CEER-B-156

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

---Page Break---

PROCEEDINGS OF UNICA WORKSHOP ON BIOMASS

AS AN ALTERNATIVE FOR THE CARIBBEAN

Caribe Hilton Hotel

San Juan, Puerto Rico

April 28-29, 1982

---Page Break---

CONTENT

Applications and Importances of Anaerobic

Waste Water Treatment ?

---Page Break---

CONTENT (cont.) Page

ENERGIA BIOMASICA 85

---Page Break---

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 fat San Juan, Puerto Rico, as part of the UNICA Science and Technology Commission Project on Development of Alternative Energy Sclence 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 en unrivaled network has been estad-Uished to make this project a rare experience: Caribbean talent is being used {o establish, at an carly 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 anslyzing Caribbean energy alternatives, the initivtive has foreseen the importance of the project and especially the recommendations from the three workshop st ?education and training, research and development, and demonstra~

tion 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 Caribbean island needs, biomass could help in the economic recovery of the region. Both

---Page Break---

?energy and food crops could be complementary, especially the production of bagasse/fiber from energy cane.

Specific demonstration projects are now needed in the Caribbean in order to implement the use of biomass as an energy alterna: tive. The only resource lacking is funding. Also important is the development of « tropical biomass institute. UNICA is in a unique Position to play an sctive role in developing regional programs, technology transfer activities, and information dissemination. All these recommendations are discussed in the presentations and workshop results.

?This workshop followed immediately upon the Fuels and Feed-stocks from Tropical Biomass Seminar I, also held in San Juan, Puerto Rico, 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 may be ordered from CEER.

Finally, thanks to all the mombers of the Commission end the CER Staff who helped make this project a success.

---Page Break---

ACKNOWLEDGMENTS

?The UNICA Science and Technology Commission acknowledges the work done by Mr. William Ocasio, CEER-UPR, in organizing this Second Workshop on Biomass as an Energy Alternative for the Caribbean, The Commission also thanks Eng. Pedro A. Sarkis, CEER-UPR, who collected and organized these Proceedings.

The Commission acknowledges with thanks the funding support received from the National Science Foundation, the Exxon Educa onal Foundation and the UNICA Foundation. It gives thanks to

?the UNICA Staff for their cooperation, for the simultaneous trans-

lations, and for other services during the workshop.

?The Commission is, of course, also grateful to all UNICA con-

?tact persons who participated in and actively supported Commission

menbers in this project

UNICA SCIENCE AND TECHNOLOGY COMMISSION

Dr. Juan A, Bonnet, Jr. CER, University of Puerto

Chairman Rico

Dr. Howard P. Harrenstien University of Miami

Dr. Gerald Lalor University of the West Indies

Dr. Eric Farber University of Florida

Dr. Franciseo Gutiérrez Universidad Central de

Venezuela

October 6, 1982

---Page Break---

WORKSHOP ON BIOMASS AS AN ENERGY ALTERNATIVE

FOR THE CARIBBEAN

APRIL 28, 1982

---Page Break---

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 Biomess 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 Founda: tion, to ali 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 @ Caribbean energy resource.

It is fitting we should be doing this in the Caribbean and

orticularly in Puerto Rico for two reasons: first, we have been

doing much research in biomass, and, second, our natural re-sources 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 sofl classifications, These are representa~ tive of southern Florida, the Caribbean in general, Central America, northern South America and large regions of Africa and Asia, ?Thus e wide range of land and water and plants and animal

---Page Break---

Varinbles may be studied. Altitudes range from sea level to mountainous. At Fl Yunque the tropical Luquilio Forest averages a rainfall of over 200 inches a year; yet within « two hour drive wt region at La Parguera where one of the world?s few Phosphorescent bsys may be found and where the rainfall seldom exceeds ten inches # year. Just 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

there is des

multiply Puerto Rico's ability to provide naturally occuring environments for interaction not only with Iaboratory-crested experiments but also with the impact of an industrialized und technologically advanced society on a densely populated island with few mineral resources of its own.

?These characteristies, unique to Puerto Rico, can be found and duplicated in varying degrees on other islnds and regions in the Caribbean.

It is therefore fitting that UNICA should be the sponsor of these two days of our four day program. Not only do we share a common geography, and, in spite of lingulstic differences, a greater conmonality of human heritage and economic needs than are generally realized, but we also share a common

ge of problems. It is for this, for exchange and common effort, that UNICA was created in 1968 ond has since yrown 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 end resources.

Energy is such » regional need. Energy is such a regional resource. The need is present, as it has always been; the Fesource continues to be largely potential. Always abundant as sun-shine, wind and vegetation, energy has also been in short supply since the ad}

t of industrialization and modern technology. Now

---Page Break---

© promise is opening up for us agsin--the promise and potential of energy here und now, constantly renewing itself--without our having to rely on imported fossil fuels to develop our modern socioties.

Biomass is such a constantly self-renewing form of energy. It offers certain, almost immediate, short-term substitute possibilities for reducing the reliance on fossil fuels; it also heralds # potential promise of substantial proportions in the long term.

Essentially a mechanism for collecting and storing sunlight in organic form, biomass has numerous attributes particularly favorable to Puerto Rico end other developing Caribbean nations. Of particu-lay note are these factors. Its varying forms ore adaptive to the region's special climatic and botanical resources and divergent land ?ond water resources. As an already integral component of the Caribbean historical experience, it ean be produced and processed with existing technologies. A rapidly deployable
cable substitute for petroleum fuels and feedstocks, it is also potentially the least expensive substitute for the petroleum fuels and chemical feedstocks in temperate regions. Finally, the world's most productive biomass forms are found in the Caribbean region, including both herbaceous species, such a8 sugarcane und other tropical grasses, and a broad range of woody forest species.

\d broadly appli-

?Therefore, as Director of the Center for Energy and Environment Research of the University of Puerto Rico where we have been working on these problems for five years now, snd as Chairman of UNICA's Conimission on Science and Technology through which we take steps to spread our good works, it gives me great pleasure to weleome you to these proceedings.

It is my hope:

4 step to furthering our mutual understanding of our common needs

snd 1 am sure yours too--that they will become

---Page Break---

?and problems and, even more significant, a major step in working toward resolving these needs and problems with shared scientific and technological solutions.

---Page Break---

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 Box 3682

San Juan, Puerto Rico 00936

---Page Break---

wny WoRRY?

In @ report dated March 17, 1982, Daniel G, Snow of A.G. Becker Inc. states:

"We Velieve OPEC will hold its official $34-a-borrel price at its March 19th meeting, but lower the price to $29 a barrel at its late May meet-ing... and possibly even to $25 2 barrel at its year-end meeting... Moreover, we believe there is Substuntial risk that, os prices move down, OPEC may lose control in a downward, leepfrogging? price

spiral to $25 a barrel (sic)... depending mainly on whether the U.S. economy has @ robust second~ half recovery..." (1).

Herbert W. Krupp, vice-president of Banker's Trust Company, Now York, has even predicted @ world surplus of oil, with stable Prices, threugh 1990 (2), These reports are illustrative of many which have been published this year by knowledgeable authorities forecasting 9 significant decline in crude oil prices over the short,

intermediate or long run, depending on the inclinations of the enalyst. Such lorecasts and current developments in the oll industry (8) are in partial or total contrast to those published a year or ore ago, sometimes by the same authorities (4) (5).

