

Proceedings of UNICA Workshop on Biomass as an Alternative for the Caribbean
Caribe Hilton Hotel, San Juan, Puerto Rico, April 28-29, 1982
Center for Energy and Environment Research

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FOREWORD By Dr. Juan A. Bonnet, Jr., Project Principal Investigator

These are the Proceedings of the Workshop on Biomass as an Energy Alternative for the Caribbean that was held on April 28-29 in San Juan, Puerto Rico, as part of the UNICA Science and Technology Commission Project on Development of Alternative Energy Science and Engineering in the Caribbean.

The second workshop in the series, this project uses the unique institutional resources of the Association of Caribbean Universities and Research Institutes (UNICA). By these means an unrivaled network has been established to make this project a rare experience: Caribbean talent is being used to establish, at an early stage, wind and biomass research.

The first Workshop on Wind as an Energy Alternative for the Caribbean was held on December 6-9, 1981 in Bridgetown, Barbados. The Proceedings were also published by UNICA.

This project was already underway when President Ronald Reagan announced his Caribbean Basin Initiative on February 24, 1982. As a forerunner for analyzing Caribbean energy alternatives, the initiative has foreseen the importance of the project and especially the recommendations from the three workshop stages: education and training, research and development, and demonstration needs.

The conclusion reached has been that biomass as an energy alternative for the Caribbean offers a unique opportunity to produce large amounts of energy. Relative to

The Caribbean island's needs could be met through biomass which could aid in the region's economic recovery. Both energy and food crops could complement each other, especially the production of bagasse/fiber from energy cane.

Specific demonstration projects are now required in the Caribbean to implement the use of biomass as an energy alternative. The only resource lacking is funding. The establishment of a tropical biomass institute is also crucial. UNICA is uniquely positioned to play an active role in developing regional programs, technology transfer activities, and dissemination of information. All these recommendations are discussed in detail in the presentations and workshop results.

This workshop followed immediately after the Fuels and Feedstocks from Tropical Biomass Seminar I, which was also held in San Juan, Puerto Rico, on April 26-27, 1982. This seminar was organized by the Center for Energy and Environment Research (CEER) of the University of Puerto Rico. Proceedings have also been prepared and can be ordered from CEER.

Special thanks go to all the members of the Commission and the CEER Staff for their contributions in making this project a success.

ACKNOWLEDGMENTS

The UNICA Science and Technology Commission acknowledges the work done by Mr. William Ocasio of CEER-UPR in organizing this Second Workshop on Biomass as an Energy Alternative for the Caribbean. The Commission also extends its gratitude to Engineer Pedro A. Sarkis of CEER-UPR, who collected and organized these proceedings.

The Commission gratefully acknowledges the financial support it received from the National Science Foundation, the Exxon Educational Foundation, and the UNICA Foundation. It also extends its thanks to the UNICA Staff for their cooperation, simultaneous translations, and other services provided during the workshop.

Lastly, the Commission is thankful to all UNICA contact persons who actively participated and supported the Commission members in this project.

UNICA SCIENCE AND TECHNOLOGY COMMISSION

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October 6, 1982

WORKSHOP ON BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN
APRIL 28, 1982

WORDS OF WELCOME by Dr. Duan A. Bonnet, Jr., Director, Center for Energy and Environment Research

Good morning, ladies and gentlemen, friends and colleagues. It is my pleasure to extend words of welcome to this group of dedicated professionals attending the UNICA Workshop on Biomass as an Energy Alternative for the Caribbean. This activity is co-sponsored by the UNICA Commission on Science and Technology, the Exxon Educational Foundation, and the National Science Foundation, to all of whom we express our thanks.

We must also express thanks to the Caribbean Development Bank for sponsoring the attendance of five representatives of five different CARICOM countries. Thank you all. During the preceding two days, we heard two dozen carefully prepared papers on various aspects of the biomass/energy problem.

For the next two days, we shall be concerned with the practicalities of finding means whereby our accumulating knowledge--research and technology transfer capabilities and the results obtained--might be applied to the current and future problems of the Caribbean, and especially to biomass as a Caribbean energy resource.

It is fitting we should be doing this in the Caribbean and particularly in Puerto Rico for two reasons: first, we have been doing much research in biomass, and, second, our natural resources themselves demand we do so. As most of you already know, Puerto Rico's mere 3,435 square miles of land contain six ecological zones and 26 soil classifications. These are representative of southern Florida, the Caribbean in general, Central America, northern South America, and large regions of Africa and Asia. Thus a wide range of land and water and plants and animals

Variables may be

Studied altitudes range from sea level to mountainous. At El Yunque, the tropical Luquillo Forest averages a rainfall of over 200 inches a year. Yet within a two-hour drive, we reach the region at La Parguera, where one of the world's few phosphorescent bays may be found and where the rainfall seldom exceeds ten inches a year. Just a few miles off the north shore lies the abyssal Puerto Rico trench, one of the world's deepest. Dwarf forests, lush valleys, volcanic karsts, wetlands - these phenomena multiply Puerto Rico's ability to provide naturally occurring environments for interaction. Not only with laboratory-created experiments but also with the impact of an industrialized and technologically advanced society on a densely populated island with few mineral resources of its own.

These characteristics, unique to Puerto Rico, can be found and duplicated in varying degrees on other islands and regions in the Caribbean. Therefore, it is fitting that UNICA should sponsor two days of our four-day program. Despite linguistic differences, we share a common geography and a greater commonality of human heritage and economic needs than generally realized. We also share a common range of problems. UNICA was created in 1968 for this exchange and common effort and has since grown to 45 member institutions. In these 14 years, UNICA has organized more than 200 meetings of various kinds, including workshops such as this, focusing on regional

needs and regional abilities and resources.

Energy is such a regional need and resource. The need has always been present; the resource continues to be largely potential. Always abundant as sunshine, wind, and vegetation, energy has also been in short supply since the advent of industrialization and modern technology. Now, a promise is opening up for us again - the promise and potential of energy here and now, constantly renewing itself, without our having to rely on imported fossil fuels.

Fuels are crucial for the development of our modern societies. One such fuel is biomass, a constantly self-renewing form of energy. It offers certain, almost immediate, short-term substitute possibilities for reducing the reliance on fossil fuels. Moreover, it also heralds potential promise of substantial proportions in the long term.

Essentially, biomass is a mechanism for collecting and storing sunlight in an organic form. Its numerous attributes are particularly favorable to Puerto Rico and other developing Caribbean nations. Of particular note are these factors: Its varying forms are adaptive to the region's special climatic and botanical resources and diverse land and water resources.

As an integral component of the Caribbean historical experience, it can be produced and processed with existing technologies. It is a rapidly deployable viable substitute for petroleum fuels and feedstocks. Additionally, it is potentially the least expensive substitute for petroleum fuels and chemical feedstocks in temperate regions.

Finally, the world's most productive biomass forms are found in the Caribbean region. This includes both herbaceous species, such as sugarcane and other tropical grasses, and a broad range of woody forest species.

Therefore, as the Director of the Center for Energy and Environment Research at the University of Puerto Rico, where we have been working on these problems for five years, and as Chairman of UNICA's Commission on Science and Technology through which we spread our good works, I welcome you to these proceedings.

It is my hope - and I am sure yours too - that this event will become a step towards furthering our mutual understanding of our common needs and problems. Even more significantly, it is a major step in working towards resolving these needs and problems with shared scientific and technological solutions.

BIOMASS OPPORTUNITIES FOR THE CARIBBEAN

Presented at UNICA WORKSHOP ON BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN

San Juan, Puerto Rico

April 28-29.

1962 By Lewis Smith, Consulting Economist, Center for Energy and Environment Research, GPO

WHY WORRY?

In a report dated March 17, 1982, Daniel G. Snow of A.G. Becker Inc. states: "We believe OPEC will hold its official \$34-a-barrel price at its March 19th meeting, but lower the price to \$29 a barrel at its late May meeting... and possibly even to \$25 a barrel at its year-end meeting... Moreover, we believe there is substantial risk that, as prices move down, OPEC may lose control in a downward, 'leapfrogging' price spiral to \$25 a barrel... depending mainly on whether the U.S. economy has a robust second-half recovery..." (1).

Herbert W. Krupp, vice-president of Banker's Trust Company, New York, has even predicted a world surplus of oil, with stable prices, through 1990 (2). These reports are illustrative of many which have been published this year by knowledgeable authorities forecasting a significant decline in crude oil prices over the short, intermediate or long run, depending on the inclinations of the analyst. Such forecasts and current developments in the oil industry (3) are in partial or total contrast to those published a year or more ago, sometimes by the same authorities (4) (5).

There is no doubt, of course, that we are experiencing a temporary glut in oil supplies. Contracts for delivery of No. 2 heating oil in May of 1982 are selling on the New York Mercantile Exchange for 14 cents per gallon, almost 22 cents or 19 percent below their lifetime high of 113.0 cents. Moreover, the glut is expected to last for some time because contracts for delivery in every month through October 1982 are also selling below their lifetime highs (6).

With winter gone, these figures from a regulated, open market in the U.S. confirm newspaper reports of significant reductions in the price of crude oil sold under regular contracts between oil companies and producer governments.

Accurate information on such crude prices is not

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Regularly available, especially when changes in FOB cost are affected by varying non-price terms. For example, the average FOB cost of Venezuelan crude oil imported by the U.S. is believed to have declined by \$4.84 per barrel or 15 percent between January and December 1981, from \$82.87 to \$28.03. More recently, Japanese companies have agreed to buy on a spot basis at least six million barrels of Iranian crude at \$26 per barrel, some \$6 per barrel below Saudi Arabian crude of the same variety, in violation of the OPEC pricing structure. Under the circumstances, one may ask, why worry about alternatives to petroleum fuels? And then, what are we doing here? We stand by the forecast which we made last fall, averaged over periods of several years, the prices of petroleum fuels will escalate at a rate at least one or two percentage points above the general rate of inflation for the Caribbean region. Over a decade, at only two percent per year, this means an increase in the real (i.e., inflation-adjusted) cost of these fuels of 22 percent. To get an idea of the impact, think of your own country and what could happen if suddenly, tomorrow, petroleum prices increased 22 percent, other domestic prices changed only enough to pass on this increase, but export prices changed not at all. Despite the relief given to oil consumers by the current price

decrease, petroleum conservation and import substitution are as urgent as ever. The present decline is only a small piece of good luck which gives us a little more time than we thought we had. We would be foolish not to take advantage of it. Our reasons for saying this are as follows: (1) Since the first oil crisis of May, 1970, the history of crude oil prices has been precisely what we are observing today--periods of declining (or stable) real petroleum prices followed by sudden increases which give the appearance of "steps" when plotted on graph paper. (2) The current oil glut appears to be caused primarily by transitory factors: simultaneous.

Recessions in several industrialized countries, both Marxist and non-Marxist, have led to overestimations of the effectiveness of President Reagan's economic programs. This has resulted in over-production and efforts to adapt specific structures for oil prices, as well as particular mechanisms for escalating them.

World oil consumption will continue to increase despite successful efforts to conserve energy and replace petroleum fuels. Even if this increase is only one percent per year compounded, the net increase in world productive capacity required at the end of twenty years will be over 13 million barrels per day. This is 26 percent more than the current maximum capacity of the largest OPEC producer.

In addition, a very substantial amount of new capacity must be added to compensate for the exhaustion of, or declining production from, existing wells. For the United States alone, this requirement could reach 10 million barrels per day by the year 2000, close to the current maximum capacity of OPEC's largest producer.

New oil fields are becoming more difficult and more expensive to find and develop, ensuring a relative inflation in oil prices in the long run. For instance, during 1975-1978, a period of relatively stable oil prices, exploration expenses in the U.S. increased at an average annual rate of 2 percent. Lifting costs rose at 9 percent for a weighted average of 11 percent. Recent technological advances and high oil prices make it more profitable to spend more, per foot drilled and per well, to find oil than in the past.

Nearly half the world's crude oil is supplied by OPEC countries. Outside of China and the Soviet Union, about 75 percent of the world's proven reserves are controlled by these same countries. The Middle Eastern countries in general, and the largest OPEC producer in particular, dominate OPEC pricing policy. Indeed, this producer has a maximum capacity equivalent to roughly one-sixth of the world's total.

Normal world consumption. Since its own needs are substantially less, equivalent to almost 7 percent of world consumption (13), it has a "swing capacity". It has repeatedly demonstrated its willingness to use this swing capacity to attain foreign policy or oil price objectives (7). Middle Eastern politics differ from politics elsewhere. Political and religious considerations often prevail over economic ones, sometimes in a manner that is entirely logical within the historical context, but which catches Westerners, both Marxist and non-Marxist, by surprise. Conflicts between nations, ethnic groups, religions, and sects are often centuries old and may have the nature of hereditary feuds or holy wars. Finally, some countries in the region have, or will soon have, nuclear bombs (14). Neither praise nor blame is intended here. However, oil-producing countries may not always be able or willing to consider the needs of small, oil-importing countries.

Sooner or later we must expect new conflicts in the Middle East or elsewhere which will adversely affect the price and supply of crude oil (15,16). Under the circumstances, the only prudent course is to develop alternate sources of energy as quickly as practicable. The fact that we cannot predict the timing or cause of the next energy crisis is not really relevant. Its consequences are likely to be severe and, to some degree, permanent. Within this context, we will now proceed to examine biomass opportunities with specific reference to the Caribbean.

WHAT IS BIOMASS?

Defined broadly, biomass consists of terrestrial vegetation (e.g. crops, weeds, and trees), aquatic vegetation, and the residues of such vegetation. It also includes animal wastes, wastes created by processing animals or biomass, and municipal wastes of biomass origin. Biomass is a renewable and indirect form of solar energy. It is sunlight which powers the chemical reaction that converts carbon dioxide and water into solid green matter and oxygen. The subtropical conditions which...

Characterize the Caribbean's utilization of biomass for various purposes. Due to warm (or mild) nights and winters, plant growth is possible year-round. Soil fertility may be greater than in the tropics, while rainfall, even when abundant, is not usually so heavy as to drown crops or wash away most soil nutrients. Due to these conditions, high yields per acre of fiber and other solids may be achieved, often superior to those attained in other climatic zones.

The uses of biomass are numerous: to feed people and animals; as raw materials for chemicals; for lumber, decoration, shade, protective surface cover; as the source of the oxygen we breathe, and, finally, for energy. An "oven dry" short ton of biomass (6 percent moisture) has about 15 million BTU of energy. On a steam equivalent basis, this is about as much realizable energy as there is in two 42-gallon barrels of residual fuel oil. The methods of converting biomass into energy are also very numerous (See Table 1). Many are still in the early stages of research or are undergoing systematic laboratory testing. However, some are operational on a commercial scale but are not yet economically feasible. Since time is crucial in implementing alternatives to petroleum and most countries cannot afford to make mistakes, our discussion will emphasize those biomass energy systems which are, first, appropriate for several Caribbean countries, and, second, commercially feasible.

ENERGY IN THE CARIBBEAN

All of the insular Caribbean countries, except Trinidad-Tobago, are petroleum importers. Consequently, the oil price increases of the last decade have had a serious effect on their economies. In monetary terms, crude petroleum and refined products increased from less than 9 percent of total merchandise imports in 1971 to about 25 percent in 1980 for countries participating in the Caribbean Alternatives Energy Systems Project of AID, CARICOM, and COB. The Caribbean energy situation is further complicated by the following additional factors:

There are several problems, each of which, in varying degrees, is common to a number of countries:

- (1) The small size of the national energy system.

(2) Low per capita income.

(3) A population density which is too high (or too low) for optimum functioning of the economy, particularly of the energy sector.

(4) A shortage of crop and/or forest land.

(5) Small markets for indigenous fuels.

(6) A tendency to replace traditional indigenous fuels with petroleum imports for given end-uses and/or acquire energy-intensive consumer goods (e.g., frost-free refrigerators, window air conditioners).

(7) Few or no commercially exploitable, indigenous fuel resources.

(8) Lack of trained personnel to carry out energy assessments, to develop alternative energy programs, and to manage energy systems.

(9) National energy pricing policies which inhibit energy conservation and the development of alternative energy sources.

Under the given circumstances, it is not feasible to simply review Table 1 and blindly recommend every biomass alternative that happens to be commercially viable and reliable somewhere in the world. Even the opportunities that one identifies as suitable for some countries may not be at all suitable for others. Hence, let us now discuss some of the more promising alternatives in Table 1.

Energy Cane

Energy cane is cane managed for growth, not for sugar or some other single end product. There are at least two important final products, and one is a biomass fuel or a form of energy. The cane plant came to the Caribbean on Columbus' second voyage in 1495 and has been continuously planted here ever since. Even today, it is still a major crop in Barbados, the Dominican Republic, Guyana, Jamaica, and Puerto Rico, for example.

(The rest of the text seems to be jumbled and unintelligible. Could you please provide a clear version?)

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The text has greater fertilizer inputs than sugar cane, although these are handsomely rewarded by disproportionate increases in yields of commercially valuable outputs. Like all cane plants, it must be dewatered in a large piece of machinery called a cane mill. Existing cane mill grinding capacity will therefore put an upper limit on bagasse energy production because new capacity costs roughly

\$15 million per thousand tons of green millable cane per day.

Harvesting energy cane, where yields may surpass 100 tons per acre of whole cane, requires expensive machinery or a substantial harvest-time labor force. As a result of this, one unavoidably obtains two intermediate products from the cane milling operation - bagasse and cane syrup. Present day economic conditions require that both intermediate products be converted to commercially valuable final products if a biomass energy system based on energy cane is to be commercially feasible. This means at least two final products, both of which should receive adequate prices. Finding an appropriate end use for the cane syrup may present a problem in some countries.

A sure way to lose money on cane, regardless of the management system, is to grow cane with only one final product in mind and treat the remaining material as a minor by-product or waste. The key to cane economics is multi-product output.

During the dead season, one must either burn pelletized bagasse or energy grasses to continue to generate electricity. For purposes of illustration, Table 2 shows possible harvest season economics for a biomass energy system based on energy cane planted on 11,000 acres with an average yield of 87 tons of green millable stems, 15 tons of tops and attached trash, and 8 tons of fallen trash. The green millable stems are ground in a mill with a capacity of 5,000 short tons per day. Electricity is sold at 9 cents per kilowatt hour, and high-test molasses is sold at 85 cents per gallon. The numbers are conservative yet very attractive. Certainly, some

Countries in the Caribbean should consider energy cane. For a detailed explanation, see (30).

TABLE 2: PRO FORMA STATEMENT OF REVENUES AND ECONOMIC COST (1982 PRICES)
BIOMASS ENERGY SYSTEMS (HARVEST SEASON ONLY) PERCENT OF \$Q MILLIONS
(TOTAL)

Revenues from sales:

- Electricity (520.3 million kwhr at 9.0¢ each) – 28.8
- High-test molasses off f.o.b. cane mill (21.2 million gallons at 95.0¢ each)

TOTAL REVENUES

Economic Costs:

- Field Costs Operational – 1
- Capital Recovery on working capital – 2

SUB-TOTAL - 8

Transportation of Biomass – 2

MILL Costs:

- Conventional (by difference) – 13.6
- Capital recovery on working capital
- Bagasse dry – 1.2

- Electric plant
- Administrative and general (10% of sales) – 47
- Contingencies (15% of sales) – 10

SUB-TOTAL - 34

TOTAL ECONOMIC COSTS - 46.8

Notes:

- 1) Working capital = 1108×7.6
- 2) 5 miles at \$1.15 per ton mile of moist stems, dry tops, and trash
- 3) Working capital = $\$08 \times 13.3$
- 4) Capital recovery and 20% maintenance on initial cost of \$3 million
- 5) Capital recovery and 15% maintenance on initial cost of \$9 million

Sources: See text

Energy grasses:

If one is solely interested in biomass energy, tropical energy grasses, such as Napier and Sordan 70A, are probably more economical than energy cane in many countries. This is mainly because they are de-watered by solar drying in the field and collected by a straightforward baling operation. However, they are also less labor-intensive, do not utilize existing mill capacity, and generate no co-products. Where flat land is relatively scarce or of poor quality, some of these features may prove disadvantageous. Even in such cases, however, it may be desirable to rotate energy grasses with food crops or use them with reduced inputs.

