republic of China is easy to install and can be operated almost immediately. However, the cost of importing the fermenter to Panama may be economically prohibitive.

Development of a locally produced, flexible, self-contained fermenter system may be desirable if an economical, durable liner can be produced. Biogas fermentation equipment has been constructed out of various types of steel, reinforced concrete, ferro-cement, concrete block and mortar, plastic, glass, and flexible covered pits.

The selection of construction materials can greatly influence the cost and economics of the complete biogas system, and should, therefore, be carefully considered at the system design stage. An ideal construction material would be one which is locally available; durable and resistant to material fatigue; easily installed and repaired in place with local labor skills. The construction material also should be economical and easily modified.

Pipelines for biogas transfer between fermenter, storage, and end-use locations have been made from plastic, rubber, etc.

Metal and glass tubing are crucial considerations in selecting the appropriate tubing. One should choose tubing that has a minimum number of joints, as these tend to become susceptible to leakage over time. Even though conventional standard lengths of PVC piping have been successfully used for biogas transfer, the number of connections required and the detrimental effects of insulation on the exposed pipes may offset its cost advantages. Continuously extruded PVC pipe, which is buried or protected from insulation and mechanical damage, would reduce the possibility and danger of biogas leaks. The estimated time, staff, and budget requirements necessary to carry out this study are presented in Appendix 7. It is estimated that three staff members could complete this study within a third of a year, with an operating budget of $21,800.

Chapter 22: National Biogas Plan

The primary objective of a national biogas program would be to develop biogas production from underutilized resources for use as a petroleum substitute in residential areas, cooperatives, small communities with biomass resources, and the industrial and governmental sectors. Secondary objectives would include: increasing the net available energy within the country; improving the standard of living for people without electrical power; increasing overall national employment; and recycling valuable nutrients present in the fermented effluent and residue. Implementing this program would reduce the rate of petroleum importation and environmental pollution currently resulting from the direct discharge of wastes into waterways. The national biogas plan should be designed to provide the greatest impact to the areas within the population where the need is greatest and the technology is most applicable. Three potential targeted areas of impact have been identified: individual residential housing areas without electrical grid connections or water or municipal sewage disposal facilities; cooperatives and small communities with biomass resources; and the industrial and governmental sectors.

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Producing sufficient organic matter waste by-products, rural communities appear to offer the greatest impact potential for this technology. The national program goals should be to: identify, collate, and disseminate vital statistics on the size and description of the currently underutilized resources throughout the country.

(a) A list of important physical and chemical characteristics of the resources and the energy needs near the resource areas are presented in Appendix 3; determine the energy needs and biogas applications in the targeted impact areas; collect available published information concerning biogas production from world sources (a partial list of potential information sources is presented in Appendix 4); identify the biogas production potential of available resources (see Appendices 3 and 4); disseminate available information; educate the targeted area groups on biogas technology; secure funding and/or establish loan programs from the government and private sectors to finance actual construction (alternative sources of funding may be obtained through grants or direct loan programs by the U.S. AID, the Food and Agriculture Organization of the United Nations, the World Health Organization of the United Nations, the World Bank, and the Caribbean Development Bank); make available designs for cost-effective biogas plants; provide information and advise on operating, maintaining, and troubleshooting biogas plants; assist in the development of large-scale biogas plants; provide technical assistance to individuals and groups within the targeted impact areas; strive to improve the energy concentration and yield of biogas from available resources; and improve the efficiency of devices using biogas fuel.

The national biogas plan should be designed to increase the knowledge and use of this technology wherever applicable throughout the country. Seminars, bulletins, and public affairs

Advertisements may stimulate interest and development. Attempts

To stimulate interest in universities, technical schools, and secondary schools, it is crucial to develop and enhance knowledge of a biogas resource base through Bionas Projects. Three major areas have been identified where biogas production could impact the Panamanian energy situation.

These areas include rural residential family units currently without electricity, cooperatives, and small communities with biomass resources and electrical energy limitations, as well as industrial and governmental sectors with sufficient organic matter resources.