?There is no doubt, of course, thet we are experiencing a temPorary glut in oil supplies. Contracts for delivery of No. 2 heating il in May of 1982 ore selling on the New York Mercantile Exchange for $1.4 cents per gallon, almost 22 conts or 19 percent below their lifetine high of 113.0 cents. Moreover, the glut is expected to last for some time because contracts for delivery in every month through Gctober 1982 are also selling below their life-time highs (6). With winter gone, these figures from a regulated, open market in the U.S. confirm newspaper reports of significant reduetions in the price of crude oil sold under regular contracts between oil companies and producer governments.

---Page Break---

Accurate information on such crude prices is not 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 (7). More recently, Japanese companies have agreed to buy on spot basis at Jeast six million barrels of Iranian crude ot $26 per barrel, some $6 per barrel below Saudi Arabian erude of the sume variety, in violation of the OPEC pricing struc~ ture (8).

Under the circumstances, one may ask, why worry about alter- notives 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 jealute at a rate at least one or two percentage points sbove the general rate of inflation for the Caribbean region. Over a decade, fat only two percent per year, this means an increase in the real G.e, inflation-adjusted) cost of these fuels of 22 percent. To get

fan idea of the impact, think of your own country and what could happen if suddenly, tomorrow, petroleum prices increased 22 per- cent, other domestic prices changed only enough to pass on this increase, but export prices changed not at all.

Despite the relief given oll 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 thun we thought we had. We would be foolish not to take advantage of it. Our reasons for saying this are as follows:

Q) Since the first off crisis of May, 1970, the history of crude ofl prices has been precisely what we ar observing

a

---Page Break---

touay--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 many in-

dustrialized countries, both marxist. and non-marxist overestimates of the effectiveness of President Reagan's ?economic programs and consequent over-production; and efforts to adapt particulor structure for oil prices and @ particular mechanism for escalating them.

(3) World oit consumption will continue to increase, despite the success of efforts to conserve energy and replace petroleum fuels (9). 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, or 26 percent more than the present maximum capacity of the largest OPEC producer.

(4) In addition, a very substantial amount of new capacity ?must be added to compensate for exhaustion of, or declin- ing production from, existing wells. For the United States alone, this requirement could reach 10 aillion barrels per day by the year 2000, close to the present maximum capacity of OPEC's largest producer (9).

(5) New oil fields are becoming more difficult and more ex- pensive to find and develop, so even # slow increase in consumption insures a relative inflation in oil prices in the long run. For example, during 1975-1978, « period of relatively stable of! prices, exploration expense in the U.S. increased at an average snnusl rate compounded of

---Page Break---

and lifting costs, at 9 percent, for a weighted average of

11 pereent (5). In addition, recent technological advances

and high oil prices make it profitable to spend relatively

more, per foot drilled and per well, to find ofl than in

the past (10,1112),

(6) Nearly half the world's crude oll s supplied by OPEC

countries. Moreover, outside of China and the Soviet

Union, about 75 percent of the world's proven reserves

?are controlled by these same countries. The middle cast~

ern 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 normal world consumption. Since its own

needs are substantially les:

equivalent to almost 7 percent of world consumption (13)

it has a "swing capacity"

and has repeatedly demonstrated its willingness to use

this swing capacity to attain foreign policy or oll price objectives

(7) Middle-eastern polities differ from politics elsewhere. Poli-
Uical ond religious considerations often prevail over econo-
mic ones, sometimes in a manner that is entirely logical
within the historical context, but which catches western-
ers, 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, nucleer bombs (14).

?Neither praise nor blame is intended here. However, of! producing
countries may not always be able or willing to consider the needs of
?small, oil-importing countries!

---Page Break---

Sooner or later we must expect new conflicts in the
Middie 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 tact thot we cannot predict the timing or cause of the next energy crisis is not really relevant. Its consequences are Ukely to be severe and, to some degree, permanent, Within this context we will now proceed to examine biomass opportunities with specific refer- fence to the Caribbean.

WHAT IS BIOMASS?

Defined broadly, biomass consists of terrestrial vegetation (e.g. crops, weeds and trees), acquatie vegetation and the resi- dues 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 Gioxide and water into solid green matt

rand oxygen.

?The sub-tropical conditions which characterize the Caribbean fare often ides! for biomass. Due to warm (or mild) nights and winters, plant growth is usually possible on a year-around basis, Soil fertility may be greater then in the tropics while rainfall, even

where abundant, is normally not so heavy as to drown crops or

each sway most soll nutrients. As a result, high yields per acre

of fiber ond other solids may be achieved, frequently superior to

those attained in other climatic zones.

?

---Page Break---

?The uses of biomass are many: to feed people and enimals; as

Faw materials for chemicals; for lumber, decoration, shade, protec-

tive surfuce cover; as the source of the oxygen which we breathe,

and, finslly, for energy. An ?oven dry" short ton of biomass (6

Percent moisture) has about 15 million BTU of energy. On a steam

equivalent basis, that is about as much realizable energy as there

is in two 42 gallon barrels of residual fuel oil.

The ways of or

jerting biomass into energy are

lso very

humerous (See Table 1). A great many are still in the early stages

of research or are undergoing systematic laboratory testing. Still

others are operational on @ commercial seale but are not yet econo-

mmically feasible. Because time is of the essence in implementing

alternatives to petroleum and most countries cannot afford to make

mistakes, our discussion will emphasize those biomass energy sys-

tems which are, first, appropriate to several Caribbean countries,

and, second, commercially feasible.

ENERGY IN THE CARIBBEAN

All of the insular Caribbean countries, except Trinidad-Tobago,

fare petroleum importers. Consequently, the oil price increases of

the last decade have

wd 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 Carib-bean Alternatives Energy Systems Project of AID, CARICOM and cob.

The Caribbean energy situation is further complicated by the following additions! problems, each of which, in varying degrees, is common to a number of countries:

(GQ) The small size of the national energy system.

---Page Break---

(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 by petroleum imports for 2 given end use and/or acquire energy-intensive consumer goods (e.g.frost free refrigerators, window air conditioners).

(1) Few or no commercially exploitable, indigenous fuel re-

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

(9) National energy pricing policies which inhibit energy conservation and the development of alternative energy sour-

Under the circumstances one cannot flip through Table 1 and blithely recommend every biomass alternative that happens to be commercially feusible and reliable somewhere in the world. Even the ?portunities that one identifies as suitable for some countries may not be at all suitable for others. Hence, duly warned, 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.

16

---Page Break---

Even today it is still a major crop in Barbados, the Dominican

Republic, Guyana, Jamsien and Puerto Rico, for example,

"

---Page Break---

sumouyun $9 twouosg Apmis oxow

aay ?(dn pue sawoXom1) uo! yeLOL

a1qeriea "sdox9 sv payeayiino saaay

fo 1ony 9 ?oN Way

$38 }04 GauoM om)

imu Ssvad jeoydory

aasaryadwoy *(

qimos3 0) pod

STO Tong 9 ?ON WM

Paritiedwog *(uosymios yyuod omy)

Wimos3 zo} padouow ssex8 jvordosy

oa aoghtns

eatsusixe soise <Bsoug so ?deg ?g'1.