Energy trees:

As indicated in Table 1, research on these is in an early stage. However, some countries may want to explore using energy trees on small plots as a source of charcoal for cooking.

Upgrading biomass:

All three examples

Given that Agri-fuel, Bechtel, and Woodex require a considerable capital investment per ton of output. However, where appropriate boilers exist, they provide for intensive use of biomass in the existing combustion infrastructure without major refitting. The Agri-fuel and Woodex processes also convert biomass to a form in which it may be stored or exported. However, given the various constraints under which Caribbean countries operate, there appear to be few opportunities for the use of these processes as yet.

Municipal Solid Waste (MSW) is a vast and complex subject. We have dealt extensively with its economics in a paper now under revision. However, the following points must be mentioned: The economic and technical feasibility of an energy system based on municipal solid waste is very sensitive to local site conditions. The design of the collection system is critical to the success of MSW energy, especially if citizen collaboration in sorting waste is required. Socioeconomic variables are important. Once a system is established, it should not be changed often. MSW is not

an agreeable raw material for energy production. It is not homogeneous and may vary frequently in moisture content, solids composition, etc. The MSW energy system must be designed with these variations in mind. The end product is typically low-pressure steam or low-BTU gas. Neither travels well, so the MSW energy facility and its customers must be located close together.

Wood and Wood wastes are already being used in Guyana, but for pyrolysis gas rather than for direct combustion. This may be good for many countries. Economics appear to favor direct combustion for wood-electric units of 10MW up; pyrolysis, 1MW down.

Anaerobic digestion of animal wastes, considering the problems noted in Table 1 and the number of small waste generators in the Caribbean, the best solution for many countries is probably to obtain proven U.S. designs but build as much of the system as possible from.

Local or regional materials are often used, except for large operations (30,000 birds or 450 head of cattle). It is probably more economical to use the biogas produced to heat a still or to refrigerate by absorption than to generate electricity. Note that the economics of these energy systems are sensitive to the end use for the residual soil. By weight, these are the most important products of the digester. It is helpful if they can be used as an animal feed supplement to replace imported ration. The typical alternate use as a soil conditioner or mild fertilizer usually has much less value. Use of the digester effluent is highly site-specific. Biogas-fired distillation of ethanol is promising.

Anaerobic digestion of municipal sewage sludge is important from the point of view of economics, health and marketing. It is vitally important to kill pathogens in the sludge, remove metals and avoid the accidental passage of raw sludge through the digester without transformation. A feasible solution might be to combine a first-stage treatment using water hyacinths with a second-stage digestion process, using a UASB or a through-type, end-feed digester. The hyacinths would be harvested and digested separately.

For the Caribbean, the only immediate way to produce fuel-grade ethanol is to ferment cane molasses. However, this begs the question - what is the best use of the cane syrup? For some countries, sugar, molasses for cattle feed, molasses for export and/or ethanol for rum are obvious answers. However, given the poor prospects for cane sugar, countries with cane mills will definitely want to look at the generation of electricity by ethanol-fired gas turbines.

Note that high test uses 32 percent less material than black strap to produce a given volume of ethanol. Also, non-fermentable solids are reduced by 76 percent. Since these constitute the major component of distillery slops, there are substantial savings in distillery operating costs and a large reduction in environmental problems. We doubt, however, that...

Ethanol as a motor fuel, either alone or in gasohol, is an attractive option for small countries. However, even small, on-the-farm fermentation facilities can be expensive, with costs starting at around \$25,000 for corn-based ones with a 10,000-gallon annual capacity. Operating such a facility requires considerable time, skill, and close supervision, especially during certain phases of operation. There are many precautions to observe in plant operation due to risks such as ignition of vapors and potential explosions.

Large facilities also have their drawbacks:

1. An extensive distribution system must be established and closely supervised to avoid contamination of the fuel. If the fuel is pure ethanol, the system must be larger than the gasoline system it replaces due to the lower energy content per volume of ethanol.
2. For ethanol-gasoline blends over 10 percent ethanol, modifications to automobile engines may be required. If pure ethanol is used, carburetors and certain other parts will need to be modified.
3. Any blended fuel may or may not lower the motorist's operating costs, but it does not increase his security of supply as long as the gasoline is made from imported crude oil.

Methanol is currently produced from naphtha and natural gas via synthesis gas, a mixture of carbon monoxide and hydrogen. About 90 percent of world consumption is as a solvent or as a chemical intermediate. Coal and biomass are potential sources of methanol, by the same route. In the latter case, biomass is gasified, the ratio of carbon and hydrogen adjusted, and the mixture cleaned and then pressurized in the presence of a catalyst to produce methanol. At present, no biomass-to-methanol plants exist, but several based on wood wastes have been announced for Europe and North America. Methanol fired gas turbines look even more promising than ethanol fired ones. Given their sizable forest resources, continental countries will definitely want to investigate this alternative.

Moreover, there is also the possibility of methanol exports. Finally, if technical and commercial feasibility is proven, Mobil's zeolite process can be used to convert methanol to gasoline. Unfortunately, methanol-from-biomass facilities require an investment of about \$2.00 per gallon (21) and do not yet provide a very good return on investment unless the biomass feedstock is quite cheap. As a motor fuel, methanol suffers from the same kind of problems as ethanol, only to a greater degree. In particular, the separation problem is more acute (21). Moreover, expensive motor modifications are required for methanol-based fuels, although the 90 percent variety has excellent operating characteristics (36).

SUMMARY

Despite the constraints limiting the options of Caribbean countries, there are a number of promising biomass energy options which have potential for several countries:

- 1) Energy Cane, for the production of electricity from bagasse and one or more products from cane syrup. Ready for trial on a commercial scale with a good probability of success.
- 2) Energy grasses, for the production of electricity from chopped solar-dried grass. Excellent possibilities.
- 3) Direct combustion of wood wastes. Commercially proven.
- 4) Anaerobic digestion of animal wastes or sewage sludge. Tricky but probably feasible on a small scale in a number of countries.
- 5) To be investigated carefully - electricity generation by turbines fired with ethanol or methanol; pyrolysis of wood.

6) For further investigation - charcoal for cooking from energy trees.

REFERENCES

1) Snow, Daniel G. "OPEC in the Test - Maximum Uncertainty Now at Hand." Fundamental Investment Research Department, A.G. Becker Inc. Chicago and New York, March 17, 1982. 13pp.

2) Anon, "Stable Oil Prices, Diminishing OPEC Role Seen." Oil & Gas Journal. Tulsa. March 22, 1982, p. 54.

3) Schmitt, Richard B. "Drilling Dip - For the Independent Oil and Gas Industry, the '81 Boom Is Turning into the '82 Bust." The Wall Street

Journal, New York, April 8, 1981. (Fa. OO, 4) Snow, Daniel G. "The U.S. Drilling Fund Industry: Growth industry for the 1980s." Fundamental Investment Research Department, A.G. Becker Inc., Chicago and New York, March 12, 1981. 14 pp. (8) Anon, "Analysts See More Gains in U.S. Oil Profits." (Re: Bache Halsey Stuart Shields Inc. forecast). Oil & Gas Journal, November 10, 1980. P. 160. (9) Anon. "Future Prices." The Wall Street Journal, New York, April 23, 1982. B. 4B. (7) Energy Information Administration. Monthly Energy Review, U.S. Department of Energy, Washington, D.C., March 1982, 101 pp. (8) Tobrehim, Youssef M. "Iranians Propel Petroleum Sales with Cut Rates." The Wall Street Journal, New York, April 16, 1982. (9) Anon. "Oil Seen Maintaining Top Energy Role." (Re: Tennessee Gas Transmission Company forecast). Oil & Gas Journal, Tulsa, November 2, 1981. P. 80. (10) Various. "Drilling Technology". Oil & Gas Journal, Tulsa, March 8, 1982, Pp. 139-187. (11) Anon. "Steam Dominates Enhanced Oil Recovery." Oil & Gas Journal, April 5, 1982, Pp. 139-159. (12) Vieker, Ray. "Exotic New Technology Used in Oil Drilling is Leading to Big Success, a Rise in Reserves." The Wall Street Journal, New York, February 12, 1982. (13) Anon. "Saudi Action Seen Leading to \$28-29/bbl. Price." Oil & Gas Journal, Tulsa, March 29, 1982. P. 57.

(14) Weissman, Steve and Krasney, Herbert. The Islamic Bomb. Times Books, New York, 1982. Pp. \$35. Rowen, H.S. and Weyant, J.P. "Reducing the Economic Impact of Oil Supply Interruptions: an International Perspective." The Energy Journal 3(1), Pp. 1-34. (15) Anon. "Potential for Crude Market Disruption Stressed." Oil & Gas Journal, February 8, 1982. Pp. 86-88. (16) Klass, Donald L. "Energy from Biomass and Wastes: An Overview." Proc. Symp. Fuels and Feedstocks from Tropical Biomass. Center for Energy and Environment Research, University of Puerto Rico, San Juan, November 24, 25, 1980. 32 pp. (17) Smith, L. "Energy Balances for Fuel and Alcohol from Puerto Rico Energy."

"Cane." Proc. Symp. Fuels and Feedstocks from Tropical Biomass. Center for Energy and Environment Research, University of Puerto Rico. San Juan. November 24-25, 1980. 25 pp. Bungay, Henry R. "Cellulose Conversion to Fermentation Feedstocks: an Overview." Proc. Symp. Fuels and Feedstocks from Tropical Biomass. Center for Energy and Environment Research, University of Puerto Rico. San Juan, November 24-25, 1980. 11 pp.

Klass, Donald L. "Energy from Biomass and Wastes: an Overview." Preprint Symp. Fuels and Feedstocks from Tropical Biomass I. Center for Energy and Environment Research, University of Puerto Rico. San Juan. April 26-28, 1982. 24 pp.

Gibbons, John H. et al. "Energy from Biological Processes." (In volumes). Office of Hemnology-Research, Library of Congress. Washington, D.C. 1980. 195 and 234 pp.

Sworden, P.G. "Seco-Dow Corning Wood-Fueled Cogeneration Project." Preprint Symp. Fuels and Feedstocks from Tropical Biomass II, Center for Energy and Environment Research, University of Puerto Rico. San Juan. April 26-28, 1982. 9 pp.

Robinson, Charles W. et al. "Peat Production and Utilization as a Methanol Feedstock." Preprint Symp. Fuels and Feedstocks from Tropical Biomass II. Center for Energy and Environment Research, University of Puerto Rico. San Juan. April 26-28, 1982. 21 pp.

Kaspers, Harry M.C. and Wout, Sixto A. "Bioenergy from Anaerobic Treated Waste Water." Preprint Proc Workshop Biomass as an Energy Alternative for the Caribbean. UNIGA. San Juan. April 28-29, 1982. 23 pp.

Beningson, Herbert E. "Development of Free Flowing Powdered Fuels from Biomass". Preprint Symp. Fuels and Feedstocks from Tropical Biomass II. Center for Energy and Environment Research, University of Puerto Rico, San Juan. April 26-26, 1982. 19 pp.

Alexander, Alex G. "Tropical Biomass: A Resource for all Seasons." Preprint Symp. Fuels and Feedstocks from Tropical Biomass I. Center for Energy and Environment Research, University of Puerto Rico. San Juan.

April 26-28, 1982. 28 pp. Alexander, Alex G. "Second Generation Energy Cane: Concepts, Costs, and Benefits." Preprint Symp. Fuels and Feedstocks from Tropical Biomass II. Center for Energy and Environment Research, University of Puerto Rico, San Juan. April 26-28, 1982. 30 pp.

Alexander, Alex G. "Sugar and Energy Alternatives of the Genus Saccharum - an Overview." Proc. Symp. Alternate Uses of Sugarcane for Development. Center for Energy and Environment Research, University of Puerto Rico, San Juan. March 26 and 27, 1979.

Chen, James, C.P., and Meade, G.P. Cane Sugar Handbook (12th edition). John Wiley & Sons, New York, 1977.

Smith, Lewis. "Pricing Mechanisms for Syrup and High-test Molasses." Preprint Symp. Fuels and Feedstocks from Tropical Biomass I. Center for Energy and Environment Research, University of Puerto Rico, San Juan. April 26-28, 1982. 40 pp.

Smith, Lewis. "Economic Evaluation of Waste Treatment Systems." Proc. Seminar Modern Techniques of Domestic and Industrial Waste Management. Center for Energy and Environment Research et al. San Juan. February 6, 1980. 19 pp.

Smith, Lewis. "On the Fructose Front" (CEER-B-122). Center for Energy and Environment

Research, University of Puerto Rico, San Juan. January 1982. 35 pp.

Anon. "On-farm Ethanol Fuel Production." Doan's Agricultural Report. Doan's Agricultural Services, Inc. April 18, 1980. 2 pp.

(64) White, Robert A. "Methanol Development, Problems and Solutions." Proc. Conf. Methanol, New York. December 1, 1980.

(85) Lane, Robert K. "Alcohol and Electric Power." Proc. Symp. The Alcohol Alternative. Alcohol Week and Chemical Week. Chicago. May 7 and 8, 1981. 12 pp. plus attachments.

(36) Stone, Charles L. "Final Report. Synthetic Fuels Program." California State Legislature. Sacramento. June 30, 1979. 29 pp plus attachments.

CARIBBEAN ENERGY ACTIVITIES SUPPORTED BY THE US AGENCY FOR INTERNATIONAL DEVELOPMENT

Presented at UNICA WORKSHOP ON BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN

San Juan,

Puerto Rico, April 28-29, 1982 by William L. Eilers, Acting Deputy Director of THE OFFICE OF ENERGY, BUREAU FOR SCIENCE AND TECHNOLOGY, Agency for International Development, Washington, D.C. 20518.

OVERVIEW OF AID PROGRAMS IN ENERGY

As reflected in President Reagan's Caribbean Basin Initiative, the countries of the Caribbean are a new major focus of the global energy assistance programs of the Agency for International Development (AID). One compelling reason for the priority assigned to energy in this region was the recognition that in many Latin American countries and in the Caribbean, the price of commonly used fuels, ranging from petroleum imports to wood and charcoal, rose more than 700 percent in the past decade. In 1970, a 60 pound bag of coffee bought 30 barrels of oil; by 1980 it bought less than three barrels. In many countries of this region, the poor often must spend 20 to 50 percent of their average daily wage for fuelwood alone. As a consequence of this growing crisis, AID established two major objectives for the region to ease immediate energy consumption and development and to help countries make the difficult transition to a new mix of energy sources that can sustain their future economies.

This year worldwide AID expenditures for energy will total about \$20 million. This divides into approximately one-third for conventional energy, one-third for new and renewable energy sources, and one-third to support traditional fuel replenishment and development, particularly wood and charcoal. Of this amount, energy projects in Latin America and the Caribbean are funded at \$21.4 million this fiscal year. The figure does not include a substantial component that will be allocated for

new energy activities within the \$350 million supplemental appropriation that President Reagan has requested for this fiscal year or the \$900 million request for the region that the President submitted to Congress for the new fiscal year beginning in October, 1982.

ADDITIONAL RESOURCES FROM THE ENERGY

OFFICE - In addition to the \$27.4 million for Latin America and the Caribbean, the central Office of Energy in AID has a budget of about \$10 million this year, some of which will be earmarked for this region. These funds and the institutions that use them are intended to provide quick-response technical assistance to individual countries and institutions in fields such as exploration and development of new sources of conventional energy, experts for energy planning assistance, decentralized hydro-power resource assessments and feasibility studies, and technical assistance in other fields of renewable energy such as biomass, wind, and solar, including photovoltaics.

In addition, the Office of Energy invests more than \$8 million each year to support three training programs. With our financial assistance, the University of Florida at Gainesville offers an intensive 15-week course for 40 participants from developing countries twice each year. The course covers a wide range of alternative energy technologies in lectures, demonstrations, laboratory work, and field trips. Participation is limited to those who have at least a bachelor's degree in science or engineering.

We also support a seven-week course in energy planning and management at the Institute for Energy Research at the State University of New York at Stony Brook, Long Island, in conjunction with the Brookhaven National Energy Laboratory.

Last year we established a new long-term \$4.5 million training program administered by the Institute for International Education which offers to 100 students annually up to two years of graduate education at U.S. universities, or equivalent internships in U.S. industry or research institutes in engineering, management and analytical experience in various fields of conventional energy.

Generation: Simple, Low-Cost Energy Technologies for the Rural Poor

The Office of Energy focuses on the provision of low-cost energy technology for the poor in both urban and remote areas. This is achieved through grants to Volunteers in Technical Assistance (VITA) and the Peace Corps to train volunteers in simple energy technologies. These organizations are working on projects such as low-cost wood stoves, charcoal kilns, wind-powered pumps, biogas digesters, and micro-hydro installations.

Caribbean Energy Programs

The principal focus of AID efforts in energy throughout the Caribbean is on national energy planning, with special attention to the development of alternative energy systems. Over the past four years, we have invested nearly \$8 million with the Caribbean Development Bank and CARICOM to conduct national energy assessments and conversion studies, and to design, test, finance, and distribute information on alternative energy technologies.

We have financed projects such as a solar/wind resources study, an assessment of Belize peat deposits, energy assessments in Barbados, Antigua, and Guyana, and organized workshops on solar crop drying and micro-hydropower. AID has just launched another Caribbean-wide activity involving about 25 separate projects designed to create employment opportunities in both the public and private sectors.

Much emphasis is placed on the stimulation of private enterprise, particularly in the energy field where numerous opportunities exist both for co-ventures with foreign investors and new small business activities for indigenous entrepreneurs. This project is concentrating on smaller countries such as Antigua, Dominica, St. Lucia, St. Kitts-Nevis, St. Vincent, Montserrat, and Barbados. AID is channeling technical and financial support through bilateral projects with other countries in the region.

In Costa Rica, we are in the process of setting up a nursery to produce one million fast-growing trees each year. More than 1,000 hectares will be planted.

We are reforesting steep marginal grazing land in farm woodlots. Also, we are strengthening energy planning in that country and conducting feasibility studies on alcohol fuels, industrial energy efficiency, small-scale hydropower, and the use of excess capacity. A national plan for energy is being developed in the Dominican Republic with our assistance. The management and technical skills of the National Energy Commission are being upgraded and short technical courses on energy subjects are now offered. An energy information system is being built. An additional \$11 million is projected for the Dominican Republic to help in formulating national energy investment pricing plans, to help industry transition to more efficient energy conversion machinery, to exploit small-scale water resources, and to improve the management skills of the Dominican Electricity Corporation.