Electricity availability within the nation is generally confined to the relatively level southern regions along the major roadway. Therefore, the development of biogas technology in areas removed from the grid or future grid areas seems most desirable. Although hydro resources are abundant in the western region, electrical development and grid connections may require a considerable time frame to connect the rural homes in the mountainous regions. Thus, biogas development in this area may be applicable.

The relative abundance of wood, compared to the low population densities in the eastern region, tends to support the continued use of wood for cooking. However, since biogas can be used for lighting and refrigeration, the development of this technology in this area may also be desirable.

The northern coastal region, which has limited electrical resources, also appears to be ideally suited for the residential and community development of biogas technology. The western and northern regions of Panama, along with the more arid southern region, seem to be best suited for the development of biogas technology.

The rural residential housing areas offer the greatest opportunity to impact the largest population (46%) within the country. Therefore, a residential biogas project is proposed to develop this area. The objectives of the project are to educate the rural population.

The community recognizes the importance and benefits of biogas technology and plans to install regional demonstration biogas plants at home sites. The design for these biogas plants should be as economical and straightforward as technically feasible. The biogas produced in residential units could be primarily used for cooking, lighting, and refrigeration. Simple and cost-effective designs for burner and mantle lamp construction have been reported (8,13).

Since 70% of the energy needs of rural Panama are derived from wood, biogas technology could significantly reduce overall wood consumption and cost. Also, the use of readily available underutilized resources, such as human and animal wastes and plant biomass, would reduce labor requirements currently expended on wood collection or charcoal production and distribution.

The fermented residue and effluent from the anaerobic fermentation have good nutrient and irrigation value (1,8). These by-products should be recycled to the soil to increase crop productivity, which isn't possible when wood is directly combusted, as most of the nitrogen is lost to the atmosphere.

Public health hazards can occur when human waste is used in biogas fermentations or the residue and effluent are used as fertilizer and irrigation water. However, The Academy (1) states that despite the survival of some pathogens and parasites, the literature documents no disease outbreaks associated with the use of digested human and animal wastes in crop production. Furthermore, they state that inhabitants of most villages or rural areas in developing countries are probably already exposed to the enteric diseases indigenous to their area. The introduction of anaerobic digesters for human or animal wastes, therefore, should not create any new or additional health hazards; on the contrary, it should reduce the present health hazards significantly (1).

The rural biogas fermentation system generally contains the fermenter, biogas storage container, and the

The necessary piping connections should be completed for the system. The design should be economical, durable, and simple. Efforts should be made to reduce material deterioration, such as metal rusting, loss of biogas due to leakage, leakage of fermenter contents, and the plugging of feed and effluent lines.

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The unit needs to be sited to maximize the use of gravity feeding when possible. It should be installed underground to ensure the agricultural productivity of the biogas plant land area isn't compromised. The fermenter should also be located away from water supplies to minimize the risk of water contamination.

The most desirable fermentation system for immediate construction in Panama seems to be the Chinese design constructed from masonry materials. Two construction methods can be developed for this project: an individual approach, where each recipient of the fermentation plant constructs the system from a common design, or an assembly line approach.

The estimated resources necessary to develop the individual construction program include core staff members to create design and educational materials, field staff members to transfer the technology in actual demonstration programs, and capital to partially subsidize the construction of the biogas plant. The subsidy program should include a method of collecting the money loaned to allow for the construction of future units. The estimated time, staff, and budget requirements needed for this project are presented in Appendix 8. It is projected that 11 staff members could complete this project within three years, with an operating budget of $996,380.

Cooperative and Community Biogas Project

Many agricultural cooperatives and small communities exist.