Xq paddoig ?dou ator aretodaoy,

suotiwaodo

ouvs 1s09-uiyy anes you trim EraMon,

uy ATaatsuaixa pasa ?Axoystq Buoy

*(s)o0t4d arenbape 38 pros aq

uso (s)ronpoad dnaks ouva jf ' Tyo [ang

9 TON WIEm oAtytradwoo KaoA oq pinoUs,

sosn a[a98 [vtoiouDeD 105 ApvoM

sawSns jou ?yimoa3 40s poSoutw aun9,

?SuNatNWO,

Seoooad [wo qwoyo-owsoyy ¥ hee

(52) WBnoayy (yt) :saamn0g

491194 0} sdsyD pooy s90n) S8z0ug

£ayroq 04 Avy paddoug

YOu wor.ros

oq 0 Key paddoug, seus8 soidoy

nyS.10s j20m3

181 10q we91s oy Cionpord-o9)

Siortad ossuaeq 10 ossosog euvs sung

491 ;0q ways 01 (ionposd-o9)

Stored osevdeq so aesedeq aug ABsoug

woTIsAgDD TIFIG -y

SWHLSAS ADMIN SSYHOIE aaZoaTas

1 gravy

---Page Break---

(ee) 298 ?4oAoMOrtey

ssoooad jootueysau eka,?

oisem

91 sararisnquos redy Fung

S191 19d poseq-poom 40 soisem

oom 10 Doom,

»/000%9$ 2 1uoW)soauy

VA SotwoUodg ?91qoIOIS ssov01d

nba J 1948-34)-350 8950 x9p0oK,

ssoo0ad

Terqoeg,

FO ult} Ipow xoufu ATU *

quodiad gg 01 dn soanjxr tong-143y

---Page Break---

suopionposd jousyjou pue auoyrow

aos Sutswosd ing *jeiuowrzodes TT Tg

ssyinsoa poxtn ?squeqd mag *Sqavau

ways aanssaad amo] 9}esou98 01 posn

Tequomrsodxe [1y1g3 sws0ys

vase fq poioaysy ?eas Uy umoad etd

*sotuouosa 0} [vot1 49 worsKe

[eruowrsedxo 1111s -ofomos

1 Adwurad ut pasn werd

4041991 109

30 yuou})

sorstoads a418 sosuouoog,

sorauituay sojorouyooy [eyasowuoa 343¢q

?oa

? $0) 998 ?gw 404 curvisosun sozwouoos

ang! Torpay pub eutyy ut oan ut siorsaaip

opwuoysno.*{tnus so suot tine sak

atquifean suoysKe tfewt ys tous-o 330

woq *Spt tos tenprsoa Jo ash oy at tratas

Joqwousss qty Wuauntaauy Tet tut O88

azynbos sou ina? ?asoys08fp posnisvsnute

Bursa "grq ut siooford tnsssooone ouog

(ponusiuoa) 1 grav

?sao 9mnand

ssao0ad uo puodep,uaiya suory

saodoad ut op pue 299 ?ounyraw

?(a9s/id o2t ?B*9) seB

S1SKpoaKd plats OF sorayasng

Suos pappazys Jo s¢shtoahg

aoTeTTT ET

sv8orq

SP1944 401s931p oF suet ram,

seiorq

SPI91s soysod sp oy uRtd 19M,

Gaas/ata_oo6

oivipaago uy

01 08) sudo)

*yuoni 539 pue spytos

Tenpisag "se304q Spt

4018931p 01 sprtos ainisa

worrsam

sand ?Wordas

poom yo wor wo.

15 1su8 wears,

oysum pros

reds turye

TasTmysCNTTT +o

194

umosq yue ED,

rutoesy,

39104

strsgpuey

Aaerjues

o8pnts oBemas

Tedroruna

?soisum [ouTuy

---Page Break---

sordwexe

Jo 9sn yfnoaty ue

SVT qtssod 82054 Couey 405) savaing

poom

J stskt

(lounge 103) sadn <oapay prow

nood ?1yAtaMm £4 a

tod's¢ 81 prays un

(ASOTSpaay WoT iw FuaMADy FOF) STeRTOIRA <a

rownnoyy 21808 pom,

naystoo sapun iuerd ayo

3 9yf1oo2 Buysn ssavoed T$qOW

owe ow

?a

?uBtsop ssao0ad

uy ymoy UOLIBIEESID Jo eoinos saat

yonpoad-&q 0} oat fsuas s>yWoNOD

2 }oW! > a1esadwoy *sasso00ad udaoad. toueurg us0g

soryyoods &ayunos st

Jo asn pus ysaq ?s9ssa904d uado. rosusa sossu1ow

woriwyaemIeg ?a

?SINGNNOO STaNd TWordsL dat

(ponuyiuos) 1 grave

---Page Break---

?There are @ number of excellent reasons why the cane

plant is well-suited to the Caribbean:

a

@

@

«@

@)

@

The

o

@)

It is @ magnificant converter of solar energy to biomass

(26).

It is capable of very high yields per acre (27).

It has input flexibility, That is, the degree of mechanization can be adjusted to match the labor supply available for cane industry work. Conversely, with energy cane, yields are high enough to suggest the possibility of increasing the labor supply by offering higher wages. This is particularly useful where foreign exchange and budget?ary considerations put a low ceiling on the degree of ?mechanization. In general, energy cane will require more labor per acre and less per ton of green millable cane

than sugar cane, at any given level of mechanization.

It is hurricane resistent.

It is very versatile. Possible final products include fenimal feed, chemicals such as ethylene and furfural, energy (in the form of electricity, steam or motor fuel), paper, sweetners and wallboard (28,29).

If the non-energy co-product(s) receive adequate pi

ce(s), the energy from energy cane should be highly

competitive with that from No. 6 fuel off

liquor

Possible limitations of energy cane are the following

It requires greater water and fertilizer inputs than sugar

cane, although these are hendsomely rewarded by dispro-

Portionate increases in yields of commercially valuable

outputs.

Like all cane plants, it must be dewatered in a large

Piece of machinery called @ cane mill, Existing cane mill

grinding capacity will therefore put an upper limit on

---Page Break---

bagasse energy production, because new capacity costs roughly $15 million per thousand tons of green millable cane per day.

(3) Horvesting energy cane where yields may surpass 100 tons per acre of whole cane (23), requires expensive machinery or u substantial harvest-time labor force,

(4) As @ result of (2), 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 @ problem in some countries. A sure way to Jose 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

© minor by-product or waste. ?The Key to cane economics is mult!-product output.

o During the desd season, one must either burn pelletized bagosse or energy grasses to continue to generate electricity.

For purposes of illustration, Table 2 shows possible harvest-season economics for # 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 ® 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 u detailed explanation see (30).

---Page Break---

TABLE 2

PRO FORMA STATEMENT OF REVENUES AND ECONOMIC COST (1982 PRICES)

BIOMASS ENERGY SYSTEMS (HARVEST SEASON ONLY)

PERCENT OF

SQMILLIONS) TOTAL

Revenues from sales

Electricity (520.3 million kwhr 9.0c ea.) 28.8 62

High-test molasses of f.0.b. cane mill

(21.2 million gallons 95.0¢ ea.)

?TOTAL REVENUES

Economie Costs

Field Costs

Operational 1

Capital Recovery on working eupital!/?/ 2

SUB-TOTAL 8 2

- Transportation of Biomass

sus-rorar! ba as

MiLL Costs

Conventionel (by difference) 13.6

- Capital recovery on working eapital!/#/ he

Bagasse dry!/5! 1.2

Electric plant!/®/ os

- Administrative and general (10% of sales) 47

Contingencies (15% of sales) 10

SUB-TOTAL 3h 65

TOTAL ECONOMIC COSTS 46.8

Ty caprte TOT avi ?