AID's overriding concern in Haiti is in agro-forestry and the management of rapidly diminishing natural resources. A new agro-forestry program costing \$5 million has set a target of nine million tropical trees, including five species: leucaena, neem, cassia, eucalyptus, and casuarina. Tree seedling nurseries are being planted in modern greenhouses. Tree planting is aimed at soil conservation, production of firewood, and generation of income for the rural and urban poor.

In Haiti this past week, we observed an innovative commercial approach to the charcoal problem. Several years ago, a Haitian entrepreneur purchased a briquetting machine from Chicago for about \$60,000. He discovered that a mix of 60 percent charcoal dust, which he obtains without charge from kilns near Port-au-Prince, and 40 percent molasses as a binder which he buys cheaply from the local sugar mill, makes an effective briquette that can be sold at about 60 percent of the price of equivalent charcoal. He secures bagasse free of charge to heat the ovens to dry the briquettes. Until this past year, he exported much of his production to Puerto Rico, but now the Haiti domestic market dominates.

The text absorbs his entire production. Since charcoal sells for \$5.00 per 30 kg bag in Port-au-Prince, he should continue to sell his entire production in Haiti to make a reasonable profit. In Jamaica, AID's energy sector assistance of \$14 million aims to increase the efficiency of industrial energy use, develop solar water heating, and improve the government's capability to plan and manage energy development. We are also testing species of fuelwood in Jamaica and initiating

demonstration and pilot activities in various alternative energy technologies. AID funds a number of programs in agro-forestry, rural energy technologies, small hydroelectric power, and other renewable energies in Ecuador, Honduras, Peru, Guyana, and Panama.

NEW RESEARCH FUNDS

Now, AID funds exist to underwrite promising research work in developing countries. Our Science Adviser's Office in AID awards several million dollars each year in research grants in a wide range of development areas, including energy. We also channel about \$5 million each year to enable the U.S. National Academy of Sciences to administer a separate program of research awards. Both programs seek research topics which involve collaborative studies between U.S. and developing country research institutions and universities. Grants have been ranging from about \$35,000 to \$150,000 and usually extend for more than one year.

CENTRAL PROGRAM ON BIORESOURCES

About \$1 million each year is provided under a Participating Agency Services Agreement to the U.S. Forest Service in our Bioenergy Systems and Technology Program. Its principal objective is to support overseas AID missions to develop projects. Bioenergy Production is the product of an integrated system that involves the identification and production of feedstocks and the design and adaptation of conversion technologies. In Costa Rica, an assessment of biomass energy options was made including production of ethanol to replace petroleum-based fuels in transportation as well as analyses of

Biogas, charcoal, and gasifiers. In Ecuador, the focus is on the use of fuelwood, crop residues, manures, and municipal wastes. In the Dominican Republic, we have examined small and large-scale woodfuel planting possibilities, as well as charcoal production and gasification. A study was made of the equipment requirements for the construction of a wood-fueled steam electric generating plant at Yaviza in Panama. Under our agreement with the U.S. Forest Service, a series of 14 state-of-the-art studies have been collected in the Bioenergy. For further information on the Science Adviser's Program of Research Grants, write to Dr. Irving Asher, Deputy Director, Office of Science Adviser, AID, Washington, D.C. 20518. For details and information on submission of proposals to the National Academy of Sciences, write to Dr. Michael Greene, Director, Committee on Research Awards, BOSTID, National Academy of Sciences, 2101 Constitution Avenue, N.W. Washington, D.C., 20418.

Bioenergy Conversion Handbook for Developing Countries. Ten additional reports are in preparation which can be added to the loose-leaf binder as they are published. Copies are available without charge. The bioenergy program is also publishing a new quarterly magazine called Bioenergy Systems Report with technical data and case material. Those interested can ask to be placed on the mailing list.

ENERGY STUDIES

Many of you are familiar with the impressive series of publications on technological innovation produced by the Board on Science and Technology for International Development of the National Academy of Sciences. A number of studies on energy and bioresources have been prepared and

published in recent years. They include booklets on energy for rural development with a new supplementary edition; methane generation from human, animal, and agricultural wastes; leucaena, firewood crops; microbial processes; food, fuel, and fertilizer from organic wastes; producer gas; sowing forests from the air; and the proceedings of a workshop on energy.

Survey Methodologies: Several new studies are in process, including the potential of alcohol fuels, and research on three crop species: acacia mangium, calliandra, and casuarina. The Office of Energy hopes to continue using the outstanding technical resources and experience of the Center for Energy and Environment Research, not only for our activities in the Caribbean and Latin America, but also for other regions. The Center deserves warm congratulations for helping to organize the symposium and workshop, which attracted an impressive number of high-quality scientific and policy papers.

EL CONCEPTO DE INTEGRACION DE SISTEMAS DE ENERGIA A LAS GRANJAS AGRICOLAS

Presented at UNICA WORKSHOP ON BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN

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INTRODUCTION: The continuous increase in energy, food, labor, and costs to prevent environmental deterioration and improve the hygiene of agricultural production systems, have forced scholars and engineers in the United States to seek solutions that mostly fulfill two basic purposes: (1) generate a certain degree of energy self-sufficiency with a greater increase in production, and (2) the use of economically attractive methods that effectively eliminate environmental contamination risks to an acceptable level within the legal scheme of regulations that protect it. Various solutions have been formulated, all with positive effects, but none in particular satisfy the basic needs mentioned. Among the most important are: (1) the use of waste to produce energy; (2) different technical practices for the recovery of disposable energy; (3) renovation of some mechanical systems in existing production systems; (4) the implementation of energy conservation and management measures, and (5) the recovery of

Materiales reusables que no comprometen la calidad de la producción. Estas soluciones por separado y algunas en conjunto han producido mejoras económicas y han facilitado la solución de problemas en los sistemas de producción agrícola. Desde luego, el grado de mejoras económicas y los logros alcanzados no han satisfecho las proyecciones hechas, especulándose que quizás la falla está en la forma poco intensa como se han implementado y coordinado en la práctica, aunque se reconoce que se ha obtenido algunos beneficios. La idea de combinar distintas fuentes energéticas imperecederas coordinadas entre sí con la utilización de técnicas propias de las áreas de ingeniería y agronomía ha generado gran interés por lo atractivo que resulta la incorporación de una serie de ventajas de tipo técnico que mejorarán la flexibilidad ya alcanzada con la mecanización y que revitalizarán más los sistemas de producción con un mayor incremento del beneficio económico. Esta idea se describe en el concepto conocido como "Integración de Sistemas Energéticos a Sistemas de Producción Agrícola" a nivel de pequeña y mediana escala. Se adiciona a este concepto de integración, la condición de minimizar toda energía residual disponible que pueda utilizarse. Asimismo para su implementación se establece como

requerimiento, el agregar a los sistemas, ya existentes en las granjas, elementos y mecanismos eficientes ya probados en otros procesos industriales disponibles en el comercio local y ensamblados con materiales de la región. En este trabajo se tratará de enfocar los aspectos más importantes relacionados con este concepto. Se indicarán brevemente el tipo de flexibilidad y limitaciones de estos desarrollos. Se usará como referencia el modelo propuesto para la finca Usarri, en Juana Díaz, que incluye operaciones y actividades de tipo industrial afines en sus métodos y procedimientos a las que realizan la industria avícola, ganadera, vacuna y porcina. Entre los tópicos a considerar se incluyen los siguientes: diferentes aspectos de

La etapa evaluativa; (2) guías y factores importantes en la fase del diseño; y (3) aplicaciones y limitaciones tecnológicas del principio; y (4) algunos aspectos económicos. La discusión de los tópicos se hará para aplicaciones en sistemas de producción ya establecidos y que recobren energía mediante el proceso biológico de digestión anaeróbica. ETAPA EVALUATIVA DE LAS GRANJAS La fase evaluativa es el primer paso a realizar para ayudar a definir los sistemas energéticos a ser integrados y tener una idea clara de las ventajas, dificultades y restricciones que técnicamente y económicamente se pudiera confrontar en la adaptación de las fuentes energéticas y elementos al sistema de producción existentes. Esta actividad se realiza en gran medida al analizar los factores internos y externos que van a afectar la planificación, diseño y desarrollo del principio.

FACTORES INTERNOS

- (1) Ventajas naturales del área
- (2) Grado de mecanización de la operación
- (3) Distribución de las facilidades existentes y características de la operación

FACTORES EXTERNOS

- (1) Tipo de actividad fabril y agrícola en las vecindades
- (2) Suministro de alimento animal, combustibles y servicios básicos
- (3) Condición de vida y mano de obra
- (4) Servicios públicos disponibles
- (5) Actitud de la gente del poblado en las vecindades
- (6) Incentivos gubernamentales
- (7) Evaluación del potencial legal y problemas ambientales

Las ventajas naturales del área están relacionadas con su localización, orientación y topografía--terreno montañoso, inclinado, plano, etc.--la disponibilidad de tierras, régimen de lluvias, evaporación, quebradas en las cercanías, depósitos de agua subterráneos, corrientes naturales, caídas de agua, manantiales, nivel freático, lagos, irradiación solar, condiciones del suelo para cultivos, régimen de vientos, condición climatológica, temperaturas máximas, mínimas y humedad. La información estadística y el análisis van a ser importantes para trazar la estrategia a seguir en el diseño y desarrollo del sistema.

Estimar el nivel de aprovechamiento de las fuentes energéticas disponibles. Un alto grado de mecanización es una situación muy favorable ya que provee un uso a la energía recuperada. Esta no solo se emplearía en el área de procesos (sistemas de secado y equipos para conservar las características físicas, biológicas y químicas del producto) sino también en la maquinaria adicional para aumentar la producción y minimizar las pérdidas para comercializar. La disponibilidad de suministros básicos como los combustibles (líquidos y gaseosos) y servicios de agua y luz son de

primordial importancia. Esto facilita un rendimiento adecuado en un sistema en que la sustitución de fuentes energéticas podría ser el patrón que ofrezca un mejor aprovechamiento de los recursos de producción. Por otra parte, los suministros de alimento animal son otro parámetro de mucha importancia. En base a él y a la disponibilidad de residuos sólidos estabilizados se consideran la adición de las operaciones de cultivo de heno y otros géneros, sistemas acuíferos para algas y peces. Su consideración es una necesidad por el crédito que en el renglón alimenticio podrían aportar al esquema. La calidad del alimento es algo que tiene que acordarse en base a un punto óptimo económico total de la operación. Debe entenderse que la operación que permite obtener las mayores ventajas tanto por los ingresos por producción y como por los créditos por recobro de energía de sub-productos y deposición de desperdicios. La distribución de las facilidades para la producción de la granja a revitalizar es de singular importancia para la aplicación efectiva del concepto. Esta distribución será más conveniente entre lo existente y uno de los prototipos de los sistemas característicos de producción como por ejemplo; producción en línea, áreas de producción en paralelo, etc. Desafortunadamente, las experiencias tenidas en algunos países en vías de desarrollo, las de granjas en la mayoría de los casos no siguen un patrón que...

Ofrezca la posibilidad de planificar una acción específica y uniforme. Hay que estudiar cada caso y definir una estrategia acorde. Por consiguiente, en base a que las actividades que se realizan en las granjas están identificadas con la distribución de áreas de proceso, se necesitará un cuadro sintetizado que caracterice las distintas funciones en cada área, tanto de máquinas como de hombres, para que las estructuras y máquinas que se adicionen sean más efectivas al acoplarlas con el formato de organización existente. La existencia de la agroindustria que trabaja con el procesamiento de productos provenientes del campo, u otro tipo de industrias ubicadas en las vecindades o en el área rural, puede significar unas ventajas para el concepto de integración. Esto podría, de forma inmediata, favorecer suministros de combustibles a precios razonables lo cual permitiría el uso del biogás en otro factor importante de la economía de la planta. También favorecen el desarrollo del principio, mejoras de las infraestructuras de vías de comunicación y la existencia de servicio público disponibles. En adición, la industria en el área proveerá experiencia que puede asistir en la solución de problemas. Para promover una actitud positiva de las personas hacia la tecnología debe de iniciarse un programa de educación, especialmente cuando las granjas estén cerca al poblado. La misma debe continuar durante el tiempo en que se realiza el proyecto. Esto tiene como propósito promover una atmósfera de confianza y credibilidad entre ambas partes con respecto a lo que se quiere hacer. La acción es necesaria en cualquier situación sea iniciativa privada o gubernamental. La participación del gobierno y el potencial legal existente en materia de regulaciones son muy importantes para el desarrollo de esta tecnología. Esta puede hacerse a través de actividades que auspicien estos desarrollos sean de tipo económicos o mediante la facilitación del trámite que pudieran interferir su iniciación y finalización. Para que el potencial

Para que sea efectivo, el gobierno, a través de las agencias responsables, debe promover la investigación continuamente para obtener los datos empíricos necesarios con el fin de promulgar el tipo de regulaciones que den guías significativas y adecuadas para el control de la tecnología implementada por el principio de integración. No se anticipan problemas ambientales. El sistema de transporte, la mano de obra y las condiciones de vida son factores que podrían afectar en algún grado la fase de diseño y desarrollo. Todo va a depender de la localización de la granja. Si la granja está en zona rural, no se espera que cambie drásticamente ya que los desarrollos se diseñan dentro de un consenso de criterios simples de tal forma que no se requieren destrezas especiales por parte del personal que trabaje en las distintas labores que se realicen. El transporte será según las infraestructuras existentes. Si en cambio, la zona rural tiene industrias a sus

alrededores, el sistema de transporte es de esperarse sea mejor que el caso anterior. La mano de obra sin destreza podría escasear y es posible que sea baja por razón de la competencia, significando esto un efecto económico de consideración en la operación. Es de esperarse que las condiciones de vida se encarezcan por la existencia de la industria y que el obrero sin mucha destreza emigre, añadiendo esto un elemento más para acelerar la escasez que esto traería. Como las grandes fuentes de energía y los procesos que se integran son muy específicos en naturaleza y los mismos requieren de áreas amplias y relativamente distantes de zonas urbanas, no se contemplan desarrollos en el perímetro de zonas urbanas. GUÍAS Y FACTORES IMPORTANTES EN LA FASE DE DISEÑO. Es importante resaltar que el desarrollo de un trabajo de ingeniería exige identificar parámetros que respalden el diseño y la ejecución de los proyectos, parámetros que muchas veces, como es el caso de la aplicación del principio de integración energética, pertenecen al dominio de disciplinas o.

De situaciones aparentemente ajenas al ámbito de la ingeniería. Por tal razón, los proyectos de esta naturaleza requieren la formación de un grupo de trabajo de tipo interdisciplinario que estudie, diseñe, especifique y desarrolle estructuras, maquinarias y elementos a integrar. Teniendo definidos los propósitos del diseño y los parámetros primarios, es importante, antes de establecer los objetivos y las metas, tener claro cuál es la capacidad y las limitaciones del sistema de producción existente. Además, un conocimiento de las propiedades físicas, mecánicas y la calidad del producto o productos, y de los desperdicios sólidos resultantes del proceso de producción, para identificar y considerar la magnitud y posibles soluciones de los problemas de flujo, recolección, manejo, almacenamiento, corrosión, seguridad y los relacionados con el diseño de estructuras y selección de equipos. El diseño debe proveer como objetivo inmediato las necesidades energéticas en un porcentaje alto empleando criterio de recobro y conservación con un costo total relativamente bajo. El diseño debe girar en torno a realizar unos sistemas simples que al acoplarlos a los existentes revitalicen y no interfieran la operación de producción. Esto requerirá observar los siguientes puntos: (1) poner en práctica ideas que sean de sentido común; (2) emplear el efecto de gravedad existente en el drenaje al máximo para que la cuota de energía que se use para operar el sistema acoplado sea mínima; (3) hacer un inventario del gasto de energía de la operación existente y clarificar aquellos casos de consumo crítico, estos consumos deben intentarse disminuir con sistemas que utilicen directamente el tiempo de contribución efectiva de las fuentes energéticas renovables: sol, viento, caídas de agua y biogás; (4) obtener el espacio necesario para los desperdicios, para buscar la mejor armonización de equipos y todas las actividades de la futura operación, esto ayudará a dar una idea más amplia sobre las limitaciones y capacidades de los sistemas.

Mediante la gestión anaerobia ha sido demostrado en estudios a nivel de escala pequeña y grande. Proyectos realizados en Brockman y Green Bay, Wisconsin, Energy Harvest, Illinois, a pequeña escala lo corroboran. Otras actividades de recobro de energía térmica residual han sido estudiadas y sus aplicaciones en modelos de plantas industriales y en actividades comerciales han sido debidamente probados. Por lo tanto, es cuestión de integrar todos estos subsistemas, evaluarlos y establecer qué logros económicos son factibles y qué prototipo es más ventajoso desarrollar. La sección que impulsa los programas industriales del Departamento de Energía de los Estados Unidos tiene bajo supervisión varios proyectos de sistemas energéticos integrados para tamaños moderados. Estos proyectos sirven para conocer las limitaciones de tipo técnico dentro de la base conceptual simplista requerida. Los mismos están distribuidos en actividades que

comprenden granjas para cría de cerdos, otras que combinan la actividad de producción de grano, alcohol y producción de leche. La actualmente en proceso de diseño en Puerto Rico comprende una ganadería de 500 cabezas Holstein que opera con una producción de leche de 1400 litros por día. El desarrollo propuesto incluye las siguientes actividades: (1) recolección y preparación de los desperdicios sólidos; (2) producción y preparación de gas rico en metano vía proceso anaeróbico de desperdicios sólidos, limpieza y almacenamiento; (3) uso del combustible biogás para: producción de fuerza eléctrica, como fuente calórica para regenerar la sustancia refrigerante usada en el sistema de refrigeración por absorción; (4) uso de la energía del viento para producir energía eléctrica que alimente las bombas de agua de suministro que succiona de los depósitos subterráneos para atender el consumo de agua en la operación principal de ordeño y el suministro de agua para los bebederos de animales; (5) uso de colectores solares para recolectar la energía.

Calorífica necesaria para mantener las temperaturas mesofílicas de operación de los digestores; (6) actividades de recolección de energía residual para el proceso de secado y también para asistir en mantener las temperaturas de operación mesofílica (98°F) en ambos digestores; este recobro también se realizará mediante el uso de intercambiadores de calor compactos para calentar agua, los cuales se acoplarán a las unidades de refrigeración de expansión directa existentes usadas para preservar la calidad de la leche; (2) actividades de conservación mediante la inclusión de un sistema de refrigeración por absorción el cual reducirá el consumo de Kw-Hr actualmente crítico por el uso del sistema de refrigeración directa; también se reciclará agua acumulada en las charcas para el proceso de dilución del sólido animal, el agua se bombeará por las charcas previniendo esto el consumo de agua excesivo y agotamiento de reservas, este reuso se sincronizará con la actividad de evaporación característica existente en el área; (8) se integran también actividades relacionadas con recolección de agua lluvia, cría de peces y algas en charcas, preparación de hatos para cultivos de heno. El material fertilizante y nutriente se obtendrá de los desechos sólidos estabilizados mediante el proceso anaeróbico. Aunque existe la tecnología para darle el uso adecuado a las fuentes de energía renovables y para realizar todas las actividades descritas, debe indicarse que las eficiencias obtenidas con los motogeneradores que han usado el biogás han alcanzado cifras del 14 al 15 por ciento. Sin embargo, el empleo de mezclas de biogás en determinadas proporciones con el diesel o gas natural parece ser la alternativa para aumentar los niveles bajos de eficiencia antes mencionados.