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Throughout the nation, these groups possess increased labor supplies, land resources, and capital, which could be directed towards the construction and operation of a centralized biogas plant. This type of centralized plant would be more

The text is cost-effective due to the benefits derived from the economy of scale. Additionally, the distribution of biogas could impact a larger number of people within a given area. The primary objective of the project is to establish community-sized biogas plants throughout the country. The secondary objectives of the project are to increase the standard of living in the targeted areas, stabilize the economy, and reduce environmental pollution resulting from the direct discharge of underutilized resources. In order to accomplish the project objectives, the following tasks have been identified: quantify and qualify the characteristics of the cooperatives and small cities, identify the energy needs and substrate resources in these areas, design the biogas system to best accommodate the area, conduct an economic and social impact evaluation of the proposed project and construct the system, if the previous evaluations were positive. The goal of the project should be to establish a minimum of one plant per province to act as an educational and demonstration facility. The estimated time, staff, and budget requirements necessary to carry out this project are presented in Appendix 9. It is estimated that 5.0 staff members could complete this project within 3.0 years with an operating budget of $784,630. Industrial and Governmental Biogas Project. Certain industrial and governmental sectors within the nation have resource potential for biogas production. The biogas produced at these locations could easily be used to replace a portion of the costly petroleum fuels currently used. A partial list of industrial and governmental residues with biogas potential is given in table 5. Therefore, the goal of the industrial and governmental biogas project should be to educate the respective groups and promote biogas production within these sectors. The estimated time, staff, and budget requirements necessary to carry out this project are presented in Appendix 10. It is estimated that 2.0 staff members could

Complete this project within 2.0 years with an operating budget of $109,000.

Specific Recommendations

The following specific recommendations are made:

(1) TRUE should continue to develop and promote biogas technology within the Republic.

(2) IRHE's program should be expanded to include a residential biogas project, a cooperative and community biogas project, an industrial and governmental biogas project, and energy studies.

(3) IRHE should expand its biogas program by including individuals from academic, private and governmental sectors.

(4) IRHE should attempt to stimulate biogas construction and demonstration units throughout the nation.

(5) IRHE, in cooperation with the academic sector, should develop teaching aids and regional conferences to educate the citizens about this alternative energy form.

Conclusion

The advantages of developing biogas production in Panama are the year-round tropical environment, which is conducive to optimum biomass growth, high insolation levels, relatively low labor costs, available labor force, a genuine need for the energy in areas not serviced by the electrical power grid and a lack of known petroleum or coal resources. Development of this technology would increase the standard of living in rural areas and retain the national currency within the local economy by reducing petroleum expenditures to foreign countries.

The most advantageous approach to biogas production in Panama should satisfy the below listed criteria. The biogas system should be economical: simple to construct and operate; incorporate gravity feeding and effluent and digested residue removal and secondary use as a feed and/or fertilizer; provide manual agitation capability or mechanical agitation by wind or water driven impellers; use solar heating by thermosyphon to maintain optimum fermentation temperatures; insulated to reduce heat losses; minimize the use of and loss of dilution water

from the system, and recover and use the valuable nutrients in the.

Digested effluent and residue. In addition, the construction requirements should use skills that are already present within the society or can be easily learned. Education of the citizens about the background theory and practical operating requirements for the anaerobic fermentation process would greatly increase biogas development success. Biogas production and use can improve the standard of living within the country. However, biogas technology may not be the complete answer to solving the energy shortage and distribution limitations within the nation. For today, and the near future, this technology appears well-suited for use in the Republic of Panama.

Acknowledgment: The technical assistance of engineers B. A. Martinez and I. Bryson is greatly appreciated. This work was performed for the Republic of Panama, contract number 31-80-DG, project for the master plan for the development of the renewable energy resources in Panama. This work was funded in part by a grant from the United States Agency for International Development, contract number 5250207, through the University of Delaware, in cooperation with the University of Puerto Rico.

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March 23, 1981

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Appendix 1 - Itinerary

Travel to Panama City, Panama

Met with Drs. K. Soderstrom and R. Lompart to discuss project and work plan

Met Ing. B. Martinez and travelled to Santiago

Worked at IRHE - Santiago

IRHE Interviewed Dr. R. Preto

Malea National Aquaculture Director

NIDA Santiago

IRHE

Visited IRHE flexible biogas plant construction site

Interview and site visit - Ing. M. Seiplay Nestlé Co., Nata, Coclé

Biogas digester aquaculture pond Instituto Agropecuario Jesus Nazareno, Atalaya

Site visit - 2 dairy farms in Santiago

Site visit - State operated duck farm (Bontyo)