2) Working capital = 1108 x 7.6

3) 5 miles 1.15 per ton mile of moist stems, dry tops and trash

4) Working capitel = $08 x 13.3

5) Capital recovery and 20% maintenance on initial cost of $3 million

8) Capital recovery und 158 maintenance Initial cost of $9 million

Sources: See text

---Page Break---

Energy grasses

If one is solely interested in biomass energy, tropical energy

Brasses, such Napier and Sordan 70A, are probebly more economical

than energy cane in many countries, mainly because they are de-

watered by solar drying in the field and collected by e straightford

balling operation. However, they are also less labor intensive, do

hot utilize existing mill capacity and generate no coproducts. 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 grt

the grasses with reduced inputs,

ses with food crops or use

Energy trees

As indicated in Table 1, research on these is stage. However some countries may want to explore two or three

i in an early

year rotation energy trees on small plots as a source of charcoal for cooking.

Upgrading biomass

All three examples given--Agri-fuel, Bechtel and Woodex-
Tequire a considerable capital investment per ton of output. How-
fever, where appropriate boilers exist, they provide for intensive use of biomass in the existing combustion infra-structure without major refitting. The Agri-fuel and Woodex processes also convert biomass to « 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.

---Page Break---

juncipal solid waste(MSW)

This is a vast and complex subject. We have dealt extensively with its economics in a paper now under revision (31). However, the following points must be mentioned:

a

@

@

wy

The economic and technical feasibility of an energy system Dased on municipal solid waste is very sensitive to local site conditions.

?The design of the collection system is critical to the sue~ cess 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 homogenous and may vary frequently in moisture content, solids composition, ete. 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 end Wood wastes

Wastes are already being used in Guyana, but for pyrolysis ges 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, IMW down,

Anserobic digestion of onimal wastes

Given the problems noted in Table 1 and the number of small waste generators in the Caribbean, the best solution for many

26

---Page Break---

countries is probably to obtain proven U.S. designs but build as much of the system ss possible from local or regional materials, 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 oF 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 product of the digestor. 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 hhas much tess value. Use of the digestor effluent is highly site specific. Biogas-fired distillation of ethanol is promising.

Anaerobic digestion of municipal sewage sludge

From the point of view of economics, health and marketing, it 4s vitelly important to hill pathogens in the sludge, remove metals and avoid the accidental passage of raw sludge through the digestor without transformation. A feasible solution might be to combine a first-stage treatment using water hyacinths with a second-stage Gigestion process, using a UASB or a through-type, end-feed digestor, The hyacinths would be harvested and digested separately.

al

For the Caribbean, the only immediate way to produce fuel-

Grade ethancl is to ferment cane mol

ses. However, this begs the

question - what is the best use of the cane syrup? For some coun-

tries, sugar, molasses for cattle feed, molasses for export and/or

ethanol for rum are obvious answers. However, given the poor

Prospects for cane sugar (32), countries with cane mills will

definitely want to look at the generation of electricity by

ethanol-fired gas turbines.

---Page Break---

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 Gistillery operating costs and a large reduction in environmental problems (30)

We doubt, however, that ethanol as motor fuel, either elone or in gasohol, is an attractive option for small countries. Even small, on-the-farm fermentation facilities are expensive (e.g. $25,000 and up for corn-based ones of 10,000 gallon annual capacity). Also

?considerable time and skill are required to operate an efficient facility... Rather close supervision is required during certain phases of operation... Many precautions must be observed in plant operation... vapors may ignite... there is the possibility of explosion? (33). Large facilities have the following drawbacks:

(2) 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 because of the lower energy content per volume of ethanol (21).

(2) For ethanol-gasoline blends over 10 percent ethanol, modi~

fications to automobile motors may have to be made. If Pure ethanol is used, carburetors and certain other parts will have to be modified (21).

(3) Any blended fuel may or may not lower the motorist's oper~

ating costs but it does not increase his security of supply 80 long as the gasoline is made from imported crude oil

---Page Break---

Methanol

Methanol is currently produced from naphtha and natural gas vin synthesis gas, a mixture of carbon monoxide and hydrogen. About 90 percent of world consumption is as a solvent or as a chemical intermediate (34).

Coal and biomass are potential sources of methanol, by the sume route. In the latter case, biomass is gasified, the ratio of carbon and hydrogen adjusted, and the mixture cleaned and then Pressured in the presence of « catalyst to produce methanol (21). At present, no biomass-to-methonol plants exist, but several based fon wood wastes have been announced for Furope and North Ame-

Methanol fired gas turbines look even more promising than ethanol fired ones (21,35). 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 invest-ment of about $2.00 per gallon (21) and do not yet give a very good return on investment unless the biomass feedstock is quite cheop.

As a motor fuel, methanol suffers from the same kind of pro-lems 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 cheracteristies (36).

---Page Break---

SUMMARY

Despite the constraints limiting the options of Caribbean coun-tries, 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 cene syrup. Rea dy for trial on @ commercial seale with # good probability of success.

(2) Energy grasses, for the production of electricity from chopped solar-dried grass. Excellent possibilities.

(8) Direct combustion of wood wastes. Commercially proven.

(4) Anaerobic digestion of enimal_ wastes or sewage sludge.

?Tricky but probebly feasible on a small scale in e number

of countries.

(8) To be investigated carefully - electricity generation by 28 turbines fired with ethanol or methanol; pyrolysis of wood.

(8) For further investigation ~ charcoal for cooking from energy trees.

30

---Page Break---

REFERENCES

G) Snow, Daniel G. ?OPEC in the Test - Maximum Uncertainly
Now at Hand." Fundamental Investment Research Depart-
ment, A.G. Becker Ine. 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,

(B) Schmitt, Richard B. "Drilling Dip - For the Independent O11
?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 1980's." Fundamental Investment Re~ search Department, A.G.? Becker Ine. Chicago and New York. March 12, 1981. 14 pp.

(8) Anon, "Analyst See More Gains in U.S. Oil Profits." (re Bache Halsey Stuart Shields Inc. forecast). Oil & Gas

Journal. November 10. 1980. P. 160,

(@) 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. ?Warch

1982, 101 pp.

(8) Tbrehim, 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 a Gas Journal.

Tulsa. November 2, 1981. P. 80.

(10) Various. "Drilling Technology". Oil &

March 8. 1982, Pp, 139-187,

Journ:

Tulsa.

(11) Anon. "Steam Dominates Enhanced Oil Recovery." Oil & Gas

Journal. April 5. 1982, Pp, 139-159,

(G2) Vieker, Ray. "Exotic New Technology Used in Olt Drilling is

Leading to Big Success, a Rise in Reserves." ?The Wall

Street Journal. New York. February 12, 1982,

3) Anon. "Saudi Action Seen Lending to $28-29/bb1. Price." OL

Gas Jou Tulsa. March 29, 1982. P. 57.

---Page Break---

an

as)

as)

an

as)

as)

(20)

ay

ny

en

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 Im-

Pact of Oil Supply Interruptions: an International Pers-

pective." ?The Energy Journal 3(1). Pp 1-34,

Anon. "Potential for Crude Market Disruption Stressed." il

4 Gas Journal. February 8, 1982. Pp. 86-88.

Klass, Donald L. "Energy from Biomass and Wastes: An

Wwerview."" Proc. Symp. Fuels and Feedstocks from

Tropical Biomass. Center for Energy and. Environment

Research, University of Puerto Rico. San Juan, Novem

ber 24, 25, 1980. 32 pp.

Smith, L. "Energy Balances for Fuel end Alcohol from Puerto Rico Energy Cane." Proc. Symp. Fuels and Feedstocks from Tropical Biomass. Center for Energy and Environ~ ment 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 Processe: ins volumes). ?Office ?ot Hemnelogy-Resesonenty Liseesy of Congress. Washington, D.C. 1980, 195 and 234 pp.