ASPECTOS ECONÓMICOS

La comparación económica de sistema a sistema es difícil hacerlo ya que la tecnología que se desarrolla en uno y otro caso van a ser diferentes. Perímetros como ingresos totales, costos de operación y conservación.

Serán, como es tradicional, las referencias fundamentales para juzgar el éxito económico de la aplicación del principio. Sin embargo, los créditos económicos por recobro de energía, medidas de conservación, mejoramiento de la calidad del producto o productos, costes de alimentos y métodos de contabilidad serán objeto de riguroso escrutinio para aceptar su validez o rechazarlos. Un formato guía para normalizar la contabilidad y realizar la evaluación de proyectos de esta naturaleza ha sido publicado por el Departamento de Energía de Estados Unidos. Para un análisis económico fundamentado en proyecciones de valor total de la inversión, costos de operación, ingresos, características de los créditos y financiamiento. Los resultados van a depender de la hipótesis teórica se recomienda considerar entre otras cosas: realidad de los números

conseguidos. Independientemente del esquema y guía y los valores que resulten no se debe presumir que estos costes y créditos son automáticamente aplicables. Antes debe realizarse un estudio de factores tales como: costos locales de mano de obra y costos de los materiales, condiciones del mercado del producto o productos, tamaño de la planta, métodos eléctricos y agua; tiempo de disponibilidad de la planta adaptada; tiempo de retención de los sólidos en la digestión anaeróbica, etc. Como se dijo antes los créditos van a variar en una y otra aplicación. Por ejemplo, en el desarrollo propuesto para la ganadería Ubarri los posibles beneficios económicos se describen según la Tabla 1.

TABLA 1 POSIBLES CRÉDITOS PARA SISTEMA INTEGRADO EN GANADERÍA UBARRI

ACTIVIDAD / MEJORA DESCRIPCIÓN DEL CRÉDITO

Molinos de Viento Reducción consumo Kw-hr por empleo de bombas de trasiego de agua

Depósitos subterráneo y agua de las charcas, Reuso del agua de actividades Reduce costos por uso de agua en el limpieza de salas de ordeño y proceso anaeróbico.

Producción alimentos - Aprovechamiento residuos sólidos Reducción de los costos de alimentación.

Animales estabilizados con complemento de fertilizante. Adición al sistema de absorción reduce el consumo de Kw-Hr actualmente crítico con el sistema de refrigeración DX para mantener la calidad de la leche. Tratamiento biológico anaeróbico y deposición de residuos: El beneficio se concibe en base a los ahorros que en costos se obtendría por empleo de materiales químicos y por consumo de energía que el tratamiento y manejo de residuos no estabilizados requerirían. Mejora la calidad del producto. Aumento de ingresos por mejores mercados. Uso de biogás en maquinaria y transporte. Ahorros por consumo de combustible. Ventas de subproductos. Material fertilizante, heno, etc. Los resultados finales del estudio servirán para corroborar estos créditos y el tipo y magnitud de gastos e ingresos.

BIOENERGY FROM ANAEROBICALLY TREATED WASTE WATER

Presented at UNICA WORKSHOP ON BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN

San Juan, Puerto Rico, April 28-29, 1982

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INTRODUCTION

The present economic situation is based on an almost unlimited supply of fossil fuels and minerals. This system has forced the consumption of raw materials to such high levels that the finite natural resources threaten to give out. The consequent threat of a world energy crisis has stimulated the search for ways to produce energy from new and renewable resources. The modern economic system has also caused the production of large amounts of domestic, industrial, and agricultural wastes. Although wastes may contain useful and valuable components, including potential energy sources, recovery is often not considered competitive because of the low prices of these products on the world market. Consequently, the disposal of large amounts of waste materials has resulted in pollution.

Of the natural environment on a global scale, it is apparent that if wastes could be considered as a source of raw materials rather than as unwanted materials of negative value, then many problems that face our society would be minimized. In this respect, wastewater can be considered as a potential source of energy. However, it's important to note that the discharge and treatment of waste waters, using present technology, consume significant amounts of energy, as can be seen in Table 1.

TABLE 1 GROSS ENERGY CONSUMPTION OF SOME ANAEROBIC SEWAGE TREATMENT PLANTS

Annual Consumption per p.c. (a) System _ in M.J. in Therms(b) _in kWh

Low-rate 35 0.33 10

Low-rated activated sludge type 55 0.52 15

Oxidation ditch(Pasveer) type 0 0.85 25

(a) A population equivalent (p.c.) is defined as the biochemical oxygen demand (BOD) by micro-organism to digest the daily amount of organic waste, discharged on the average by one inhabitant. In this case, 1 p.e. equals a BOD of 54 g O₂/day. Another approach is to define p.e. in a relationship with the chemical oxygen demand, whereas the organic waste is chemically oxidized to conform with the K₂Cr₂O₇ method and with the amount of Kjeldahl-nitrogen (TKN) present in the discharged waste. Assuming the relationship COD BOD 2.5 for untreated domestic sewage and a discharge of 10 g TKN/p.e day, 1 p.e. equals then 2.5 x 54 = 135 g O₂/day (without nitrification) resp. 135 + 4.87 x 10 = 180 g O₂/day (with nitrification)

(b) Conversion factors 1 Btu = 1.06x10⁵ 1 therm = 10⁵ Btu

It is assumed that the total energy consumed in the U.S. for domestic municipal wastewater processing costs more than \$130 million annually. The secondary and tertiary treatment may

increase this amount by nearly ten times. This is equivalent to an energy volume of 100 million barrels/yr of oil, which is approximately one percent of the total energy consumption in the U.S. (2).

The situation in the Netherlands Antilles is as follows: the annual energy costs for conventional

Aerobic treatment of the domestic water in the capital, Willemstad, with a population equivalent of 100,000 (excluding industries), would likely cost between \$145,000 and \$365,000, depending on the type of system used. This accounts for approximately 16 percent of the total annual cost for wastewater treatment.

It should be understood that another 60 percent of the total costs are due to capital liabilities. Therefore, there seem to be more significant budget items than "energy" to cut costs on. Moreover, it's important to note that in the Caribbean, large amounts of energy are consumed for purposes other than wastewater treatment. In the Netherlands Antilles, for instance, the annual energy costs of air conditioning are estimated at \$23 million. A dramatic decrease can be achieved by adopting more climate-adapted design and construction for tropical housing.

However, due to the significant capital investment required for waste management and the rising energy costs and consumption, alternative processing methods should be explored and trialed. Priority should be given to those processes that not only conserve energy but also produce energy and reduce capital costs. The University of the Netherlands Antilles (UNA) began researching anaerobic wastewater treatment using an upflow anaerobic sludge bed system (UASB) at the end of February 1982. If the investigations prove successful, the UASB system will become a substantial part of an integrated waste processing scheme.

The high costs of waste management pose a problem for Curacao due to the small scale of the various waste disposal facilities. Under the proposed scheme, wastewater treatment and solid waste handling facilities would be combined into one processing plant where waste recovery might become feasible. Valuable materials like glass, plastics, and scrap should be separated from the municipal waste for local manufacturing or export. The organic fraction will be converted into compost, along with the surplus sludge derived from the wastewater treatment.

Waste-water treatment unit. Only a small fraction of the original volume has to be discharged as sanitary landfill. This compost and treated effluent will be used in agriculture. Consequently, local employment will be stimulated and Curacao will become less dependent on imported food and other necessities. In an arid climate like there is on Curacao, water is scarce and expensive. The value of a "second quality" water like treated effluent will amount to \$0.60/m³.(4) The UASB reactor will be an internal energy source of the integrated plant since it is likely that methane will be produced. See Figure 1, THE UASB-SYSTEM New methods have been developed in energy saving waste water treatment techniques. This has led to the development of the Upflow Anaerobic Sludge Blanket Reactor (UASB). It was during experimental work on a continuous anaerobic process at the Wageningen Agricultural University in the Netherlands that the degree of sophistication required for practical commercial use was achieved. (5) The main part of the UASB system consists of a reactor tank in which a mixed bed of bacteria is located. This microbial population is composed of facultative and strict anaerobic bacteria which utilize chemically bound oxygen. In the UASB system the raw waste water passes through the reactor in an upward direction and pollutants are absorbed by the microorganism. The digestion is, in essence, a sequential process. Complex organic matter is hydrolyzed and, subsequently, acid forming bacteria

converts the hydrolyzed compounds into simple molecules, viz. volatile fatty acids (VFA), CO₂, N₂, and H₂. The VFA and other intermediates in turn serve as substrate for methane bacteria and are mainly converted into CH₄ and CO₂. In a balanced digestion process, however, the separate steps take place simultaneously at an optimal temperature of 33°C (90°F). The gas produced rises to the surface at the top of the reactor where it is carried off via a gas globe and a water seal, also at the upper area.

In the reactor, the separation of sludge and effluent takes place. A disadvantage of the UASB process is its sensitivity to disturbances if certain limits in the fluctuations of pH, loading rate, and temperature are exceeded. Another possible disadvantage may be that anaerobic treatment must be considered as a primary biological treatment facility. Residual pollution, the presence of vanadium, and anaerobic conditions, compel subsequent aerobic biological treatment of discharge to sewage. In moderate climates, the process temperature is sometimes a problem too, and the system is self-supporting only if strongly polluted wastewaters are processed. However, in the Caribbean, there is no need for an external heat supply since temperatures are almost at a constant and optimal level of 27°C (81°F). This implies that the system may also be energy self-supporting even in the case of processing weakly polluted wastewater. Some advantages of the anaerobic upflow process are: Substrate loading reactor, the anaerobic biomass can take care of heavy loads (10 kg COD/m³ day) because of the high.

Tempo 100,00 Biological treatment including UASB processing TS 30, 0008/99, NEW recovery Sanitary Benefit and construction ethane energy, ED 2, Windrow or aerated static pile green composting facility, Unreclaimed effluent Flare 1, CONCEPT OF AN INTEGRATED WASTE PROCESSING SCHEDULE FOR CHICAGO

Treated Effluent, Sludge Blanket, UASB SYSTEM

Fig. 2: Process flow diagram, Centrifugal pump, In-line capacity \$800 mt/n vessels, \$004, In-line capacity \$800 m/n, Gas meter, Water seal (water pressure co, 2"), UASB-reactor, 500L, Timer container for alternating sump

Sludge retention of the reactor, viz. 25-30 kg VSS/m³, and the fairly high specific bio-activity of the sludge, viz. 0.7-1.1 kg COD/kg VSS/day at 30°C. As a result of the high loading.

Rate: Short hydraulic retention times, such as six hours, are possible. Small-sized facilities are required, thus, in many cases, anaerobic (pre) treatment has proven to be financially competitive with aerobic treatment and other anaerobic treatment facilities (Table 2, Table 3).

Sludge Quality and Quantity: The sludge is well-stabilized, easily settles, and has a high dry matter content (Sludge Volume Index 10-30 ml/g). Compared to aerobic treatment systems, surplus sludge production is relatively small (4-10 times lower) and amounts to 5-15 percent of the removed COD.

Nutrients: As a consequence of the low sludge production in the anaerobic process, fewer nutrients

(nitrogen and phosphorus) are required compared to aerobic processes.

Energy: Since the ambient temperature in the Caribbean is almost optimal for the process and energy is only required for pumping, an energy surplus should be expected.

ENERGY PRODUCTION

From a given amount of average type waste having a general composition of C, H, O, and N, a rough estimate of the producible methane can be obtained from the formula: $3 aH,0 42434) CO, + ann, B+3 2 3$. The COD of the same waste can be calculated with the formula $Cy Hy O Ng + 2m 2 nO, + (@/2-b 3/2 @) M0 + ANH$.

From both formulas one can deduce that the stabilization attained in anaerobic treatment is directly related to the methane production, since the ultimate oxygen demand is two mols O₂ / mol CH₄. This is in accordance with the equation: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. From this, one can calculate that oxidation of 1 gram mol C, (22.4 l at 0°C/760 mm Hg) demands 64 g Oxygen, or 1 kg COD equals 0.35 m³ (°C, 760 mm Hg).

The relationship between CH₄ and COD is given by the formula: $V_{ong} = A(Y) 0.85 b_{coy} c_{nn} c_{op}$. Where V_{ong} is methane production (m³, 0°C, 760 mm Hg), Y is yield factor: fraction of removed COD used for the development of new bacteria (sludge growth), generally 5-15% L_{cop} is waste load expressed as kg COD and N_{cop} is processing (removal) efficiency.

OF COD OR

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COMMODITY Y SSONKI-ISVN SLIDERAW 49 SLD © rene

Since the generated methane is a fraction of the total production of biogas, there is a slight variation in energy content. Depending on its "purity" biogas has a heating value of 7000-8500 Kcal/Nm³ methane City or 29-40 MJ/Nm³ CH₄, (740-2060 Btu/ft³) which means that an equivalent of about 3 kWh/Nm³ CH₄, (roughly 80-40%) can be obtained. At Curacao presently 1 kWh costs 80.145 (April 1962).

APPLICATIONS AND IMPORTANCE OF ANAEROBIC WASTE WATER TREATMENT

Because the development of modern anaerobic systems, especially the UASB-type, is rather new, only a relatively small number of industrial-scale plants are in operation. Most of these plants operate in countries like the Netherlands, West Germany, Sweden, and the U.S.A. Since high biogas production allows internal energy supply for heating, there are substantial advantages in moderate climate countries. UASB processing has general applications to a wide variety of agricultural and related industries. Also, the treatment of other wastewaters from industrial and

non-industrial sources have proven to be feasible. Some examples of wastewaters tested on pilot-plant-scale and/or tested on industrial-scale are outlined in Table 4.

TABLE 4 OUTLINE OF SOME INDUSTRIAL - SCALE OPERATING OR PILOT PLANT SCALE TESTED UASB APPLICATIONS FOR WASTE WATER TREATMENT.

Treatment of leachate from sanitary landfills (6) Heavily polluted leachate (COD 25000 ppm) contains high amounts of heavy metals, hence there is a risk of contamination of groundwater. Laboratory research and pilot-test at 20°C and 33°C have shown that COD-removal efficiencies of more than 70%, respectively 30% are possible with a biogas production of 0.52 Nm³/kg removed COD (57% CH₄). An extra advantage is a removal of metals from the effluent up to 98% efficiency.

TREATMENT OF WASTE WATER FROM SLAUGHTERHOUSES AND MEAT

Processing Industries:

This application is currently being tested with a 30 m³ reactor in the Netherlands. The subsidiary aims are energy generation and protein recovery.

Treatment of Wastewater from Starch Industries:

Several starch industries in the Netherlands are now equipped with UASB systems. For example, a maize starch industry with 60,000 p.e., has capital costs of US \$16.70/p.e. At potato starch industries, wastewater (COD 18 kg/m³) is treated at loading rates up to 18 kg COD/m³-d. At a loading rate of 5 kg COD/m³-d. (40 p.c./m³), a biogas production of 8.5 - 7.5Nm³. (71-774 CH₄) per m³ treated effluent is obtainable, as well as a pollution removal efficiency of 95% as COD and 98% as BOD. The net surplus is used for starch processing.

Beet Sugar Industries:

Many beet sugar factories in the Netherlands are now equipped with UASB systems. Loading rates of 20 kg COD/m³-d. (100 p.c./m³) at high purification efficiencies are possible. The net energy surplus is used as boiler fuel in the factory.

Breweries:

In 1981/1982, the construction of the world's largest industrial anaerobic wastewater treatment complex at the Helena Beattie Company in La Crosse, Wisconsin was completed. The brewing produces over 1 million bbl (150 million l) per year. The plant is designed to process over 10,000 ml/l (5 MOD) of brewers' wastewater with a pollution rate of 1800 g BOD/m or 2880 g COD/m. The total load amounts to 347,000 kg BOD/day or 54,300 kg COD/day. A reduction of 458 BOD is expected. Methane production is calculated at 17,600 m³/d (621,600 ft³/day) with a heating value of 7130 kcal/m³ (900 BTU/ft³). Options for using the bio-energy are either electricity generation or boiler fuel. The gross value of the biogas is estimated at (1981) \$816,870 per annum (40/therm). The operating costs (personnel, utilities, chemicals, maintenance and sludge removal) are estimated at (1981) \$240,000/year or \$492,288/year including process heating.

The operating benefits are therefore \$324,582 per year. Capital costs, exclusive of sewer or street work, or outside utilities, would be \$6.5 million as of the fourth quarter of 1981. "Based on the projected return on bio-energy, this would imply a 20-year payback; however, it is expected that as energy prices inevitably rise, the rate of return will increase and the payback interval will decrease.

DOMESTIC WASTE WATER

At the University of Wageningen, the birthplace of the UASB system, remarkable results have been achieved with domestic sewage. Under dry weather flow conditions, a 65 - 85% COD reduction was obtained at temperatures higher than 6°C (43°F). The biogas production amounted to 220 l/kg COD (at 20°C or 68°F). A net CH₄ production of 7.6 - 9.1 Nm³ CH₄/p.e./year is expected (1 p.e. equals 544g BOD/m³d). However, during rainfall in a combined sewerage system, COD reduction is expected to diminish to 50-75%.

The climate in the Caribbean offers ideal conditions for the UASB process as an energy-producing unit. Since temperatures are generally higher than 24°C (75°F) and there are only small fluctuations in the average annual temperature, no heating of the reactor will be required. The produced biogas can therefore be used for other purposes. In this respect, waste waters from local food processing industries (such as cane sugar, distilleries, meat processing, etc.) are undoubtedly promising energy sources.

In the Netherlands Antilles, there are only a few food processing industries. No pollution loads are known for these industries since an overall study of environmental pollution has not yet been completed. The following pollution figures are only rough estimates. A rum distillery is located on St. Maarten, but no production figures are available yet. Because of results at other fermenting and distillery industries, a high pollution rate and therefore a high gas-production may be expected. For example, with molasses industries, 10 kg BOD/m³, BOD/COD = 0.8, expected gas production is 4Nm³ CH₄/m³.

Treated wastewater is expected to have a certain pollution ratio. The Amstel Brewery on Curacao produces 132,000 hl of beer per year. Breweries, like most food industries, do not operate identically. Some use Lauter tuns, others use mash filters; some recover liquor, others do not; some use corn grits, others use rice, and so on. Consequently, the amount of waste and the pollution load of the sewage may differ considerably. The wastewater volume varies between 20-40 hl per hl of beer produced. Pollution rates range from 500-1800 € BOD/m³ or 940-2900 ¢ COD/m³.

Assuming the same sewage characteristics as for the Heileman Brewery (see Table 4), the pollution loading rate is estimated at 38,500 p.e. with a gas production estimated at 1460 Nm³ (51600 l³) of CH₄ per day. This volume equals a heating value of 49x10³ MJ (464 therms) per day. This energy may be used as a fossil fuel substitute for steam generation. If electricity were generated from this biogas, an annual production of 1,600,000 kWh with a local substitute value of \$232,200 (or \$6.93 per p.e.) can be estimated.

In this situation, not only is an energy credit obtainable, but reusable water is also a possibility. Due to the arid climate in the Netherlands Antilles, the main fresh water source is distilled seawater, with a price range between \$2 - \$4.50/m³. In the beet sugar industry, a significant reduction of the use of process water can be realized by recirculating treated effluent.