Site visit - Santiago municipal slaughterhouse

IRHE Returned to Panama City

29 30 April 1, 1981

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Site visit - Open TRE, Panama

IRHE, Panama

TRHE, Panama Canal Zone city

Appendix 2

Sites Visited

Nestlé Company, Ing. Martin

"Simplifying Chief of Technical Department, Panamanian Food Company, Nata Factory. Province of Coclé, Republic of Panama. The Nestle Company operates two plants within the Republic of Panama, located in Los Santos and Nata. These plants produce a variety of products including canned condensed milk, tomato products, vegetables, and soups. The plant has the capacity to process 200,000 liters of milk per day. However, it currently operates at 67.5% of its milk capacity due to low milk production. The site has an installed electrical capacity of 1500 Ki (IRHE) and utilizes between 60-70% of this capacity. The plant operates 24 hours a day, year-round. Bunker fuel (1135.6 liters/day) is used to power the steam generators at the plant and it also has an 800 and a 400 KW diesel backup generator for use in case of grid failure. During peak production periods, the two factories employ 1000 personnel. Overall, the Nata plant operates at 60% of capacity during harvest seasons. Although the Nata plant produces waste, it is recycled and used as animal feed on adjacent farms. Low-temperature solar collectors are identified as the best method to impact the energy demands of the factory. Reducing the use of artificial lighting would also lower the electrical demand.

On Thursday, we visited the Instituto Agropacreario Jesué Nazarano Atalaya. This establishment serves as both a parochial high school and an agricultural training center where students live on-site during class periods. Students also receive training on the farm operations connected with the school. They live and eat in a dormitory setting at the school. Student numbers vary from 130-160. To reduce costs and recover energy from waste, an anaerobic digester was constructed and began operation in October 1979. The school maintains a 34-sow farrow to finish farm. Swine waste is manually flushed from some of the pens into a settling tank (2.24 m3). The settled solids are then diverted into another tank for further solids separation. The supernatant is drained to an..."

The aquaculture pond and the solids are added to the fermenter. The second tank is flushed 12-13 times per day, with the solids also being added to the fermenter. The fermenter, which has a 14.0 m^3 waste capacity and a 4.0 m^3 gas storage capacity, is a cylindrical concrete tank buried in the ground with a floating metal cover. A 16 m^3 water-diluted gas holder is also used for gas storage.

After digestion, the fermented solids are retained in a sack filter and the effluent enters the aquaculture pond. The pond, which is stocked with tilapia and carp, is drained, harvested, and cleaned annually. The fish are either consumed at the school or sold.

The small fermenter capacity is insufficient for the herd. A second fermenter, made of red-mud plastic, has been ordered and is currently awaiting arrival and installation at the site. The added capacity will increase the school's gas production potential - currently, an estimated 90% of the cooking is conducted with biogas. The additional capacity would be used for cooking and for operating internal combustion engines.

The school staff are proposing to compress and use the extra biogas in mobile engines, which does not appear to be energetically efficient. It would also seem that since so much labor is used in separating the solids by settling, it might be simpler to collect the solids by hand and add them to the final separating tank. This would decrease water usage and probably reduce production costs, as swine normally defecate in one area of the pen.

The mariculture pond at the farm receives the digested effluent. The pond measures 400 m^2 and is 1.5 m deep in the center and 1.25 m deep at the edge. The pond density is 2.5 fish/m^2.

Two dairy farms were visited near Santiago. The first farm was an unautomated farm with a 45-cow milking population. The cows were individually roped and brought to the milking area. The cow's calf was then released and allowed to suck until milk let down occurred, at which time the calf was tied and the cow milked by hand. The milk was then... (text cuts off here).

The milk was transferred to milk cans and left alongside the road for pickup and transportation to the Nestlé Company. The cows were then placed out on pasture until the next milking period. This farm used no electricity, and the small amount of waste collected in the corral area was deposited near the parlor.