Sworden, P.G. "Seco-Dow Corning Wood-Fueled Cogenes
tion "Project." Preprint Symp. Fuels and Feedstocks
from Tropical Biomass Il, Center for Energy and Envi
ronment 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 Il. Center for Energy
and Environment Research, University of Puerto Rico.
San Juan. April 26-28, 1982. 21 pp.

---Page Break---

aay

2s)

28)

en

(28)

28)

(so)

an

«32

ay

Kospers, Harry MC. and Wout, Sixto A. "Bioenergy trom ?Anaerobic Treated Waste Water.? Preprint Proc Work: shop Biomass «:s an Energy Alternative for the Caribbean. UNIGA. San Juan. April 28-29, 1982, 23 pp.

Beningson, Herbert E, "Development of Free Flowing Pow- dered Fuels from Biomass". Preprint Symp. Fuels and Feedstocks from Tropical Biomass Il. Center for Energy and Environment Research, University of Puerto Rico, Sen 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 Feodstocks from Tropical Biomass Il. Center for Energy and. Environment Research, University af 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 Researen, University of Puerto Ric, San Juan. March 26 and 27 , 1979.

Chen, James, C.P. and Meade, G.P. Cane Sugar Handbook Centh edition). ?John Wiley & Sons: "New York. 1977

Smith, Lewis. "Pricing Mechanisms for Syrup and High-test

Molasses." Preprint Symp. Fuels and Feedstocks {rom 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 Sys- tems." Proc. Seminar Nodern Techniques of Domestic and Industrial Waste Management. Center for Energy and Environment Research ct 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." Donn's Agricultural Services, Inc. April 18, 1980. 2 pp.

---Page Break---

(64) Wnide, Robert A. "Methanol Development,

tions." Proc. Conf. Methanol, New

198)

Problem) and Solu-

?ork. December 1,

(85) ANE, Robert K. "Alcohol and Electric Power." Proc. Symp.

The Alcohol Alternative. ?Alcohol Week and. Chemigal

Week. Chicago. May T and 8, 1981. ?12 pp. plus?

Tachnents.

(36) Stone, Charles L. "Final Report. Sysithetic Fuels Program."

alifornia State Legislature. Sacramento, June 305 1979,

29 pp plus attuehments.

a

---Page Break---

CALILGEAN ENERGY ACTIVITIES SUPPORTED BY

?THE V8, AGENCY FOR INTERNATIONAL DEVELOPNINT

Presented at

UNICA WORKSHOP ON BIOMASS AS AN

ENERGY ALTERNATIVE FOR THE CAKIBEEAN

San Juan, Puerto Rico

April 28-29, 1982

By

William L. Eilers

Acting Deputy Director

THE OFFICE OF ENERGY, BUREAU FOR SCIENCE AND TECHNOLOGY

Agency for International Development

Washington, D.C. 20518

---Page Break---

OVERVIEW OF AID PROGRAMS IN ENERGY

As reflected President Reagan's Curibbean Basin Initiative, the countries of the Caribbean are @ new mojor focus of the global energy assistance programs of the Agency for International Devel- opment (AID). One compelling reason for the priority assigned to ?nergy in this region was the recognition that in many Latin Ameri~ ?ean countries ond 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

+ ALD established

two major objectives for the region to ease immedtia

alone. As a consequence of this growing cris energy cons-

its 10 development and to help countries make the difficult transition to @ new mix of energy sources that can sustain thelr future economies

tn

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 evelopment, particularly wood and charcoal. Of this mount, 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 allocsted for new energy activities within the $350 million supplemental appropriation that President Reagan has requested for this fiscal year or the $900 million Fequest for the region that the President submitted to Congress for the new fiscal year beginning in October, 1982.

---Page Break---

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 hay a budget of about $10 million this year, some of which will be eurmurked for this region. ?These funds and the institutions which use them are intended to provide Guick-response technical assistance to individual countries and institutions in fields such as exploration and evelopment of new sources of conventional energy, experts for energy planning assistance, decentralized hydro-power resource assessments and feasibility studies, and technical assistance in vther fields of renewable energy such as biomass, wind, and soler, 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 treats a wide range of alternative energy technologies in lectures, demonstrations, laboratory work fand field trips. Participation is limited to those who have at least a bachelor's degree in science or ongineering. 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 « 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 conven tional energy. Students in this program are now at work in geol= BY and geophysics, petroleum engineering, coe! mining engineer-

a

---Page Break---

ing, electricol engineering, energy resource planning and manage-ment, and hydroelectric power generation,

SIMPLE, LOW-COST ENERGY TECHNOLOGIES FOR THE RURAL POOR

The Office of Energy also focuses on the provision of low-cost energy technology for the poor in both cities and remote areas through grants to the Volunteers in Technical Assistance (VITA) land to the Peace Corps to train volunteers in simple energy tech nologies. These organizations are working on projects such as low-cost wood stoves, charcoal kilns, wind-powered pumps, biogas digesters, and nicro-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. During the past four years we have invested nearly $8 million with the Caribbean Development Bank and CARICOM to conduct national energy assess ments ond conversion studies and to design, test, finance and dis tribute information on alternative energy technologies. We have financed projects such as a solar/wind resources study, an assess~ ment of Belize peat deposits, energy assessments in Barbados, Antigua and Guyana, and we have organized workshops on solar crop drying and minthydropower.

AID has just launched another Caribbesn-wide activity involv- ing about 25 separete projects designed to create employment opportunities in both the public and private sectors. Much emphasis is placed upon stimulation of private enterprise particularly in the energy field where numerous opportunities exist both for coventures with foreign investors and new small business activities for indigenous entrepreneurs. This project is concentrating on

---Page Break---

Smaller countries such as Antigua, Dondnica, St. Lucia, St. Kitts-INevis, St. Vincent, Montserrat and Barbados.

AtD Js 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 cach year. More than 1,000 hectares will be Planted in farm woodlots by reforesting steep marginal grazing land. We ore also stwengthening energy planning in that country and conducting feasibility studies on alcohol fuels, industrial energy efficiency, small-scale hydropower and the use of excess capacity.

4 national plan for energy is being developed in the Dominican Kepublic 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

formation system is being built, An additional $11 million is

Projected for the Dominican Republic to help in formulating national

nergy investment pricing plans, to help industry «t

Inge to more

efficient energy conversion machinery, to exploit small-scale water

resources, and to improve the management skilis 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 tropics! trees, including five speciesiaucaena, neem, cassia, eucalyptus, and casuarina. Tree seedling nurseries are being planted in modern greenhouses. Tree planting is aimed at soil con-servation, production of firewood end 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 Haitian entreprencur purchased a briquetting machine from Chicago for about $60,000. He discovered that a mix of 60

---Page Break---

Percent charcoal dust, which he obtains without charge from kilns near Port-au-Prince, and 40 percent molasses as @ binder which he buys cheaply from the tocal sugar mill, makes an effective briquette which can be sold at about 60 percent of the price of equivalent charcoal. He secures bagasse free of charge to heat the ovens to Gry the briquettes, Until this past year, he exported much of his Production to Puerto Rico, but now the Haiti domestic market is absorbing his total production. Since charcoal sells for $5.00 for a 30 kg beg in Port-au-Prince, he should continue to sell his full production in Haiti and make a reasonable profit.