The slaughterhouse on the island of Curacao slaughtered in 1980: 195 cows, 42 calves, 5,999 pigs, 3,901 sheep, 1,512 goats, 14 turtles and 18 other animals. The pollution loading rate is estimated at approximately 8000 p.e, or 1400 kg COD/m³ per day. This equals a methane production of 400 Nm³ per day or 75,000 Nm³ of CH₄ per year, meaning a substitute value of electricity for the amount of approximately \$92,700 or \$4.10 per p.e. per year.

Currently, industries in the Netherlands Antilles are required by law to purify wastewater or they are taxed for discharging wastewater. Consequently, up to now,

Industries have been interested in wastewater treatment only if a positive income is obtained from the process. Even then, however, wastewater treatment probably will be considered "branch-foreign" unless high energy credits are obtained from it.

With respect to domestic wastewater, the Curacao government plans to construct several wastewater treatment plants for the town of Willemstad within a few years. One aerobic activated sludge plant (4000 p.e.) is already under construction. Because almost all construction materials are imported, capital costs of a plant of this size are very high (up to \$140/p.e.).

A wastewater treatment facility composed of a UASB reactor as a primary biological stage and a trickling filter as a secondary biological stage is expected to be financially competitive with the single activated sludge systems being planned for the town of Willemstad (100,000 p.e.). A gross energy production of 800,000 Nm³ CH₄/year with a heating value of 2.39×10^2 J/year (2.26 10² therms/year) may be feasible and would provide an electricity generation of 2.4×10^2 kWh with a local value of \$348,600 or \$8.49/p.e.

Estimates of investment costs and running costs of a one-stage aerobic wastewater treatment plant and a two-stage UASB facility are made in table 5.

TABLE 5 COST ESTIMATE OF 100,000 P.E TREATMENT FACILITIES

1 Stage aerobic treatment | 2 Stage activated sludge UASB + aerobic treatment

Load: 100,000 p.e. or 13,500 kg COD/day | 10,000 p.e.

Loading rate, 1° stage: 10 p.e./m² | 40 p.e./m² or 5.4 kg COD/m²

Efficiency 1° stage: 70% | 2° stage: 25% | Overall: 25%

Volume 1° stage: 10,000 | 2,500 m³ | 2° stage: - | 3,000

Methane production: 800,000 Nm³/year

Capital costs (x1000\$): Sedimentation - | Sludge drying \$3350 | UASB + gasholder \$1400 | Dual-fuel generator - | \$100

Total per p.e.: \$80 | \$48.50

Annual costs (1000\$): Investment costs \$920 (11.58% of p.e.) | Maintenance \$38.5 of p.e. - | \$19.6 (1.308% of p.e.)

The following is the corrected text:

200 contingencies 200, 160 97 (2b of 1) So, Ho 100's Ref TS Energy production (electricity) equals minus 248.6 Total 1600 2 costs per pack. () 16 7 per a rested effluent (> " 18 NB. Estimate does not include net revenues from effluent sales: \$0.56/m" or \$1.63 million/year (water losses assumed 208). In that case, a single-stage aerobic activated sludge plant is financially self-supporting, and a 2-stage wastewater treatment plant has a net revenue of \$964,000/year, which can be used for operating the integrated waste processing scheme (fig. 1).

From these calculations, one can see that:

1. Investment costs of the two-stage (UASB + activated sludge) facility are 39 percent lower than for the one-stage activated sludge facility.
2. Annual costs of the two-stage facility are 50 percent lower than for the one-stage facility.
3. In case effluent sales for irrigation purposes are realized, the one-stage facility will be self-supporting, while the two-stage facility has a net revenue of \$964,000/year, which can be used for operating the integrated waste processing scheme as indicated in fig. 1

ARRANGEMENT OF TEST EQUIPMENT UASB REACTOR PROCESSING DOMESTIC WASTE WATER

Before and during the tests, several logistic and technical problems had to be solved. Two factors made this difficult. There is only limited analyzing capability at the UNA and no equipment for field investigations. There was no budget in 1982 for this purpose, and the budget for 1983 has been cut drastically because of the economy. The initial investigations were made possible with the help of some local institutions which made some equipment and materials available. The designed pilot-plant has a capacity tuned to the capacities of local available pumps and measuring instruments. The installation as a whole includes after some modifications (see Fig. 2):

1. Centrifugal pump for optional influent supply to storage vessels and optional discontinuous, automatically time-controlled, sludge water recirculation in the UASB.

Reactor (cap. 800 L/h).

2. Storage vessels (400 L).

3. Pulse pump for feeding UASB reactor from storage vessels.

4. Gas meter.

5. Water seal.

5. CASB-reactor (500 L) composed of two old drums and a tilted plate interceptor with a gas globe, welded together.

Waste water treatment and methane generation proceed as follows: substrate containing influent is

made to flow upwards through the reactor by means of the pulse pump. The gas produced in the process is carried off via the gas globe at the top of the reactor, the gas volume meter, and the water seal. In the upper part of the reactor, the sludge/water mixture is separated by the tilted plate interceptor. The sludge flows back into the reactor vessel and the treated effluent overflows into the storage vessels or is directly discharged.

Time controller for alternating operation of centrifugal pump and pulse pump.

8. Filter as a prevention against clogging in the recirculation system.

9. Devices for water flow indication and manual control and temperature measurement.

The installed flow scheme has the following processing options:

1. Raw influent is periodically pumped to the storage vessels and after that the UASB reactor is fed during a predetermined time interval. The overflow of the UASB reactor returns to the vessels. Sludge water mixing is optional. Before the vessels are refilled with raw influent, treated effluent is discharged to the sewers (batch type system).

2. Raw influent is continuously pumped to the storage vessels and the UASB reactor is fed simultaneously. Return flow of the treated effluent to the storage vessels and/or sludge water mixing are optional.

The installation was assembled at the site of the municipal wastewater treatment plant "Klein Hofje". This plant consists only of a facility for primary sedimentation (Dortmund-type) and anaerobic digestion of primary sludge. Partly stabilized sludge from this digester was used to start the UASB-reactor on February 28, 1982. The average composition of the initial sludge in the reactor was approx. 12 kg.

TSS/m³; 806 vss. RESULTS: A sludge adaptation period of six weeks was projected. However, the pilot test experienced several technical breakdowns and, consequently, low efficiency resulted. The effective operation of the pilot plant is only 60 percent until now, and therefore, the start-up period has not yet been completed. At the Klein Hofje site, municipal wastewater from a separated sewer is discharged. Based on a daily discharge of 50-80 l/cap. day and a load of 54 g BOD or 125 g COD/cap. day, a pollution rate of more than 1500 g COD/m³ was expected. The pollution rate, however, was never more than a disappointing 486 g COD/m³. This low value cannot only be explained by assuming biological oxidation during long hydraulic retention time in the sewerages. Probably, large amounts of infiltration water are entering the sewerages as well. It was noticed that especially after rainfall, the COD sharply decreased. A consequence of this phenomenon is that even after start-up and sludge adaptation, the UASB reactor will not operate at a maximum loading rate because hydraulic retention time will become the limiting factor.

Shortly after the first start-up, it turned out that a raw wastewater supply directly to the UASB reactor was not immediately possible because of clogging effects in the influent system and centrifugal-type pump. For that reason, wastewater was periodically pumped into the storage vessels. The UASB reactor was fed from there. Since the biomass in the reactor was not completely adapted, the organic loading rate was kept low by returning the overflow to the storage vessels. Under these circumstances, the produced biogas was not released very well from the sludge particles unless the reactor can be brought into vibrations. Forced recirculation of the

sludge-water has given some improvement. The results of this period are given in Table 6. From these results, it is apparent that the average COD-removal efficiency is still low; however, on some days, a COD removal of 60 percent was observed.

More was obtained, and on March 18, the pulse pump was damaged and had to be replaced. The subsequent test period was characterized by a decrease in biogas production, from 22 L/day to less than 6 L/day. Eventually, production stopped. The sludge content proved to be very low, and the reactor was refilled with new sludge. However, on April 8, the packing of the centrifugal type pump started to leak, rendering the supply of raw influent impossible. This pump still has not been replaced and tests have temporarily stopped.

TABLE 6: TEST RESULTS

Period: March 27 - April 7

Pollution ratio influent (gO/ni?): 325 - 3008

Effluent (gO/ni?): 7370s

Efficiency (%): 7 - 48

Load (geuD/4 n?): 0.455 - 0.600

Gas production theoretical (No^l/period): 61.5 - 138.5

Gas production measured (ni* biogas/period): 192.4 - 232.2

Gi ratio: 5668

Hydraulic retention time average (day): 1

Recirculation rate: a7? - 0.004

Assumption Gi production: 1s 0.35 Q-Y

Sludge content during test periods March 2-14: 12 kg TSS/m³; 818 VSS

Initial sludge content of test period April 1-7: 14.6 kg TSS/m³; 89% VBS

Average temperature: 30°C

Correction for temperature; no corrections for solubility of gas in wastewater

CONCLUSIONS

1. UASR processing of industrial wastewater represents a cost-effective and promising method of waste removal and energy recovery.
2. The climatic conditions in the Caribbean are exceptionally suitable for achieving optimal net energy production. It is anticipated that domestic wastewater can be treated with a high energy yield. However, further feasibility studies are necessary.
3. A higher benefit from wastewater treatment can be obtained if energy production is desired and if the treated effluent is reused as process water for industries or irrigation.

Acknowledgments: We wish to thank the Sanitary Department of the Isle of Curacao for its support of this research.

Mr. Joop Willems, Mr. Franklin Fecunda, and Mr. Arthur Eliza of UNA are greatly appreciated.

References:

1. Koot, A.C.J.; Treatment of waste water, 1980, Delft, Netherlands.

2. Jewell, W., Switzenbaum, M.S., and Morris, J.W.; "Municipal waste water treatment with the anaerobic attached microbial film expanded bed process," Journal WPCF (53), 1981, pp. 482-490.
3. Gill, Ir. Chris; Private Communication, UNA, 1982.
4. Winkel, Ir. Chris; Private Communication, Dept. of Agriculture, Animal Husbandry, and Fisheries, 1982.
5. Lettinga, G., et al.; Several publications, e.g. a) "Feasibility of anaerobic digestion for the purification of industrial waste waters," 4th European Sewage and Refuse Symposium EAS Munich, 1978, b) "Anaerobic treatment of raw sewage," H2O (14) 1981, no. 10; 214, UDC 628.356.6 (in Dutch).
6. Kaspers, H.M.C., et al.: a) "Anaerobic treatment of leachate from controlled tips of NSW," 5th European and Refuse Symposium EAS Munich, 1981, b) "Accumulation of metals in biological sludge from anaerobic treatment of leachate," H2O (14) 1981, no. 3; pp 43 (in Dutch).
7. Richards, E.A.; "Bio energy from anaerobically treated waste water," 1981 (not published), RME associates, 9305 N 124th Street, Brookfield, Wisconsin 53005, (414) 783-5406.
8. Keenan, John, U.; Iraj Kormi; "Anaerobic digestion of brewery by-products," Journal WPCF, Volume 53, Jan. 81, pp. 66.

EL INRLA DENTRO DEL DOMINIO DE LA ENERGIA BIOMASICA

Presentado en UNICA WORKSHOP ON BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN San Juan, Puerto Rico 28-29 de abril de 1982 Por Aubert Parfait

It is necessary to point out from the beginning the concerns of the National Institute of Agronomic Research in the field of biomass. According to Chartier, the energy valorization of biomass, more than any other energy medium, is in permanent interaction with other sectors of activity (food production, wood production), which means that macroeconomic problems should be considered.

Considerarse detenidamente. Por consiguiente, se ha procurado organizar las investigaciones dirigidas por el I.N.R.A, en una Comisión de Energía Biomédica. Para asegurar especialmente la definición y la evaluación de los programas. A la misma vez, se han designado delegados regionales para la energía. Una de sus responsabilidades es dar a conocer mejor las actividades de I.N.R.A. En el último informe de actividades de la Comisión de Energía Biomédica se presentaron los programas en proceso bajo tres áreas: Los Recursos, Bases de la producción, potencialidad de producción del territorio, mantenimiento de la naturaleza renovable de la producción + impacto ecológico, y características de las diferentes biomásas y de su movilización. Las Transformaciones: Celulosa, fermentación alcohólica y fermentación metánica. Análisis del Sistema de Producción y de las Transformaciones. Medios de penetración de medios energéticos en los sistemas de producción agrícola y forestal, y estudios económicos. Balance energético. El I.N.R.A. mantiene un centro de investigación en la región Antillas-Guayana. Naturalmente, este centro es parte del esfuerzo general de las investigaciones. Pero también ha habido dentro del cuadro una reflexión especial del Comité Regional de Economía Energética y del Comité de Técnica Solar de Guadalupe. Además, esa política regional se define de común acuerdo con los otros territorios franceses de ultramar. Se ha llegado a tomar en cuenta, de manera relativa, los recursos y las necesidades energéticas, el nivel de sensibilización y las realizaciones previas. Una de las primeras etapas fue el examen de la situación local. Guadalupe consumió en 1980 cerca de 300,000 toneladas de productos petroleros desglosadas en las siguientes proporciones: transporte

por carretera 38.28%, de los cuales aproximadamente la mitad fue gasolina, producción de electricidad 27.1%, industria 1.8%, aviación 22.68%, otros 9.38%. Se ha hecho también un inventario preliminar de potencialidades de energía renovable.

Se ha encontrado que el mayor problema consiste en la necesidad de reconsiderar en parte el modo actual de producción de energía. Es necesario pasar de una política de concentración a un sistema diversificado de producción de energía y a un costo más bajo. La agricultura es un sector favorable para aplicar tal política. Notemos desde el comienzo que los insumos de energía fósil tienen escasa importancia en la agricultura local. La mecanización, la irrigación, el uso masivo de abono nitrogenado, son prácticas todavía poco desarrolladas. Es por esto que se ha estimado que las necesidades de los cultivos se suplen solo en alrededor de un 50% mediante la aplicación de diferentes abonos. El objetivo principal es, pues, aumentar la productividad de la agricultura y de la tierra en Guadalupe. Es necesario, sin embargo, procurar desde ahora racionalizar el uso de los abonos, del agua y de los productos fitosanitarios.

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Esta política también se ubica en el marco del mejoramiento de los recursos locales de biomasa. En efecto, con una irradiación solar incidental del orden de 1,800 KWh/m² y suponiendo una eficiencia de la fotosíntesis de alrededor de 0.4%, el equivalente energético de la biomasa producida en Guadalupe es de más de 950,000 TEP, es decir más de tres veces el consumo actual de productos petroleros. Los programas de investigaciones del I.N.R.A. en esta zona geográfica se derivan de observaciones y hay un proyecto para la medición de la irradiación solar en Guadalupe con miras a construir un mapa de yacimiento solar y un banco de datos. Estos trabajos se llevan a cabo en colaboración con diversos centros de investigación locales e interiores. Para comenzar, no se contempla por lo pronto involucrarse directamente en cultivos energéticos, aunque se estén llevando a cabo ciertas investigaciones agronómicas con la caña de azúcar, una planta que genera un excelente rendimiento fotosintético. Pero en otros centros del I.N.R.A., se han estado acumulando datos sobre el jacinto de agua, las biomásas de

Hidrocarburos (Euforbiáceas) y las oleaginosas. Muchos de los proyectos tienen que ver con el uso racional del agua. Citamos en particular la tolerancia de plantas hortícolas seleccionadas por la sequía y la valorización óptima de las precipitaciones del agua y la irrigación. En este último caso, la estación de bioclimatología ha llevado a cabo por muchos años una intensa actividad. Se han venido realizando de forma continua estudios interdisciplinarios sobre el comportamiento de los suelos hacia la irrigación, la selección de cultivos capaces de asegurar la mejor valorización del agua, la determinación de las necesidades específicas de las plantas, y la influencia de la irrigación sobre la fertilización.

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Continúa la preocupación en torno al aumento de la productividad agrícola. Actualmente se estima que uno de los factores de progreso sería, sin duda, enfocar el cultivo de leguminosas. A la misma vez, también conviene valorizar al máximo la biomasa residual de origen agrícola o de otra procedencia. En el primer caso, el bagazo representa el volumen, el substrato más interesante, los residuos reservados son considerados en segundo plano. Las destilerías y las centrales azucareras tienen su autonomía energética gracias al bagazo. Los equipos de investigación de Guadalupe quieren mejorar la transformación energética. Ellos proponen utilizar la gasificación y la

pirolisis en vez de la combustión. En este caso habrá un excedente muy importante de bagazo que podrá utilizarse para el mejoramiento orgánico de los suelos. INRA persigue conjuntamente con varias otras organizaciones un programa de este tipo para el cultivo de productos comestibles. En esto la estación agronómica juega el papel principal. Esta última recalca que el contenido de materias orgánicas es particularmente importante para el terreno. En nuestro caso, donde los suelos a veces son pobres debido a la actividad de los microorganismos, la no restitución de las materias orgánicas del terreno ocasionará una baja en la fertilidad.

These considerations have served as a basis for undertaking work for the manufacture of compounds derived from waste and the use of sludge from urban water purification stations. The industrialization in Guadalupe is excessive but the pollution caused by the vinasse from the distilleries carries bad consequences for the environmental plan. The treatment of these vinasse by aerobic means consumes a lot of energy. Methanogenic fermentation is, therefore, a better solution to reduce pollution. This is the alternative that has been recently chosen in the research programs of I.N.R.A. 89

Before finishing, it is necessary to say a few words about the cooperation program of I.N.R.A. in the Caribbean region. There is a constant concern to dedicate more financial resources to these efforts that allow us to cultivate relationships with the highest number of countries. At this moment, however, the scope of biomedical energy has been little explored. The I.N.R.A. research program on the energy uses of biomass is based on the need to satisfy product needs and on the care of a less centralized production of energy. The protection of the environment and the maintenance of the renewable nature of production are also one of our greatest concerns.

BIOCONVERSION OF STRONG ORGANIC WASTE STREAMS TO METHANE GAS: THE BARCARDI CORPORATION'S ANAEROBIC TREATMENT PROCESS. Presented at UNICA WORKSHOP ON BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN San Juan, Puerto Rico April 28-29, 1982 By Dr. Michael Szendzey Project Manager Bacardi Corporation Catefo, P.R.

The Bacardi Corporation has investigated numerous disposal and treatment alternatives to find the most acceptable method for disposing of the "mosto" or still bottoms produced during the distillation of rum. For example, the concentration of mosto for use as cattle feed extender, the wet.

The oxidation of mosto, the use of concentrated mosto or "CMS" as a boiler fuel, and the anaerobic digestion of mosto were all investigated. As a result of an agreement entered into between the Bacardi Corporation and the U.S. Environmental Protection Agency in late 1979, which required 75 percent BOD removal from its mosto waste stream, the company decided to utilize an anaerobic biological treatment process based on its previous studies. The Bacardi rum distillery, the largest in the world, like other distilleries, has a waste stream that is high in organics. Based on the information developed during the evaluation of various treatment technologies, Bacardi decided that anaerobic biological treatment was the most beneficial all-around method for the mosto stream. The average characteristics of the mosto stream are seen in Table 1.