The second farm was semi-automated and consisted of a 4-cow milk parlor. A single electrically driven vacuum pump connected to 4 bucket milkers was used at the farm. Following milking, the milk was transferred to milk cans for transportation to the processing plant.

A third dairy was observed in which the cows were herded and milked by hand. The milk was placed in the bulk cans and transported by horseback to the roadway for truck transportation to the processing plant. Although cattle produce an estimated 1.29x10^11 Kg of waste annually, current cattle husbandry techniques in Panama do not result in a concentrated waste problem. The only periods when collection would be feasible is during the milking period. All other times the animals are generally on pasture, which makes collection impractical.

A state-operated duck farm (Montjo) was visited. The operation maintained a 200-head duck flock. The objective of the farm was to educate and develop a duck population within the country. Waste from the site was collected periodically from the ground and could be used for biogas; however, the small flock population and long exposure time to the environment would result in nutrient losses.

The Santiago municipal slaughter plant was also visited. The plant processes 90 head daily (cattle and swine). All blood, feces, rumen, and intestinal contents are flushed into an anaerobic lagoon. The plant employs 30 workers and 10 administrators and operates 6 days a week. The plant consumed 12,080, 12,400, 11,360 KW of electricity during August, September, and October, respectively. The plant also used diesel fuel to power some of the equipment. This plant appears to offer great potential for energy recovery.

Biogas Production. A careful analysis of the power requirements and demand periods would define the biogas impact potential for the facility. Also, an analysis of the biodegradability of the waste stream would be needed to fully estimate the biogas production potential. A floating cover over the existing lagoon would probably provide the simplest solution for the fermenter. If biogas production was sufficient, the gas could be used for hot water/steam production or refrigeration. Use of the gas for electricity is also a potential since the plant uses about 520 KW of electricity/day. If the demand is relatively constant, a 75 KW generator would be able to meet this demand.

Appendix 3. Physical and Chemical Survey of Available Resources

Waste Characteristics:
- Amount produced/time
- Total solids
- Volatile solids
- Ash content
- Mineral composition
- Total nitrogen content
- Ammonia nitrogen content
- Total carbon
- Inorganic carbon
- Organic carbon
- pH
- Bop cop
- Gross energy
- Amino acid profiles
- Mineral composition
- Viscosity
- Particle size distribution
- Lignin content
- Cellulose content

Energy Needs:
- Kilowatt electricity
- Peak power demand
- Power demand profile/unit
- Steam or hot water requirements
- Other

1. Land area available for biogas plant
2. Potential funding sources
3. Current waste disposal history
4. Discharge locations
5. Proximity to other buildings, residential areas

Appendix 4. Sources of Biogas Information

Libraries
Journals:
- Biotechnology and Bioengineering
- Compost Science
- Conservation and Recycling
- Journal of Animal Science
- Poultry Science
- Transactions of the American Society of Agricultural Engineers
- Agriculture Experiment Stations in the United States, Canada, United Kingdom, India, Taiwan

Commercial Firms Producing Biogas:
- Biogas of Colorado, Inc.
- Sheaffer and Roland, Washington, DC
- Hamworthy Engineering Ltd., U.K.
- The Energetic Hog, P.R.
- Hamilton Standard, Inc.
- Koplan Industries, Bartow, FL
- Commercial human waste treatment firms

Organizations:
- National Academy of Sciences, U.S. Department

Department of Energy, Washington, DC 39

Appendix 5.

Objectives: Identify and quantify all potential biogas resources and energy requirements and energy interface locations within the nation.

Duration: 1.0 years

Staff: 2.0

Education Requirements: Formal education to include a degree in Science and/or Engineering. Prior experience in energy auditing techniques and anaerobic fermentation techniques is necessary.

Budget:

Salaries and wages: $20,000.00
Equipment:
- Drying oven: $1,000
- Muffle furnace: $3,000
- Portable pH meters (2): $1,200
- Chemical analysis: $5,000
- Office supplies: $1,500
- Travel, Domestic (2 vehicles): $5,000

Total: $36,700

Appendix 6.