In Jamaica AID's energy sector assistance of $14 nillion is aimed at increasing the efficiency of industrial energy use, developing solar water heating, and improving the government's cepability to plan and menage energy development. We are also testing species of fuelwood in Jamaica and initiating demonstretion and pilot activities in various alternstive energy technologies.

AID funds @ number of programs in agro-forestry, rural energy technologies, small hydroelectric power and other renewable energies in Ecuador, Honduras, Peri, Guyana and Panané.

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 miltion each year to enable the U.S. National Academy of Sciences {fo administer a separate program of research awards. Roth programs seck research topics which involve collaborative studies between U.S. and developing country research institutions snd univer-

---Page Break---

sities. Grants have been ranging from about $35,000 to $150,000 and usually extend for more than one yea

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 Bio-energy 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 odaptation 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 Gusifiers. Im Ecuador the concentration is upon 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 construction of a wood-fueled steam electric generating plant at Yaviza in Panamé.

Under our agrecment with the U.S, Forest Service a series of

14 state-of-the-art studies have been collected in the Bioenergy

urther Thformation on the Seience Adviser's Program of Research Grants, write to Dr. Irving Asher, Deputy Direcefor, Office of Science Adviser, AID, Washington, D.C. 20518. For detoils and information on? submission of pro-posals to the National Academy of Sciences, write to Dr, Michael Greene, Director, Committee on Research Awurds, BOSTID, National Academy? of Sciences, 2101. Constitution Avenue, N.W. Washington, D.C., 20418.

a

---Page Break---

Bioenergy Conversion landbook 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 Guta and case material. Those interested con ask to be placed on the mailing st

ENERGY STUDIES

Many of you are familiar with the impressive series of publi- cations on technological innovetion 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, enimal and agricultural wastes; leucaena, firewood erops; microbisl processes; food, fuel and fertitizer from organic wastes; producer ges; sowing forests from the air; and the proceedings of a workshop on energy Survey methodologies. Several new studies are in process, inclu- ding the potential of aleohol fuels, and on three crop spe

a8 acacia mangivm, calliandra and casuarina.

The Office of Energy hopes that it will continue to be possible to use the outstanding technical resources and experience of the Center for Energy and Environment Research, not only for our acti~ vities in the Caribbean and Latin America, but for other regions well. The Center deserves warm congratulations for helping to organize the symposium and workshop which have attracted an im- pressive number of high- quality scientific and policy papers.

---Page Break---

EL CONCEPTO DE INTEGRACION

DE SISTEMAS DE ENERGIA A LAS GRANJAS AGRICOLAS

Presentado en

UNICA WORKSHOP ON BIOMASS AS AN

ENERGY ALTERNATIVE FOR THR CARIBBEAN

Facultad de Ingenieria

Universidud de Puerto Rico

Mayaguez, Puerto Rico

---Page Break---

INTRODUCCION

BI incremento continuo de los costos de energia, alimento, mano de obra y costes para prevenir el deterioro del ambiente y mejorar la higiene de los sistemas de producción agricola, han obligado a ?estudiosos © ingenieros en los Estados Unidos @ la busqueda de soluciones que mayormente cumplan dos propésitos basicos: (1) geneTer clerto grado de autosuficiencia energética con un mayor incremento en la producción y (2) el empleo de métodos económicamente atractivos que eliminen en forma efectiva los riesgos de contaminación al ambiente a un nivel aceptable dentro del esquema legal de Tegulaciones que lo protegen. Distintas soluciones han sido formuladas todas ellas de efectos positives, pero sin que una en

Particular satisfaga las necesidades bésicas mencionadas. Entre las ?mas importantes se encuentran: (1) el uso de los desperdicios para Producir energia; (2) las distintas précticas de tipo técnico para el recobro de energia desechable; (3) renovacién de algunos sistemas mecénicos en los sistemas de produceiin existentes; (4) la pueste en pricticn de medidas de conservacién y administrucién de energia ys (5) el recobro de materiales reusables que no comprometen la calidad de la produccién, Estas soluciones por sepsrado y alguns

conjunto han producido mejoras econémicas y han facilitado la solucién de problemas en los sistemas de produceién agricola. Desde luego, el grado de mejoras econémicas y los logros alcanzados ?no han satisfecho Ins proyecciones hechas, especulindose que quizés 4a falla esta en la forma poco intensa como se han implementado y coordinade en la prictica aunque se reconoce que se ha obtenido algunos beneficios.

La idea de combinar distintas fuentes energéticas imperecedera coordinadas entre si con la utilizacién de técnicas propias de las reas de ingenieria y agronomia ha generado gran interés por lo atractive que resulta la incorporacién de una serie de venti tipo téenico que mejorardn la flexibilidad ya aleanzada con la meca-

---Page Break---

nizacién y que revitalizardn mas los sistemas de produecién con un

?mayor incremento del benefielo económico, Esta idea se describe en

el concept conocido como "Integracién de Sistemas Energéticos a

Sistemas de Producciin Agricola" a nivel de pequefla y mediane

escala. Se adiciona a este concepto de integracién, In condicién de

minimizer toda cnergia residual disponible que pueda utilizarse.

Asimismo para su implementacién se establece como requerimiento, el

agregar @ los sistemes, 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

region.

En este trabajo se tratané de enfocar 108 aspectos mas impor-
tantes relacionados con este concepto. Se indicwin brevemente tipo de flexibilidad y limitaciones de estos desarrollos. Se usar como referencia el modelo propuesto para la finca Ubsrri, en Juana Diaz, que incluye operaciones y actividades de tipo industrial afines en ?sus métodos y procedinientos a las que realizan la industria avicola, ganadera, vacuna y poreina,

Entre los t6picos a considerar se incluyen los siguientes:
(2) diferentes aspectos de la etapa evaluative; (2) guias y factores importantes en la fase del disefo; y (3) aplicaciones y limitactones tecnolgicas del principio; y (4) algunos aspectos econémicos.

Ln discusién de los tépicos se haré para aplicaciones en siste-
mus de produccién ya establecidos y que recobren energia mediante ?el proceso biolégico de digestién anaerébicw,

ETAPA EVALUATIVA DE LAS GRANJAS

Ln fase evaluativa es el primer paso a realizar para ayudar a definir los sistemas energéticos a ser integrados y tener una idea

clara de Ins ventajas, dificultades y _restricciones que téeniea y

---Page Break---

econémicamente se pudiera confrontir on lx adaptucién de las fuen-

tes cnergéticas y elenientos a! sistema de produccién existentes.

Esta eotividad se renlizs en gran medida al anslizar los factores

imternos y externos que van 1 alectar lu planificaeién, aisefio y

desarrollo del prineipio.

FACTORES [NTERNOS

(2) Ventajus naturales det aren

(2) Grado de meconizacién de la operacién

(8) Distributén ce las favilidudes eaistentes y caracterl

de la operaci acién

my org:

FACTORES EXTERNOS

(G) Tipo Ge actividad fabril y agricola en las vecindades

(2) Suministro de slimento snimul combustibles y servicios bast

(8) Condieién de vida y mano de obra

(4) Servicios pabticos disponibles

(G) Actitud de la gente del poblado en las vecindades

(G)_Incentivos gubernamentales

(1) Evatuación det potenciat legal y problemas ambientales

Las ventajas naturales del rea estin relacionadas con su loca~ lizacién, orientacién y topografia--terreno montafoso, inelinado, plano, ete.--ln dispontbilidad de tierras, régimon de Huvias, eva~ Poracién, quebradas en las cereanias, depésitos de agua subterré- eos, corrientes naturales, caidas de agua, manantiales, nivel

frigtico, Iagos, irradiación soler, condiciones det suelo para culti- vos, régimen de vientos, condicién climatoljgica, temperaturas méximas, minimas y humedad. 1s información estadisticn y el anélisis van @ ser importantes para trazur la estrategia a seguir en el

---Page Break---

disefio y estimar el nivel de aprovechamiento de Ins fuentes ener-
géticas disponibles.