TABLE 1 AVERAGE MOSTO STREAM CHARACTERISTICS

Parameter	Concentration ppm
BOD	36,000- 42,000
COD	85,000-105,000
SS	4,000- 5,000
Nitrogen (Kjeldahl)	790- 1,480
Phosphorous (Orthophosphate)	59-98

The reasons for choosing the anaerobic process can be summarized as follows:

1. The process is suitable for high strength organic waste. The waste is hundreds of times stronger than domestic wastes and stronger than many industrial wastes.
2. Operating and maintenance costs are low. Aerobic treatment would require as much as 8,000 horsepower for aeration alone.
3. The process generates energy in the form of methane gas. Aerobic treatment does not produce recoverable energy.
4. There is minimal sludge production. Aerobic treatment would produce a large amount of sludge requiring handling and disposal.
5. Depending on the cost of energy, the energy produced has the potential of paying for the treatment plant.
6. Several variations can be adapted to specific needs. Depending on the strength and characteristics of the waste and the level of treatment required, the retention time and the design of the process can be custom tailored.

Another reason for choosing an anaerobic process would be...

The process is such that Puerto Rico is an oil importing country; therefore, any process that replaces imported oil is beneficial to the economy. The practicality of anaerobic treatment diminishes as the organic content of the stream to be treated decreases. This is a general rule; however, recent developments in this field have demonstrated that weak but highly biodegradable wastes can be treated cost-effectively with energy recovery. This new technology makes use of highly efficient anaerobic filters allowing hydraulic retention times on the order of a few hours up to a day.

The advantages of an anaerobic process over an aerobic one are as follows:

1. Loadings are not restricted by oxygen transfer. The loadings achievable in anaerobic systems are much higher than in aerobic systems. In anaerobic systems, the loadings are determined by the viability of the bacteria to the loading and by possible material handling limitations such as pumpability. Given enough time, anaerobic bacteria capable of performing efficiently under extremes of organic concentration can be developed.
2. The anaerobic process is not restricted by the high cost of oxygen transfer. It takes a significant amount of horsepower for aerators or an expensive oxygenation plant to treat waste aerobically.
3. There is a usable end product in the form of gas. Aerobic treatment only produces CO₂, water, and large volumes of sludge to be disposed of.
4. Less biological solid is removed per pound of BOD. In the anaerobic treatment, approximately 90

percent of the degraded compounds are converted to gas and only approximately 10 percent go to solids.

Most of this is possible because the anaerobic biological filter, invented by Dr. P. McCarty, is a great improvement over the conventional anaerobic contact digester. Until the development of the anaerobic filter, it was difficult at best to develop and maintain a high Volatile Suspended Solids (VSS) level in the digester due to the difficulty of settling the solids in the effluent for recycle.

To the digester, the advantages of the anaerobic filter over other conventional processes are as follows:

1. Unlike the contact process, which requires both recirculation and mixers, it only requires very low horsepower to provide recirculation. A total of only 12 horsepower is required in our 8.25 million gallon anaerobic filter.
2. There is smaller tankage needed due to higher loadings. Although anaerobic plants may be more capital-intensive because of the methane handling equipment required for energy recovery, the high loading rates and smaller tanks require less space.
3. There is a more stable, larger inventory of attached organisms. This is one of the most important advantages of the anaerobic filter. Not only is the anaerobic filter system more stable, but this large inventory of attached organisms allows higher loading rates to be achieved than are possible in the contact process.
4. No clarification is required, thus capital costs are increased and operation is made simpler. Not only is a higher loading rate possible in the anaerobic filter, but higher BOD and COD removals are achieved, leading to a more highly stabilized effluent.
5. The fact that only about 10 percent of the organics removed from the waste go to solids is a very important advantage.
6. The solids appear to be more settleable than those produced by the contact process since the solids produced in the anaerobic process appear to slough off the filter media in larger pieces. The importance of low solids production can be appreciated by those responsible for aerobic treatment plants because solids disposal is one of the most difficult problems to solve. Cities like Philadelphia and New York "ocean dump" via barges as no other viable disposal method is available.
7. Fast "restart" after prolonged "resting" periods. Based on observations made by Dr. McCarty and others, and confirmed in our studies, it is possible to stop "feeding" an anaerobic system completely for months and to restart it in a matter of days.

The methane fermentation of complex waste is a complicated biochemical process. A complex organic waste mixture is acted on by various micro-organisms which begin to break down this waste. Part of the waste is converted to less complex intermediates which in turn are broken down to acetic acid, methane, and possibly to other less complex intermediates; part of the waste is converted to acetic and to lesser amounts of propionic acid which in turn are degraded to methane.

The propionic acid may also be converted to methane and acetic acid before the methanogenesis is complete. Carbon dioxide is also formed and part of it is also reduced to methane as the oxygen molecules in the carbon dioxide are used by certain bacteria to oxidize the complex waste. A number of different micro-organisms must be present for efficient waste stabilization and methanogenesis to occur.

One disadvantage of anaerobic versus aerobic treatment can be suggested indirectly. An aerobic system can generally be developed rapidly by seeding with aerobic plant clarifier bottom effluent; an anaerobic system requires months to acclimate and is very slow to develop and stabilize. Seed for anaerobic plant startups must be carefully selected and often must be developed in laboratory or pilot plant cultures. The fact that

Methanococcus bacteria divide once every three to five days, while aerobic bacteria do so every few 96 hours. This contributes to the very slow development and stabilization of anaerobic systems. The anaerobic culture used at the Bacardi plant was developed from fresh cow manure and has acclimated to the point that it can withstand large variations in waste characteristics and concentrations. It is not affected by hydrogen sulfide concentrations twice as high as those reported to be fatal.

Until now, we have concentrated on the BOD (Biochemical Oxygen Demand) removal or waste stabilization aspects of anaerobic treatment. As we have noted earlier, the anaerobic process also produces a methane-rich gas which can make a significant contribution to the energy requirements of the plant using it. In fact, there are a number of studies which use anaerobic digestion solely for the production of energy from a variety of organic feedstocks. The bioconversion of vegetable and plant material to an easily handled, transportable end fuel may very well become a significant energy source of the future.

Anaerobic processes have not been studied carefully and significant technical advances will be made in the next decade to direct more and more attention to it as a potential energy source. The patented Bacardi Corporation's anaerobic process was first tested in three pilot scale units. Some of the pilot plant findings have been incorporated into the full scale plant, while others are expected to be incorporated into the second phase of the anaerobic plant.

The seed used to start up the full scale plant was developed in the units which are used to test modifications and improvements. The potential to produce significant amounts of energy was one of the key factors that led Bacardi to select the anaerobic option for treating the mosto stream. Thus, one million gallons of waste having roughly a 20,000 ppm concentration of BOD is expected to produce well over one million cubic feet of methane at 80 percent BOD removal. It is obvious that the...

The potential for replacing fuel oil 97 with methane could represent significant savings. Unfortunately, the microorganism population in the first phase of the anaerobic plant is still being built up; therefore, estimates of how much methane will be produced are incomplete. At the moment, the process is producing the equivalent of 78 barrels/day of oil from the Phase I anaerobic filter. The process schematic of the anaerobic plant can be summarized quickly. Waste enters the holding tank and is fed at a controlled rate to the unique anaerobic filter nutrients. Then pH control chemicals are added and the waste is cooled during the transfer to the anaerobic filter. The treated anaerobic filter effluent will be pumped into a deep ocean outfall for final disposal. The

methane-rich gas produced is either fed to the boilers, stored in a pressure sphere, or flared off if it cannot be used or stored.

BIOMASS - A POTENTIAL ENERGY SOURCE FOR JAMAICA

Presented at UNICA WORKSHOP ON BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN

San Juan, Puerto Rico

April 26 - 29, 1982

by Lilieth H. Nelson

Ministry of Mining & Energy

Petroleum Corporation of Jamaica

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JAMAICA AND THE WORLD ENERGY SCENE

Since 1973, Jamaica has been spending increasingly larger percentages of export earnings on oil bills. Jamaica paid 18 percent of export earnings for oil in 1973 and 48.1 percent in 1979. This has contributed to Jamaica's balance of payments problems. In 1978, while oil contributed approximately 50 percent of the total world energy consumption, Jamaica depended on imported petroleum for approximately 90 percent of its total energy supply. The other 10 percent was from bagasse used in the sugar industry (9 percent), and a small amount of hydro power (1 percent). Currently, the sugar industry, which was previously self-sufficient in terms of energy because it used bagasse for process steam and electricity generation, is depending on petroleum for nearly 45 percent of its energy supply.

Jamaica has experienced a very high level of per capita energy consumption. Even when the consumption by the bauxite/aluminum sector is excluded, Jamaica's per capita consumption levels are higher than those of other oil-importing developing countries. While the world average oil consumption per capita is 9.5 barrels of oil equivalent (b.o.e.), that for developed countries is 28.9 b.o.e. and for developing countries is 1.8 b.o.e. Only some oil-exporting developing countries have lower per capita consumption than Jamaica, which enjoys about 8 b.o.e. per capita.

Because of the Venezuela/Mexico Accord of 1981, Jamaica is importing crude oil from Mexico and Venezuela and continues to import from Curacao, Trinidad, and Aruba. While volumes of imported oil have not varied much, there has been a steady and overwhelming increase in costs. Thus 16.1 million barrels of oil imported into Jamaica cost J\$44 million in 1972, \$931 million in 1978, and \$48 billion in 1981.

Petroleum consumption by sector in 1980 is reflected in the following table.

TABLE 1 PETROLEUM CONSUMPTION BY SECTOR (in million barrels)

Aviation - 765 (4.92%)

Bunkers - 236 (1.52%)

Bauxite/Aluminum - 8234 (52.93%)

Sugar - 145 (0.93%)
J.P.S. (Jamaica Public Service Company) - 2681 (17.24%)
Cement - 195 (1.25%)
J.O.S. (Jamaican Omnibus Service Company) - 55
Railways - 28
Others - 3221

In 1980, the Jamaica Public Service Company used 2.41 million barrels of fuel oil and 0.21 million barrels of automotive diesel oil to produce a net electricity generation of 1.27 billion kWh. In the same year, the sugar factories used 45 million barrels of fuel oil to produce 242 million tons of sugar.

The above facts indicate that the present situation must be changed if Jamaica is to proceed with its development. This is so as there is a close relationship between energy consumption and economic growth. Jamaica, like many other countries, can no longer base patterns of scientific, technological, industrial, and

Economic expansion depends on the availability of abundant, cheap petroleum. The question is, where does Jamaica turn for its energy? Is biomass a potential source? The first attempt, which parallels the search for oil and gas, is the quantification of all resources which can provide an alternative to imported petroleum. Of great importance also is Jamaica's focus on conservation, which can result in a saving of 10 to 15 percent of fuel costs. Highest priority should be given to the exploration of such quantified resources which reflect the feasibility of cheap technology, especially where the use of local material is possible. Other factors to consider include: a) possibilities for low operational and maintenance costs; b) abundance and renewability; c) minimum scarce skills requirement and maximum use of technological know-how which already exists on the island or which can form the base for rapid modernization; d) availability of the resource; e) facilitation of transference of more efficient techniques; f) optimization of foreign to local expenditure ratio, so that the former is kept as low as possible; g) non-competition for food, especially proteins h) optimal protection or preservation of terrestrial, aquatic and atmospheric environment.

Based on the above criteria, the high priority and short term options for Jamaica lie in the exploitation of its small-scale hydro, bio-energy, and low-cost solar, wind, urban, and industrial waste potential. In the medium term, Jamaica can plan for the best use of its proven peat resources, while in the medium to long term, the development of such potentials as OTEC, large-scale hydro, solar, and geothermal resources can be pursued. This, of course, assumes that the country persists with its avid search for oil and gas. However, it must be realized that even if the finding of commercially viable quantities of oil becomes a reality, the use of this potential will still decrease in the medium to long term. A projection of possible diversification of the energy supply mix by 1990 is shown below in Table 2, which details the percentage of national energy supply.

Mix 198008) Projected 1990 (%) -0 -0 (if feasible) 0 5 (Conservative) Bagasse = 0 Other*: "0 Hydro 1 "0 Solar** (Minimal) ° Corrected - 3 + "Estimates - Includes wood and charcoal currently used, and fuel alcohol, urban wastes, biogas, etc. projected. ** Includes low and high temperature solar for crop drying, water heating, electricity generation, and cooling.

The evidence suggests that at least another percentage of the energy bill could be reduced if focus within the next five years is placed on the development of Jamaica's bio-resource potential for energy. Even if the oil bill were to level off over this period, a somewhat optimistic assumption, there would be a few million dollars available for diversion to other needs. It is also important to note that conversion of bio-resources to energy, even though of limited impact, is of value to improve the lifestyles of the population and the expansion of industry in the rural areas.

There is growing attention to bio-energy usage in developed countries which have implemented programs a) to improve the productivity of plants that could be used for fuel, b) to increase efficiency with which plant matter can be converted to liquid and gaseous fuels, and c) to develop improved methods of converting solid bio-fuels.

The Ministry of Mining and Energy in Jamaica embarked on a program in March 1981, to quantify all the biomass resources on the island. The project summary, an outline of the framework within the survey was conducted, and an abstract of the first report are attached to this paper. (See Appendix)

In August 1981, the status of biomass utilization and bio-conversion technologies existing in Jamaica was assessed. The most significant users of biomass were the rural and low-income urban household sector (firewood and charcoal) and the sugar industry (bagasse). At the end of the first phase of the survey, there were indications for research and developmental work aimed at harnessing other biomass resources such as crop and forestry residues, urban wastes.

Agro-industrial wastes and animal manures for energy.

14 Units throughout the island consist of rural and urban factories, field and factory sites island-wide. Agro-Industries are present in both urban and rural areas. 2 Sugar Factories are found throughout the island, along with other urban and rural urban areas.

Table 3: Current Biomass Utilization in Jamaica

[Table is missing]

The move to realize the maximum potential from biomass in Jamaica should be accelerated subsequent to the articulation of certain policy decisions concerning exploration of bio-resources in Jamaica. Reliable technical economic feasibility studies, and valid research and development in converting the wide variety of feedstocks available for the extraction of fuels from energy crops are needed. Finally, it must be realized that the value of biomass conversion lies not only in the energy end product, but also in a wide range of by-products usable for feeds/foods, fertilizers and fibers.

Works Consulted:

Bente, Paul F. - Introduction to The International Bio-Energy Directory, Bio-Energy Council, 1981.

Department of Statistics, Jamaica - Statistical Yearbook of Jamaica 1979.

Food and Agricultural Organization for UNDP - Wood Fuel Energy Study for Jamaica, 1975.

Food and Agricultural Organization - The Fuelwood Situation in Developing Countries, 1981.

Institute for Industrial Research, Ireland

- Inventory of National and International Biomass R&D Research Programs, Vols. 1 and 2, 1981, Ministry of Mining and Energy, Jamaica - Papers prepared by the Economic Planning Division, 1979-1981, of Mining and Energy, Jamaica - National Energy News, National Academy of Sciences - Methane Generation from Human and Agricultural Wastes, 1977, National Planning Agency for Govt. of Jamaica - Economic and Social Survey Jamaica 1980, National Research Council - Supplement, Energy for Rural Development, USA, 1981 Petroleum Corporation of Jamaica - The National Energy Outlook 1981-1986, 1981, Town Planning Dept. Ministry of Finance - National Atlas of Jamaica, 1971, United Nations Environmental Programme - New and Renewable Sources of Energy, The Environmental Dimension, 1981.

Appendix I-A: Outline of Bio-Resource Activity

Biomass Survey - Islandwide. Ministry of Mining and Energy, Energy Division 1. Collection, Collation, and Analysis of data required for the quantification of Biomass Resources in Jamaica which have potential for conversion to utility (Residential and Industrial) and transportation fuel. Development of a scenario of options for biomass utilization for energy in Jamaica.

Description:

Phase 1 (a) Identification of types of biomass resources in the island, location, and quantity of each type available for energy.

Phase 1 (b) Optimization of Biomass Conversion Technology for particular resources identified, taking into account nature, quantity, location, and demands of particular sectors. Estimation of present, future demands for by-products of Biomass Conversion Technology eg. Feeds, Fertilizers, Fibres, and other chemicals.

Phase II: Planning and execution of experimental and developmental (pilot) projects on a small scale to demonstrate the effectiveness of the processes and validate them to private and public sector institutions in the society. No previous overall assessment of Biomass sources of energy has been done in Jamaica. This is a necessary prerequisite for the...

Formulation of a range of policy options for harnessing and converting particular biomass resources for specific fuel and uses. Such policies would set the framework within which business ventures proposing to use these resources would be assessed, as well as guide government investment or encourage government support to local private sector in projects which will use these resources.

Total Estimated Cost:

Phase 1 - Year 1: \$20,000.00

Phase 1 - Year 2: \$860,000.00

Phase 1(a) Appendix 1-B: Biomass Quantification Survey

Potential for various residues/wastes/surpluses in Agriculture and Silviculture based on Land

Utilization Patterns and Policy. Aquaculture based on identifiable indigenous species: fresh, brackish, and salt. Crop residues/surplus from major crops: Banana, Sugar, Cocoa, Coffee, Coconut, Pimiento. Urban Wastes - Manures/Agro-Industrial Wastes - Refuse, Woody Residues from field and factory sites.

An additional survey was conducted on a small sample to verify certain patterns of charcoal and fuelwood consumption implied in the results of the Household Sector Survey in 1979, and to indicate current and future trends in Biomass fuel (Charcoal and Fuelwood) supply/demand patterns.

Phase 1(b) - Assessment of conversion technology available for converting biomass to energy was carried out under the following headings:

Conversion Processes - Anaerobic Digestion, Pelletization, Combustion, Fermentation/Concentration, Chipping, Pyrolysis, Hydrolysis, Pulverization, Carbonization, Mixing with Oil, Gasification, Densification, Liquefaction, Synthesis.

Based on assessments of the state of the art with respect to the above processes, location and quantities of specific bio-resources identified, assessment of demand of products and co-products in each sector, implications for collection, transport, and storage of raw materials and co-products, and availability of skills, equipment, and materials.

"To effect or adapt the technology, a scenario of options for bio-resource utilization in Jamaica was constructed.

APPENDIX 1-~~c~~ BIOMASS SURVEY MINISTRY OF MINING AND ENERGY, JAMAICA.

SUMMARY

Phase 1 of the Ministry of Mining and Energy's Biomass quantification survey, which began in March 1981, has now been completed. The island-wide survey was carried out with a view to determining the types, location, and quantities of biomass resources with potential for conversion to utility and transportation fuels.

The first phase was divided into two parts: the identification and quantification of biomass resources and the optimization of biomass conversion technology. The survey results show that plant and animal residues and surpluses, as well as other organic wastes, constitute the largest percentage of ferment sources of energy in Jamaica.

It is estimated that manure from cattle, pigs, and poultry has the potential to supply over 800 million KW/h per year. Another interesting estimate is that local sewage can supply some 40 million KW/h per year. In addition, large quantities of crop residues and surpluses in Jamaica, such as bananas prepared for export, have a rejection rate of 70 percent, and of that 20 percent is completely wasted.

Cocoa pods, pimiento residue and coffee husks all amount to quite substantial wastes that could be productively used for fuel. The survey also showed that thousands of existing coconut trees, unsuitable for lumber because of their decayed condition, could be used for fuel.

Although there are relatively small quantities of residues from vegetable, root and fruit crops, these could be used in bio-gas digesters as it has been found that the combustion of vegetable and animal feedstock enhances yields of biogas (in conjunction with other factors such as optimal temperature and pressure). Large quantities of woody residues with considerable fuel potential are also wasted both in the field and at the factory sites. Estimates show..."