Biodegradability Study Requirements

Objectives: Determine the biodegradability rate(s) and biogas production potential(s) of identified resources

Duration: 1.5 years

Staff: 1.0

Education Requirements: Formal education to include a degree in Biochemistry or Bioengineering. Experience in anaerobic microbiology techniques and assay procedures is necessary.

Budget:
- Salaries and wages: $18,000
- Equipment:
  - Large water heating/cooling bath: $3,500
  - Jar fermenters/tubing/glassware: $5,000
  - pH meter: $700
  - Balance: $2,500
  - Laboratory contingency: $1,170
  - Chemical analysis (commercial): $8,000
  - Office supplies: $1,500
  - Travel, Domestic: Included
  - Literature searches, photocopy fees: Included

Total: $41,620

Appendix 7.

Design and Material Study Requirements

Objectives: Educate engineering staff; select the optimum biogas design and construction materials; and produce working designs for residential, cooperative, community, and governmental-sized biogas plants

Duration: 0.33 years

Staff: 3.0

Education Requirements: Formal education to include an Engineering degree and Applied Microbiology degree. Drafting and knowledge of culture characteristics is desirable.

Budget:
- Salaries and wages: $19,800
- Office supplies: $2,000

Total: $21,800

Appendix 8.

Residential Biogas Project Requirements

Objectives: To educate the rural community about the importance and benefits of biogas technology; plan for the installation of regional

The demonstration of biogas plants at homesites will span for 3.0 years. There will be 11 staff members in total: 1 coordinating and education staff member who is formally educated in engineering and bioengineering technology; 9 regional field staff members working in each province - they are required to have formal education in engineering along with training and experience in biogas technology. The field members will secure participants, adapt biogas designs for use at specific homesites, supervise construction, operate techniques, and handle biogas plant maintenance and repair. They should also be capable of troubleshooting field problems. Lastly, there will be 1 secretary.

Salaries and wages:
- Coordinating and education staff member ($20,000/year) $60,000
- Regional field staff ($10,000/year) $330,000
- Secretary ($6,500/year) $19,500

Equipment:
- Office supplies ($20,000/year) $60,000
- Portable pH meters $5,400

- Construction tools (tapes, saws, shovels, trowels, etc.) for members $4,500
- Transportation vehicles (10 in total) $100,000

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Subsidy loan program: Assuming an $800 material cost per residential biogas plant, 50% loan from the government, and the construction of 10, 20, and 30 residential biogas plants in years 1, 2, and 3 for each region respectively, the total cost would be $216,000. Subtotal: $905,800. Including a contingency of $90,580, the total comes to $996,380.

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Appendix 9:
Objective: Establish community-sized centralized biogas plants in each province.
Duration: 3.0 years
Staff: 5 members - 1 coordinating and education staff member formally educated in engineering and bioengineering technology; 3 regional field staff members, each working in a 3 province area. The field members will secure project participants, adapt biogas design for use at specific cooperatives and communities, supervise construction, handle operating techniques, biogas plant maintenance and repair, and be capable of troubleshooting field problems. There will also be 1 secretary for the main office.
Budget: 48 (to be specified)

Cooperative and Community Biogas Project Requirements

Education staff member ($20,000/yr) $60,000. Regional field staff ($10,000/year) $90,000. Secretary ($6,500/year) $19,500. Equipment Office supplies ($10,000/year) $30,000. pH meters $1,800. Construction tools (tapes, saws, shovels, towels, transits for each regional staff member) $4,000. Transportation.

Appendix 10. Objective Duration: Staff Budget 49.

Industrial and Governmental Biogas Project Requirements: Educate the industrial and governmental sectors about the potential impact of biogas technology on their individual operations. Duration: 2.0 years.

Staff requirements: 1 coordinating and education staff member to be formally educated in engineering and bioengineering technology. 1 secretary.

Salaries and wages: Coordinating and education staff member ($20,000/yr) $40,000. Secretary ($6,500/yr) $13,000.

Equipment: Office supplies and training aids ($20,000/yr) $40,000.

Transportation: Vehicle (1) $10,000. Fuel and maintenance ($3,000/year) $6,000.

Total: $109,000.