Un alto grado de mecanizacién es una situacién muy favorable ya que le provee un uso a la energia recuperada. Esta no solo se ?emplearia en el érea de procesos (sistemas de secado y equipos para conservar las caracteristicas fisicas, Diologicas y quimicas del producto) sino también en la maquinarie adicional para aumentar la produccién y minimizar las pérdidas para comercializar.

La disponibitidad de suministros bésicos como los combustibles (iquide © gaseoso) y servicios de agua y luz son de primerisina importancia, Esto facilita un rendimiento adecuado en un sistema en que la sustitucién de fuentes energéticas pudiere ser el patrén que ofrezea un mejor uprovechamiento de los recursos de produccién. Por otra parte, los suministros de alimento animal son otro pari-
metro de mucha importancia. En base a 61 y a la disponibilided de residues sélidos estabilizados se consideran; In adiciin de las operaciones de cultivo de heno y otros géneros, sistemas aquiferos

para alges y peces. Su consideraciin es una necesidad por el crédito que en el renglén alimenticio pudieran aportar al esquema

idad det

alimento es elgo que tiene que acordarse en base a un punto éptimo

econdmico total de la operacién. Debe entenderse que In c

que permite obtener las mayores ventajes tanto por los ingnesos por producción y como por los erédites por recobro de energit

de sub-productos y deposicién de desperdicios.

La distribución de las faciiidades para la producción de la granja a revitalizar es de singular importancia para In aplicación efectiva del concopto. Esta distribuciin seré mis conveniente entre

in existente s uno de los prototipos de

los sistemas caracteristicos de producción como por ejemplo; produc-ción en linew, areas de producción en parelelo, ete. Desafortunemés se acerque la orgunizac

damente las experiencias tenidas en algunos paises en via de

a

---Page Break---

desarrollo, las de granjas en lo mayoria de los casos no siguen un patrén que ofrezca la posibilidad de planificar una aceién especitfica Y uniforme. Hay que estudiar cada caso y definir una estrategia ?ecorde. Por consigviente, en base a que las actividades que se realizan en las granjas estin identificadas con Ia distribucién de ?areas de proceso, se necesitaré un cuadro sintetizado que caracte- rice las distintes funciones en cade drea, tanto de miquinas como de hombres, para que las estructuras y méquinas que se adicionen sean mis efectivas sl acoplarlas con el formato de onganizacién existente.

La existencia de la agro industria que brega con el proces

niento de

woduetos provenientes del campo, u otro tipo de

?iu locelicadas en las vecindades 0 en el érea rural, ven @

significar unas ventajas para el concepto de integracién. Esto podrie de forma inmediata, favorecer suministros de combustibles # precios razonables lo cual permitiria et uso del biogas en otro factor importante de le economéa de la planta. También favorecen el

desarrollo del principio, mejoras de las infraestructuras de vias de comunicacién y In existencia de servicio plblico disponibles. En adicién, la industria en el rea proveeré experiencia que puede asistir en la solucién de problemas.

Para promover una sctitud positiva de las gentes hacia teenologia debe de iniciarse un programa de educacién, especial mente cuando las granjas estén cerca al poblado. La misma debe continuar duronte el tiempo en que se realiza el proyecto, Esto tiene como propésito promover una atmésfera de confianza y eredibi- lidad entre ambes partes con respecto a lo que se quiere hacer. La accién es necesuria en cualquier situacién sea iniciativa privada o gubernamental.

La participacién del gobferno y el potencia! legal existente en materia de regulacfones son muy importantes para el desarrollo de

---Page Break---

esta tecnologia, Esta puede hacerse a través de actividades que ?auspicien estos desarrollos sean de tipo econémicos 0 mediante la facilitacién del trémite que pudieran interferir su iniciacién y finalizacién. Para que el potencial legal sea efectivo, el gobierno a través de las agencias responsables, deben promover la investign cién continuamente para obtener el dato empirico necesario con el fin de promulgar et tipo de regulaciones que dé gufas significativas y adecuadas para el control de la tecnologia implementada por el principio de integracién. No se anticipan problemas umbientales.

EI sistema de transporte, ln mano de obra y las condiciones de vida son factores que podrian afectar en algin grado le fase de disefio y desarrollo, Todo va « depender de Ia localizacién de ta granja. Si la gronja esté en zona rural no se espera cambien dris- Hicamente ya que los desarrollos se disefian dentro de un concenso de criterios simples de tal forma que destrezas especiales no se requieren por parte del personal que trabsje en las distintas Iabores que se realicen, EI transporte seré segin las infreestructuras existentes, Si en cambio le zona rural con industrias @ sus alrede- dores, el sistema do transporte es de esperarse sea mejor que el caso anterior. La mano de obra sin destreza pudiera escasear y es posible que sea baja por razén de la competencia, significando esto lun efecto econdmico de consideracién en la operacién. Es de esperarse que las condiciones de vida se encerezcan por Ia existencla de Ia industria y que el obroro sin mucha destreze emigre adi-

cionando ésta un elemento més para acelerar la escasez que esto

tracria. Como las gran

las fuentes de energia y los procesos

que se integran son bien especificos en naturaleza y los mismos

requicren de reas amplins y relativamente distantes de zonas urba-

nas no se contemplan desarrolios en el perimetro de zonas urbanas.

GUIAS Y FACTORES IMPORTA}

NTES EN LA FASE DE DISENO

Es importante resaltar que el desarrollo de un trabajo de inge~

---Page Break---

nierfa exige identificar parfmetros que respalden el disefo y la ejecucién de tos proyectos, parimetnos que muchas veces como es el ?caso de 1s splicacién del principio de integracién energética, Pertenecen al dominio de disciplinas 0 de situsciones aparentemente ajenas al émbito de la ingenieria. Por tal razén los proyectos de este natursleza requieren Ia formacién de un grupo de trabajo de tipo interdisciplinario que estudie, disefe, especifique y desarrolie, estructuras maquinarias y elementos a integrer.

Teniendo definido tos propésitos del disefio y los parémetros primarios es importante y antes de establecer los objetives y las Bulus se debe tener claro cual es Is capacidad y Hmitaciones del sistema de produccién existente. Ademis, un conocimiento de las Propiedades fisicus, mecinicas y calidad del producto 0 productos y de los desperdicios sélidos resultantes del proceso de produceién, Para identificar y considerar ta magnitud y positles soluciones de los problemas ce flujo, recoleccién, manejo, alniacenamiento, corro~ sién, seguridad y los relacionados con el disefio de estructuras y seleccién de equipos.