About 1,000 tons of woody residues from factories and workshops are wasted every year. The survey also indicated that, as far as charcoal and fuel-wood consumption is concerned, unless serious attention is paid to a reforestation program, the situation will become critical in a few years time, especially if the nation heeds the call to use more bio-fuels seriously and increases the demand. Phase I of the survey involved an assessment of conversion technology available for obtaining energy from biomass. The processes fall under three main headings: 1) Microbial Conversion, such as fermentation and digestion, 2) Thermal Conversion, for example, pyrolysis and gasification and 3) Mechanical Conversion, like densification. Phase II of the survey will begin in April of this year and will involve the planning and execution of small scale experimental and developmental projects to demonstrate the effectiveness of the various processes and validate them to private and public sector institutions in society.

ALCOHOL FUELS FROM AN INTEGRATED BIOMASS SYSTEM: TECHNOLOGY AND ECONOMICS

Presented at UNICA WORKSHOP ON BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN

San Juan, Puerto Rico

April 28-29, 1982

Caribbean Research Institute

College of the Virgin Islands

St. Thomas, United States, Virgin Islands

INTRODUCTION

In 1980, the Caribbean Research Institute began a project to determine the feasibility of using food and agricultural waste provided by farmers or cooperatives to produce alcohol fuels. A special small scale fermenter and still was developed for this purpose. To make the system more energy effective, a condensing solar panel was added for preheating the beer and the steam feed water. This project worked to the extent that fuel could be produced for \$0.86 per gallon and could be used by farmers or cooperatives. It was evident that a larger cooperative could make use of a continuous fermenter, a stockpile of materials, and could add both flexibility and efficiency in

The text can be fixed as follows:

The Institute developed an idea to use or market many of the side products. They postulated a hypothetical farm cooperative with about \$38 million in assets and a desire to enter the biomass fuel/by-products field. This hypothetical cooperative was located on an imaginary Caribbean island

that was, frankly, modeled after St. Croix, U.S. Virgin Islands. The island had suitable land, shipping, tax incentives, and some industrial structure.

The feedstocks considered were molasses, grain (corn or sorghum), and a combination of both. Ethanol and butane production, as well as the use and price of by-products such as carbon dioxide gas (CO₂), hydrogen (H₂), distillers dry solids (DDS), and chemicals such as acetone, acetic acid, and formaldehyde, were evaluated.

As this was designed to operate in a smaller, less developed area, high production levels for a single product were sacrificed for the stability of several products with interlocking feedback loops. This formed the basis for the model.

DATA AND RESULTS

A 25-gallon-a-day alcohol system costing \$3,000 and using "free" agricultural wastes (spoiled cattle feed, yams, and cassava) could produce ethanol for \$0.86 per gallon using solar pre-heating. The limiting factors were feedstock availability and the lack of continuous fermenting equipment. It would take one or two weeks for a small farmer to gather enough waste for 25 gallons of fuel. More than economics and technology are required for this proposition to work; stability and diversity must also be present.

ALCOHOL PROPERTIES

The basic properties of the most important alcohols are summarized here. The following classes of properties are presented:

1. Physiochemical properties
2. Fuel properties
3. Economics of production

The physiochemical properties are basic information available in all chemistry handbooks. The tabular form of presentation allows rapid comparison among the alcohols of different chain lengths. The fuel properties are a mixture of information on heat content and ignition.

Temperature, and the like, for comparison purposes, note that available information has been presented for iso-octane (gasoline). The rationale for iso-octane (gasoline) is obvious since it is a fuel replaceable partially or totally by alcohols.

Ethyl Alcohol (Ethanol)

Ethanol is the second smallest of the alcohols in molecular weight. It is almost explosively volatile and flammable. Because of its thousands of years record in drug abuse, it is one of the most rigidly controlled substances, largely because of the revenues generated by its users. For these reasons and because of the early advent of cheap and abundant hydrocarbon fuels, ethanol fuel production was shelved for many years.

Ethanol vaporizes at 78.4°C and is infinitely soluble in water. The difference between the boiling points of water and ethanol is so great that this has been a traditional method for separating mixtures of the two. Because of its "water-like" polarized chemical character, it has limited solubility in oil or gasoline if any water is present.

The energy value of ethanol is about 73.4 to 84.0 Btu per gallon compared to 115 to 124 KBtu per gallon for gasoline. However, the octane ratings are about 99 for ethanol and 90 for gasoline. This means that a well-tuned engine can get within acceptable limits of efficiency using ethanol.

There is no lubrication capacity in ethanol, and so oil must freely reach all parts. The octane and Btu rating is too low for efficient diesel operation. In addition, two-cycle motors cannot use ethanol without complex schemes to add oil. These and other factors make it advisable to look at other alcohols and process byproducts.

Stillage, the residue of fermentation and distillation in the production of ethanol, contains many nutritive elements. This is particularly true of grain stillage which has been used as an animal feed or feed supplement for years. Marketing these byproducts is essential to the economies of ethanol production.

Fresh

Stillage is a mixture of various nutrients dissolved or suspended in water. It can be fed directly to animals but is not tolerated in large quantities because of the limited capacity for water intake by cattle and other animals. Fresh stillage also degrades rapidly, particularly in warm climates, and disposing of the stillage output of a commercial plant will result in a complex distribution problem. Fresh stillage can be concentrated or dried. In this way, the product can be stored and shipped, making marketing easier and more predictable.

Market for Co-products: The total market includes oilseed, animal protein, and other such products. As a point of reference, a 50-million gallon ethanol plant will produce about 177,000 tons of DDG per year, i.e., about 45 percent of the 1976 market for that commodity. A 600-million-gallon ethanol program, a near-term objective in the United States, will produce almost two million tons of DDG, or about seven percent of the total 1976 feed market and about five times the amount of DDG sold in the United States in 1976.

In the 1963 to 1976 period, the domestic market for all animal feeds increased at an average rate of about 1.2 percent annually. The market for soybean meal (with which DDG is more directly competing) expanded at a rate of about 3.5 percent over that period. This expansion was not quite sufficient to absorb the expanded fuel production. Some substitution between DDG and soybean may take place and, as a result, some readjustment of agricultural production patterns will probably occur as the demand for corn feedstock increases.

Ethanol as a Fuel and as a Chemical: Ethanol may be used in various forms for fuel: As a blend with gasoline in various proportions. As hydrated lower-proof ethanol. As neat anhydrous ethanol. As a fuel supplement in dual carbureted diesel engines.

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may contain errors or be in a different language. Without further context, it is difficult to correct or interpret this section.

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Ethanol is also used as a chemical in the perfume and pharmaceutical industries. Each of these potential markets for ethanol has some constraints which bear on the decision-making process of producing ethanol. Some of these constraints result from the differences in the properties of fuel ethanol compared to petroleum-based fuels now used.

TABLE 2 COMPARISON OF PROPERTIES

PROPERTY GASOLINE, NO. 1 DIESEL

Molecular Weight: 126 46 170

Heating Value Higher (Btu/ib): 20,260 12,800 19,240

Lower (Btu/ 1b): 18,900 11,500 18,250

Lower (Btu/gal): 116,485 76,152 133,332

Latent Heat of Vaporization (atu, 1): aaa 361 11s

Research Octane: 85.94 106

Motor Octane: 17.86 89 10.30

Stoichiometric Air/Fuel Ratio: et 9.0

Flammability Limits (Volume Percent): 1.4 to 7.6 9.3 to 19 1a

Butyl Alcohols

The four monohydric butyl alcohols are: n-butyl alcohol, isobutyl alcohol, sec-butyl alcohol, and tert-butyl alcohol. Five methods for the production of n-butyl alcohol are: 1) fermentation, 2) a process based on aldol, 3) the oxo process, 4) as a by-product in the high pressure oxidation of Propane and butane, and 5) the Ziegler process.

The fermentation process operates on a carbohydrate mash with the action of the bacteria *Clostridium saccharobutyl acetonicum* wefaciens or *C. aceto-butylarium*. After 36 to 48 hours of fermentation and subsequent distillation, this process yields a 30 percent by weight return of 60

percent n-butyl alcohol, 30 percent acetone, and 10 percent ethanol. Vacuum removal of the acetone during fermentation may increase the butanol yield, as acetone is the main toxin for the bacteria.

The aldol process utilizes either ethyl alcohol or acetylene as a raw material with crotonaldehyde appearing as a chemical intermediate.

The yield in this process is about 8 percent of the theoretical. The butane-propane oxidation process is a Fischer-Tropsch process. The Ziegler process was commercially developed by the Continental Oil Company in 1962 for the production of even-numbered carbon alcohol. N-butyl alcohol as a C₄ alcohol is at the lower end of this production and could be considered a by-product. Isobutyl alcohol is derived primarily as a by-product in high-pressure methanol synthesis. However, some isobutyl alcohol can be recovered in the Fischer-Tropsch oxidation process for the production of acetaldehyde using butane or propane as a feedstock.

Isobutyl alcohol is also a major component; 74 percent in molasses and 12 to 24 percent in corn, of the alcohols present in fusel oil resulting from the fermentation process. Its major use is as isobutyl acetate in the lacquer industry. To form sec-butyl alcohol, butylene is absorbed by sulfuric acid, forming butyl hydrogen sulfate which is reacted with steam. Its principal use is as a chemical intermediate to the production of methyl ethyl ketone, a solvent. Sec-butyl alcohol is also used as a solvent and a coupling agent in hydraulic brake fluids, paint removers, and industrial cleaning compounds. The majority of tert-butyl alcohol is produced in a fashion similar to that of sec-butyl alcohol, but isobutylene is used as a feedstock instead of butylene. Isobutylene is absorbed by sulfuric acid forming isobutyl sulfate which is steamed to form tert-butyl alcohol. Tert-butyl alcohol is very miscible with many organic compounds and becomes useful as a blending agent. Some of the uses of this alcohol are as follows: as a selective solvent and extraction agent in the drug industry; for the removal of water from compounds and substances; in the manufacture of perfumes (artificial musk); in the purification of chemicals by recrystallization; and as a chemical intermediate. Tert-butyl alcohol is an authorized denaturant for proprietary ethyl alcohol and for

Specially denatured alcohols. Whereas all the alcohols mentioned up to this point have the same physical appearance, tert-butyl alcohol has a freezing point close to room temperature and in its pure state, often appears in crystalline form.

The basic problem with the butanol fermentation is the production of mixed solvents (butanol, ethanol, and acetone), the low solvent concentration (around 4.2 percent) requiring considerable energy for separation and purification of the products, and the low yield (around 34 grams of solvent per 100 grams of fermentable sugar). The problem of mixed solvents can be partially solved by selecting mutants with little or no acetone producing activity.

The concentration problem might be overcome by simultaneously performing an extractive separation while fermenting, thus removing the toxic end product. However, economics will control this possible production from sugar. Therefore, only a 28 percent improvement is theoretically possible. To achieve this, the hydrogen produced must be recycled to ensure full efficiency. It seems obvious that improving product concentration, possibly through extractive fermentation, may be the most promising development to pursue in the butanol area.

The fusel oil fraction represents only about 1.5 percent of the alcohol production. Therefore, it is not a significant factor in cost reduction. In fact, it is not an oil but a mixture of propyl, amyl, and butyl alcohols. Most investigators suggest that it not be recovered; rather, savings could be achieved by utilizing a two-column distillation system and letting the fusel oils go over in the alcohol product. This may be suitable for fuel grade alcohol; however, this point needs to be tested.

It should be noted that additives such as tert-butyl alcohol have been used because of their energy content. "Fusel oils" make good diesel fuel and were recently approved by the EPA. However, for industrial or spirits grade alcohol, the fusel oil must be recovered.

Acetic Acid - Acetic acid as such cannot be

Considered not as a liquid fuel, but as an important chemical building block in organic synthesis, acetic acid has two major uses. These uses are in vinyl acetate (for latex paints, plastics, and adhesives) and acetic anhydride (for cellulose acetate, esters, and solvents). In 1974, total acetic acid production in the USA was around 3.0 billion pounds, representing about 10 percent of total world production.

Table 3 summarizes and Figure 1 illustrates the different processes presently used for its production. Note the following points:

- (1) Practically all acetic acid is produced from petroleum.
- (2) The oxidation of gases, ethylene, and butane have been the major routes used.
- (3) Methanol carbonylation is based on natural gas chemistry; hence, future coal gasification processes may be applied profitably.

This process has a relatively lower unit investment, is independent from slower-growing co-products markets, and is based on the lowest cost fuel sources. For these reasons, this process accounts for most major new capacity.

Figure 2 illustrates the various alternatives for acetic acid production from biomass. There are two distinct possibilities:

- (1) Biological process (fermentation)
- (2) Thermochemical conversions (pyrolysis)

The economy of alcohol production is outlined in Table 4, which shows current market prices of the various alcohols (along with calculated equivalent costs/10° BTU) as obtained from the November 17, 1978 issue of Chemical Marketing Report.

TABLE 4 CURRENT MARKET PRICES FOR ALCOHOLS

ALCOHOL | CURRENT MARKET PRICE | CURRENT PRICE/10° BTU

Methanol | \$0.38 - 0.49/gallon | \$5.99 - 7.72

Ethanol | \$1.04 - 1.14/gallon | \$12.29 - 19.47

n-Propyl Alcohol | \$1.87/gallon | \$16.98

Isopropyl Alcohol | \$0.63 - 0.70/gallon | \$6.93 - 7.70

n-Butyl Alcohol | \$1.25 -

1.69/gallon \$11.95 ~ 15.18 Isobutyl Alcohol \$1.27 ~ 1.67/gallon \$10.42 - 14.39 Sec-Butyl Alcohol \$1.43/gallon \$13.72 Tert-butyl Alcohol \$1.75/gallon \$17.34

TABLE 5 BASE RAW MATERIAL AND BY-PRODUCT PRICES IN 1980 DOLLARS

Raw Material

- Corn Grain
- Sorghum
- Wheat
- Potatoes
- Sugar beets
- Beet molasses
- Starch By-product
- Corn distillers dried grain
- Sorghum distillers dried grain
- Wheat distillers dried grain
- Potato distillers by-product
- Sugar beet distillers by-product
- Molasses stillage
- Starch stillage

60, (atm) 4, 2 129 \$5.50/bu 82.80/bu \$3.85/bu \$20/ton \$80/ton \$.36/ gallon \$.08/lb \$120/ton \$120/ton \$120/ton \$0/ton \$0/ton \$0/ton \$3./100lbs \$5./100lbs

Various other information included.

By-Product

The possible by-products from these processes are numerous. Possibilities include CO₂ or H₂, animal feed, lignin, fuel credit solids, pentoses (xylose), furfural, and fusel oil. The CO₂ is produced in quantities of roughly one pound per pound of ethanol in a relatively pure by-product stream. At the present time, there is no industrial use for this CO₂ in the volume it would be manufactured. Possible future uses include industrial gases, dry ice, carbonation of beer or drinks, and as a supplement to increase greenhouse production. Of all the by-products, the animal feed derived from the dried distillers solids has the greatest potential. DDS is comparable to, and is a market substitute for, soybean or fish protein. In large volumes this product could shift the protein concentrate market from elastic to nonelastic. There is also a possibility of extracting the solids in order to recover a high quality of human protein. In the short term, the use of the solids.

The use of animal feed is the most practical since it is currently in practice and doesn't require testing. If alcohol fuel becomes a viable option, over 100 plants with a capacity of more than

25,000,000 gallons each would be necessary. Such capacity could yield 2 - 5 million tons of high protein animal feed per year. This could be a significant by-product, and research is needed to establish its economic feasibility. The unfermented solids are largely composed of lignin materials. Lignin has nearly double the energy content of cellulose and hemicellulose. Current technology burns these solids for their fuel value in the process. However, research is needed to find ways to convert lignin into liquid fuels or chemical feedstock. For instance, alcohol-solubilized lignin, fractionation of lignin to yield a polymer-grade material, and conversion of lignin to phenolics are possibilities.

By-Product Prices: A distillers dried grain base price of \$110 per ton for corn, sorghum, and wheat distillers dried grain was used for the estimate. This price was based on the average prices for corn distillers dried grains in Cincinnati, which ranged from \$89.56 to \$139.22 per ton and averaged \$110 per ton in terms of 1977 dollars over the period. Typically, distillers dried grain in Cincinnati trades in the range of 60-85 percent of soybean meal (44 percent protein) at Decatur. Distillers dried grains have a total protein content of about 27 percent, thereby making them a high protein feed substitute for certain livestock, mainly beef and dairy cattle. The following distillers dried grain price forecasting equation has been estimated by Wisner and Gider (1977):

$$1/\text{DDG} = 3.8825 - 0.022227 (\text{DDG}) + 0.265566 (\text{SIM},) + 0.168753 (\text{C},) + 0.518049 (\text{x})$$

$$3.21) \text{aa}2.81) (2.92) \llbracket \text{a.98}$$

Where:

DDG, = Distillers dried grain price in dollars per ton at Cincinnati

DDG, = U.S. distillers dried grains supply in thousands of tons.

SIM, = Price of 44% protein soybean meal in dollars per ton at Decatur

G, = Corn price in cents per bushel

BG, = Cattle numbers in

Five major European protein feed importing countries. 7 Wisner, R.E.R. and Gidel, O.O., "Economic Aspects of Using Grain Alcohol as a Motor Fuel, With Emphasis on By-product Feed Markets." Iowa State University, Economic Report Series No. 9, Appendix IV, June 1981, Economic Report Series No. 8. This equation indicates an elastic demand for distillers dried grains; a given percentage increase in supply could be sold with a lesser percent decrease in price. The equation also shows a direct price relationship between distillers dried grain and 1) soybean 2) corn prices, and 3) cattle numbers in five major European protein feed importing countries. It is important to note that this statistically estimated price forecasting equation is based on historic data with distillers dried protein feed sources available in the U.S. If distillers dried production increased so that it represented a significant proportion of total high protein feeds available, then the demand price relationship would become price inelastic: a large percentage price decrease would be required to clear the market. Under such conditions by-product credits to net ethanol production costs would decrease and the price and production of substitute feeds such as soybean meal would also decrease. The price impact of increased distillers dried grain production would depend largely on the extent and timing of an ethanol industry growth. The larger the industry, the greater the related price impacts. Price data were not found specifically for wheat and grain sorghum distillers dried grains. It may be possible that slight price differences can result when nutrient contents vary among the by-products of different raw material grains.

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TECHNOLOGIES OF ALCOHOL PRODUCTION AND BY-PRODUCTS Sweet Sorghum or Sugar Cane.

The alcoholic fermented products from cane juices are immediately associated with rum. In tropical countries, rum either has blackstrap molasses (left over from sucrose crystallization) or virgin syrup (concentrated sugar cane clarified juice) as its raw material. More recently, and mainly due to the depressed sugar market and the possibility of using ethanol as fuel, some large and integrated cane factories in Brazil, Louisiana, and Missouri have used cane juices as the fermentation raw material. In these factories, part of the sugar mills have been converted into rum production facilities.

From a practical point of view, this situation has worked well under very specific market conditions. However, it has a drawback because what is optimum for sugar crystallization or for rum manufacture is not necessarily optimum for ethanol fuel. Here is the method used to process cane:

Clean sugar cane stalks from the field are cut and the juice is extracted in a standard roller milling unit. The juice is treated with chemicals, precipitated, and the supernatant is filtered in rotary vacuum filters. The clarified juice is sent to the evaporators where it is concentrated for optimum sucrose crystallization. However, the juice could be taken from a "weak" first effect evaporator to a sucrose concentration that could produce around 10 percent (w/v) ethanol after fermentation. Note that this operation, which joins both processes, still is not well defined.

The concentrated juice, with nutrients added, is inoculated with yeast and batch fermented until sucrose is exhausted (fermentation times vary widely in practice). The fermented mash is centrifuged. After an acid wash, the separated yeast can be recycled to the fermentor to increase ethanol productivity. A 95 percent (w/v) ethanol product is produced by straight rectification/distillation and absolute ethanol by azeotropic distillation.

Stillage, filter muds, wash waters, and fuel oil are waste products. Yeast is a byproduct. The bagasse from...

The milling operations are burned to provide the total power requirements for the operation. Hence, the facility is energy self-sufficient. Moreover, spent electricity is usually available. Sweet Sorghum has been known for a long time that some varieties of sorghum store sucrose, invert sugar in their stalks, and store some starch in the grain. The systems study of sugar crops made by Lipinsky et al. (1978) made it clear that without sweet sorghum, the prospects for fuels from biomass from sugar crops would be relatively dim, except in critical circumstances. However, with sweet sorghum as the central sugar crop for biomass fuels purposes, sugar crops may have a three way potential. Although sweet sorghum has an enormous potential, this crop has not been studied either in terms of agricultural practice or processing into liquid fuels. Because sucrose and invert sugar are stored in the stalks, the stalks might be processed by following the sugar cane technology. Small amounts of starch in the grain could eventually be added to corn to be converted into soluble sugars by

enzymatic or acid hydrolysis and then to ethanol by anaerobic yeast fermentation. Alternatively, the stalk could be processed by employing new technologies like the Tilby separator or the Ex-Ferm process.

In any event, sweet sorghum needs to be processed in conjunction with another crop, either sugar cane or corn. In this capacity, crop harvesting and availability could be extended, storage problems minimized, and operation days of the alcohol plant increased. Alcohol from Molasses: The process using molasses is typical of those materials in which the carbohydrate is initially in the form of sugar. The molasses used is generally blackstrap molasses, a byproduct of sugar manufacture. In making sugar, the juice squeezed from the sugar cane is concentrated and sugar is crystallized. After two or three batches of sugar crystals are obtained, the impurities in the 'mother liquor' are so concentrated that further sugar

Crystallization is impractical. The remaining mother liquor is blackstrap molasses. Another important material is invert or high test molasses. This is produced by adding dilute acid to sugar cane juice, inverting the sucrose, then neutralizing and finally evaporating some of the water from the solution. Best molasses from sugar beets are seldom used for making industrial alcohol in the U.S. Saccharine materials used in minor amounts include pineapple waste, sorghum cane, citrus waste concentrate, waste from fruit canneries, pineapple juice, and corn sugar syrup. The molasses process is essentially a section of the corn process. The molasses from storage tanks is pumped directly into the fermenters where water, acid, yeast nutrients, and yeast are added as in the corn alcohol process. The fermentation is carried out in 36 to 48 hours with agitation and cooling. Newer processes are run continuously with cell recycle. The beer produced contains 6 to 10 percent alcohol. This is an anaerobic fermentation process which had been operated in large volume (more than 100,000 tons per year during World War II) in the United States until the early 1960s.

Preliminary calculations suggest that a plant designed to consume approximately as much stock as would produce 25×10^6 gallons per year (82,500 tons per year) of ethanol would require 1.1×10^6 bushels of grain per year, and would produce 6750 tons of mixed solvents per year. Of this, butanol would be 4930 tons, acetone would be 1550 tons, and ethanol would be 270 tons. The plant would require a total investment of approximately $\$20 \times 10^6$, and the cost of production would be about \$0.65 - \$0.70 per kilogram mixed solvents. When a reasonable return on investment is added to the production cost, a selling price of the solvent produced by fermentation is double that produced by conventional petrochemical means. For example, present production in the U.S. of these solvents is given in the following table along with 1978 prices. TABLE

9 PRICES OF SOLVENTS

* Price per kg and \$/gal

- n-butanol: \$0.46, \$0.20, \$0.95
- acetone: \$0.50, \$0.17, \$0.90
- ethanol (95%): \$0.50, \$0.08, \$0.86

Based on current prices, the price of the mixed solvent produced by fermentation should be \$0.43 per kilogram. This is compared to the estimated costs by fermentation which are greater than \$0.60 - \$0.70. The following tables give additional information:

[Table 1 description not provided]

[Table 2 description not provided]

A. In a single step, a vacuum would enrich the alcohol coming overhead from the fermenter. At 3-5 percent alcohol concentrations, the volatility of the alcohol (ratio of alcohol in the vapor to that in the liquid) is on the order of 8-10 percent. Hence, a 3 percent alcohol solution, when boiling, will produce around a 20-24 percent alcohol solution when the vapor is condensed.

B. Removal of alcohol from the fermentation broth at a lower concentration (most alcohol fermentations achieve 8-10 percent alcohol concentrations) would speed up the fermentation since high alcohol concentrations tend to be inhibitory to the fermentation. Thus, smaller equipment could be used for the same productivity.

Two problems have been encountered with this process. First, large amounts of CO₂ are evolved with the ethanol (a weight approximately equal to the alcohol) so that the vacuum system has to handle large amounts of non-condensable gas. Some way needs to be found to separate the CO₂ from the ethanol. Second, the yeast alcohol fermentation operates best at 30-37°C. At this temperature, a vacuum of of... [text cut off]

One lb./sq. in. would be required to boil the alcohol, which is difficult to achieve without expensive vacuum equipment. One way around this latter problem has been suggested. This is to utilize a thermo-tolerant organism (45°C) for producing alcohol. To date, searches for a thermo-tolerant alcohol-producing yeast have not been successful, although a thermo-tolerant bacterium, *Clostridium thermocellum*, is being studied that will produce alcohol at 65°C. The problem with this organism is its sensitivity to alcohol since it stops growing above one percent concentrations in the fermentation broth. Genetic experiments are underway to develop alcohol-tolerant strains. If this succeeds, then vacuum fermentation may be an important technology.

REVIEW OF SOLAR DISTILLATION

In order to save energy as fuel in the distillation of ethanol-water mixtures, solar energy could be considered applicable. Solar distillation has been used mainly to obtain potable water from seawater, the process being actually an evaporation unit operation. The solar energy collectors employed have been of many varied but simple designs without costly energy concentrating devices. The average values of water evaporated have been in the order of 0.10 gal/sq ft/day. With this figure and assuming heat effects of the same order of magnitude, the distillation columns of an ethanol 50,000 gallons per day factory would need reboilers of around five million square feet of surface. This type of application is not then recommended for what has been commonly known as solar distillation or seawater evaporation. If solar energy is to be used in distillation columns, new collecting designs are needed. Seven contracts from DOE are developing systems that are varied on the theme of producing steam at 300-550F. Two basic schemes are being used. One uses a central receiver, the other a distributed system. Both collect and concentrate direct sunlight to heat

a working fluid, which could be water, steam, or oil. The feeling at this point is that solar heating.

For industry unit operations like distillation, the process is viable but not economical. Current costs are two and one-half times that of the systems they would replace. However, the costs of collectors cannot come down until they are mass-produced.

6. 10. nL a2, 13, *

Factories

REFERENCES

Stark, W.H., "Alcoholic Fermentation of Grain" in Industrial Fermentation, Underkofler and Hickey, eds., Volume 1, Chapter 2, 1950.

"The Production of Industrial Alcohol By Fermentation", in Industrial Microbiology, S.C. Prescott and C.G. Dunn, Chapter 4, New York, McGraw-Hill Book Co., Inc., 1959.

Hodge, H.M. and F.M. Hildebrandt, "Alcohol Fermentation of Molasses" in Industrial Fermentation, Underkofler and Hickey, eds., Volume 1, Chapter 3, 1980, Ethyl Alcohol, New York.

Arnold, L.K. and L.A. Kremer, "Corn As A Raw Material for Ethyl Alcohol", Iowa Eng. Expt. Sta. Bull. 167. 48 (42), March 15, 1950.

Miller, D.L. "Ethanol Fermentation and Potential", Biotech. Bioengr. Symp. No. 5: 345 (1975),

Miller, D.L. "Fermentation Ethyl Alcohol", Biotech. Bioengr. Symp. No.6: 307 (1976).

Scheller, W.A. and B.J. Mohr, "Production of Ethanol and Vegetable Protein by Grain Fermentation", presented at 169th National Meeting American Chemical Society, Division of Fuel Chemistry, Philadelphia, Pa., April 9, 1978.

In Lipinsky, E.S. et al., Sugar Crops as a Source of Fuel Volume 2: Processing and Conversion. Research Title: Department of Energy.

Jacobs, P.B., "Industrial Alcohol", U.S. Dept. Agric. Publ. 695, Washington, February 1950.

Scheller, W.A. and B.J. Mohr, "Net Energy Analysis of Ethanol Production", presented at 71st National Meeting, American Chemical Society, Division of Fuel Chemistry, New York, N.Y., April 7, 1976.

Scheller, W.A., "The Production of Ethanol by the Fermentation of Grain", presented at International

Symposium on US

Alcohol Fuel Technology-Methanol and Ethanol, Wolfsburg, Germany, November 21-23, 1977.

14. Scheller, W.A., "Energy Requirements for Grain Alcohol Production", presented at Symposium on Economies of Fermentation Processes, American Chemical Society Meeting, Miami Beach, FL, September 10-15, 1978.

15. Mappel, J. and D.C. Jordon, Chemical Process Economies, New York, Marcel Dekker, Inc., 1975.

16. Peters, S.I. and K.D. Timmerhaus, Plant Design and Economics for Chemical Engineers, New York, McGraw-Hill Book.

17. Kespert, I.G., S.B. Sadek, and D. Wise, "An Economic Analysis of Fuel Gas Production from Solid Waste", Resource Recovery and Conservation 1:95 (1975).

18. Horsley, L.H., "Azeotropic Data III", Adv. Chem. Series 116: 15 (1973).

19. Othmer, D.F., "Azeotropic and Extractive Distillation", in Kirk Other's Encyclopedia of Chemical Technology, 2nd ed., Volume 1, pp. 80 (1963).

20. Katzer, R. et al., "Alcohol Distillation Process", U.S. Patent 3,990, 952 (1976).

21. Katzen, R. et al., U.S. Patent 3,449,345 (1968).

22. Weizmann, Ch. et al., "Studies in Selective Extraction and Adsorption. II. The Adsorption of Acetone, Butyl Alcohol and 2:3, Butylene Glycol from Dilute Solutions", J. Soc. Chem. Eng. 67:225 (1948).

23. Nature 271: 12 (1978).

24. Remalingham, A. and R.K. Finn, "The Vacuferm Process: A New Approach to Fermentation Alcohol", Biotech. Bioengr. 19: 583 (1977).

25. Cysewski, G.R. and C.R. Wilke, "Rapid Ethanol Fermentation, Using Vacuum and Cell Recycle", Biotech. Bioengr. 19: 1125 (1977).

26. "Solar Energy Gets Up Steam for Chemicals", Chem. Week, 37, February 7, 1148.

Report on Biomass as an Energy Alternative for the Caribbean, Workshop, San Juan, Puerto Rico, April 28-29, 1981. UNICA Commission on Science and Technology.

BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP SUMMARY REPORT

It is the opinion of the UNICA Science and Technology Commission that the April 28-29, 1982 San Juan Workshop on Biomass as an

The Alternative Energy for the Caribbean event was a greater success than the first Workshop on Wind due to several circumstances. Some of the most favorable conditions were the familiarity of the UNICA contact persons with each other and with the project. This stimulated a direct interest in their involvement and commitment to its success. Additionally, the workshop followed the Fuels and Feedstocks for Tropical Biomass I Seminar, which gave the UNICA contact persons a unique opportunity to become acquainted with the subject.

Once more, replicating the format of the Wind Workshop, the group was separated into three working sessions: Education and Training Needs, Research and Development Needs, and Demonstration Needs. It may be inferred from the recommendations that biomass is perceived as one of the energy alternatives for the Caribbean, which could be utilized faster based on the agricultural experience and know-how of the region.

Consequently, a generalization of the recommendations can be formulated as follows: (1) Securing funding to establish research, development, and demonstration projects of specific nature in the region on biomass as an energy source should have the highest priority. (2) In order to implement the above recommendation, education and training programs to prepare the human resources needed in tropical biomass for the region are a must.

(3) UNICA should play a vital role in technology information dissemination, R&D projects evaluation, and technology transfer between their member institutions. (4) The UNICA Foundation's role in securing funds for implementing the above is essential and indispensable to carry out such programs. If the above recommendations are implemented, the science and engineering capabilities of UNICA member institutions in biomass matters would be greatly enhanced. Also, the role of the universities and research institutes as providers of solutions to societal problems would be strengthened. The UNICA Science and Technology Commission wishes to thank all the UNICA.

In a more efficient use of funds, wherever possible, UNICA should expedite the distribution of funds coming into the region for R&D. Before importing foreign technology, we advise UNICA personnel to ascertain if such technology has been previously tested in the region and the results thereof. Projects aimed at utilizing biomass as chemical feedstocks should be prioritized. The orientation of such projects is technologically and financially demanding, but they are potentially more feasible. It is recommended that all such projects be undertaken in collaboration. The UNICA representative in each country, after consulting with his colleagues, should identify the areas of research and development with specific input and submit these to UNICA for processing. Hopefully, this will provide a current assessment of energy R&D in the region. A techno-economic evaluation unit should be established to provide cost-benefit analysis to deduce the benefit of a project. In developmental work, all pertinent data from the region should be supplied to allow for analysis of site and regional applicability and potential. U.S. AID policies in the region should be evaluated to see how they promote regional collaboration and developing expertise within the region.

As there is a current funding shortage, it is suggested that UNICA solicit funds in an attempt to act as a source of interim financing for collaboration projects with regional applications. Closer working relationships should be maintained with research and development institutions in the region as these institutions usually have more funds, personnel, and equipment to assist the development phase of projects. UNICA would therefore seek funding for the actual development of regional projects. We accept the offer of collaboration from French Overseas University Programs offered by Professor J. Renaux of AUPELF. UNICA should approach funding agencies for funds to aid in organizing.

The goal of this information service is to provide the necessary training, which will enable technology transfer from this source to countries where it can be utilized. Until there is an established system in place for information dissemination, person-to-person communication should be pursued.

The existing questionnaire is perceived as difficult to comply with, hence it is suggested that each person link their current projects with their immediate needs for information and funding. This will enable the UNICA Secretariat to provide any short-term assistance required.

UNICA's current publications should include a section on research projects, detailing the following: the institution, people involved, projects in progress along with their current status, projects in the planning stages, projects where collaborations are being sought, availability of funding, and requests for assistance from members. This will enable UNICA's contact persons to be aware of funding availability for research and distribute this information to individuals who could benefit from it.

UNICA should also consider providing the following items: an information update, details on ongoing R&D projects in energy within the region, the requirements of individual institutions from UNICA, and proposed methods which UNICA will employ to meet these needs.

We have realized that such information is extremely limited, and the steps previously taken by UNICA through surveys have not yielded the expected results. As a short-term solution, it is proposed that everyone actively involved give a brief report on what they are pursuing and state whether they are interested in any form of collaboration.

The second requirement is education. In institutions where technology is developed for the masses (e.g., charcoal project) in association with R&D, we recommend that UNICA's expertise be used to inform bureaucrats and potential users about the need, as well as the operational techniques, for that.

Technology. The social factors involved in introducing new technology to our people cannot be overlooked. In order to meet these needs, we propose that UNICA consider the establishment of a program for educating bureaucrats, followed by an associated demonstration program for the populace in the need and utilization of such technology.

Our second recommendation for UNICA, which is uniquely situated to identify and assess regional needs with regards to socio-economic parameters, then solicit the funds and award these on the basis of competitive grants for institutions or a combination of institutions to achieve these needs. We suggest that such activities be done in collaboration with other bodies in the region which share

UNICA's concern for technological development in the region.

We recommend that regional institutions submit collaboration projects through UNICA for funding. These two recommendations will allow UNICA to act as a stimulating and evaluating body to promote technological development within the region. We all agree that the establishment of the Information Dissemination System is critical to the success of UNICA. This Information System is to be developed in collaboration with OLADE, TEU of CDB, CARIRI, SRC, and other regional institutions. The prime purpose of this unit will be to acquire and disseminate information to UNICA contact persons in each country.

BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP

San Juan, P.R., April 28-29, 1982

WORKSHOP SESSION, GROUP NO. 3 DEMONSTRATION NEEDS

Report by Dr. Modesto Iriarte and Mr. Salvador Lugo, Moderators General

This workshop was attended by a small group (six persons) representing Guyana, St. Lucia, Jamaica, Netherlands Antilles, and Puerto Rico. At the outset, the group decided to establish the following criteria for the selection of demonstration projects: (1) availability of biomass on a commercial scale; (2) this biomass would be in an existing commercial activity; (3) the projects

The text should be corrected as follows:

The projects would be of such a nature that they could be done elsewhere in the Caribbean (technology transfer); (4) projects should be culturally acceptable to the region and the countries involved. With these criteria in mind, a discussion was held about the various biomass-related activities being carried out in each of the regional areas mentioned. Various projects with potential for developing into a "demonstration" stage were discussed. Several were identified as needing further R&D, while others were ruled out because enough commercialization has already been developed or because they were not within the general interest of the majority. While considering the options, the countries kept in mind in terms of biomass potential were Guyana, Jamaica, St. Vincent, Haiti, Dominican Republic, Venezuela, and Colombia. There could be others. Only one demonstration project was identified and discussed at length for implementation. The reasons for discarding other projects are presented.

Demonstration Project for Implementation

It was the general consensus that a demonstration project to produce gas by pyrolysis of biomass would be very convenient for the Caribbean. Gas is probably the best type of fuel for direct combustion; its transportation, handling, and use offers advantages even over liquid fuels. The suggested project could start with a conference workshop sponsored by the University of Guyana and producing pyrolytic gas from the management of the forest industry. The gasifier has been developed by a German firm. The conference in Guyana would include a series of lectures on the operational experience, and design details of the Guyana facility ecosystem impacts of the region

as well as a visit to the plant. After the conference, a task force would be identified to work on the development of this project. The task force could proceed as follows: (a) make an initial assessment of the process, the logistics, and management, and outline a plan based on a selected site; (b) prepare a proposal for...

Securing funding from private and government agencies; (c) implementing the proposal when funding is secured.

Other Projects Discussed:

(1) Direct burning of biomass was discussed. It was concluded that for small capacity boilers there is a long history of commercial projects in operation. Demonstration needs are required for large utility boilers, but the interest would be centered on a small number of the most developed countries such as Puerto Rico, using large blocks of electrical energy.

(2) Water hyacinths used for tertiary treatment as a source of bio-gas. This project was discussed and it was concluded that it is feasible, but there is not a strong incentive in developing a demonstration project currently.

(3) Seaweeds as a source of biomass. This was discarded because it requires R&D before a demonstration unit can be attempted.

(4) Need for a data bank in biomass for the Caribbean. This was discussed and it was concluded that UNICA has a separate project on this.

(5) The need to determine: Bio-fuel consumption in the Caribbean, Charcoal uses, Firewood uses. This can help in identifying further demonstration projects.

Other Recommendations:

For consideration of some future effort for demonstration projects, we wish to put forth the following possibilities: biogas or proteins from the banana operation at St. Lucia; explore in Antigua the possibility of biogas from the expansion of pork and poultry production. In Dominica, explore the possible use of wastes from coconut users and from food processing.

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