El diseho debe proveer como objetivo inmediato las necesidades energéticas en un porciento alto emplesndo eriterio de recobro y conservacién con un costo total relativamente bajo. El diseflo debe sirar en torno a realizar unos sistemas simples que al acoplarlos a los existentes revitalicen y no interfieran la operacién de produc-

cién. Esto requeriré observar los siguientes puntos: (1) poner

fen préctica ideas que sean de sentido comin; (2) emplear el efecto

de grovedad existente en el dren al méximo para que la cuota de

energia que se use pare operar ef sistema acoplado sea minima; (3)

hacer un inventario del gasto de energia de la operacién existente y

clarificar aquellos casos de consumo eritico, estos consumes deben

?tratarse de disminuir con sistemas que utilicen directamente el

de tiempo de contribucién efective

de las fuentes energéticas renovables-~sol, viento, caidas de agua y

biogas; (4) obtener el espaci

---Page Break---

desperdicios--para buscar la mejor armonizecién de equipos y todas las actividades de la futura operacién, esto ayudaré a dar una idea mas amplia sobre las limitaciones y capacidedes de los sistemas scoplados; (5) evitar automatizar Ia operacién de los sistemas recordando que Ia misma debe ser en su mayor parte manual para srmenizar una operacién simple con el nivel de preparacién del elemento humano que atenderd la administracién y funcionamiento de todo cl sistema de produccién; (6) establecer un término aceptable entre flexibilidad deseada en el sistema como un todo y la economia de la construccién y produceién; el grado de flexibilidad va a ser lun factor de mucho impacto en el esquema econdmico de Ia opera clén; (7) tener siempre presente que por In naturaleza de la operactén, nivel de destreza humana y combustible resultente del Proceso anuerdbico la seguridad es un factor a considerar en el Aisello de las estructuras y en Ia seleccién de equipo y maquinaria; (#8) considerar el problema de corrosién inminente, por raz6n del

terial orginico y los productos resultantes det proceso de Gigestién anaerébiea; estos materiales deber ser de caracteristicas tales que prevengan o inhiban la corrosién; (9) mantener los pro- blemas de contaminacién al ambiente a un nivel bajo; deben antici parse soluciones sencillas en caso de mancjos erréticos, fellas human

18 © casos fortuitos; (10) todas las ideas, cambios y adicio~

nes deben de orientarse hacia un objetivo: mantener un alto grado

de eficioncis y efectividad det sistema para evitar situaciones conti~

nuas de fuera de servicio © interrupciones en la operacién por

tiempos largos: y (11) uso al miximo fuentes residusles de energta

conio una buena politica de conservacién.

APLICACIONES Y LIMITACIONES

El desarrollo y prueba de distintos prototipos es le fase que

permite evaluar la efectividad del principio y las limitaciones de tipo

tecnolgica. Estas dos cosas incidirén a su vez en el grado de

---Page Break---

efectividad funcional y en el tipo de beneficio econémico a conse-

uir.

Resultados de estudios de naturaleza empirica sobre el uso del

sol, egua y viento para producir energie han dado resultedos favo~

rubles. El recobro de energia del desperdicio animal mediante la

Gigestién anaerébiea na sido demostrado en estudios a nivel de scala pequefia y grande. Proyectos reslizados en Brockman y Green Bay, Wisconsin, Energy Harvest, Ilinols, a pequefia escaia lo corroboran. Otras actividades de recobro de energia térmica resi- ?dual han sido estudiadas y sus aplicaciones en modelos de plantas industriales y en actividades comerciales han sido debidamente pro~ bados. Por lo tanto es cuestién de integrar todos estos subsistemas, fevaluarlos y establecer qué logros econémicos son factibles y qué prototipo es mas ventajoso desarrollar.

La seccién que impulsa los programas industriales del Depart: mento de Energia de los Estedos Unidos tiene bajo supervisién varios proyectos de sistemas energéticos integrados para tamafios

moderados. Estos proyectos servinin para conocer de las limitaclo- nes de tipo téenico dentro de la base conceptual simplista reque~ rida, Los misnos estin distribuides en actividades que comprenden granjas pura erfa de cerdos, otras que combinan la actividad de produceién de grano, aleohol y produccién de leche. La actual mente en proceso de diseflo en Puerto Rico comprende una ganaderia de 500 cabezas Holstein que opera con una produccién de leche de

1400 litros por dia. BI desarrollo propuesto incluye las siguientes

actividades: (1) recoleceién y preparacién de los desperdicios

sélidos; (2) produccién y preparacién de gas rico en metano vie

proceso unserdbico de desperdicios sélidos, limpieza y almacenamien~

to; (3) uso del combustible biogas para: produccién de fuerza

eléetrica, como fuente calorifica pare regenerar la sustancia refri-

Gerante usada en cl sistema de refrigeracién por sbsorpeién; (4)

uuso de la energia del viento para produeir energia eléetrica que

---Page Break---

fatimente las bombas de ogua de suministre que succiona de los

épositos subterréneos para atender el consumo de agua en la

?operacién principal de ordefio y el suministro de agua para los

bebederos de animales; (5) uso de colectores solares para recolectar

1 energia calorifica necesaria para mantener las temperaturas

?mesofilicas de operacién de los digestores; (6) uctividades de reco-

bro de energia residual pera proceso de secado y también para

asistir el mantener las temperaturas de operacién mesofilica (98°F)

?en ambos digestores; este recobro también se realizaré mediante el uso de intercambiadores de calor compactos para calenter agua los cuales se acoplordn a las unidades de refrigeracién de expansion directa existentes usadas para preservar la colidad de ia leche:

(2) actividades de conservacién mediante le inclustén de un sistema

de refrigeracién por absoreién el cual reduciré el consumo de Kw-Hr actuuinente critico por el uso del sistema de refrigeracién directa; también se reciclaré sgua acumulada en las charcas para el proceso de dilucidn det sélido animal, el agua se bombesré pe:

las charcas proviniendo ésto el consumo de agua excesivo y agote-miento de reservas, este reuso se sincronizaré con Ie actividad de evaporaciin caracteristien existente en el

\dicamente de

irea: (8) se integran

también actividades relacionadas con recoleceién de agua luvia, cris de peces y algas en chareas, preparacién de hatos para cultivos de heno. E} material fertilizante y nutriente se obtendré de los des~ Perdicios sélidos estabilizados mediante el proceso anaérobico.

Aunque existe la tecnologis para darle el uso adecusdo a las fuentes de energie revsables y para realizar todas las actividades Gescritas, debe indicarse que las eficiencias obtenidas con los moto-generadores que han usado el biogas han aleanzado cifras del 14 al 15 porciento. Sin embargo, el empleo de mezelas de biogas en determinadas proporcfones con el diesel o gas natural parece ser la ?olternativa pura aumentar los niveles bajos de eficiencia antes mencionado.

---Page Break---

ASPECTOS ECONOMICOS

La comparacién econémica de sistema a sistema es diffell hacerlo ya que lu tecnologia que se desarrolla en uno y otro caso van a ser diferentes. Perimetros como ingresos totales, costos de operacién y conservución serin, come es tradicional, las referencias fundamen-tales para cnjuiciar el éxito econdmico de le aplicacién del principio. Sin embargo los eréditos econdmicos por recobro de energia, medi-

Gas de conservacién, mejoramiento de la calidad del producto 0 pro~
Guctos, costes de alimentos y métodos de contabilidad serén objeto
Ge riguroso escrutinio para aceptar su validez 0 recharzarlos, Un
formato guia para normalizar la contabilidad y realizar la evaluacién
de proyectos de esta naturaleza hu sido publicado por el Departe-
mento de Energie de Estados Unidos.

Para un anilisis econémico fundamentedo en proyecciones de
valor total
de Ia inversién, costos de operacién, ingresos, caracteristicas de

los créditos y financiamiento. Los resultados van a depender de la

ipo teérico se recomienda considerar entre otras cosa:

realidad de los niimeros conseguidos.

Independientemente del esquema y gule y los valores que
resulten mo se debe presumir que estos costes y eréditos son auto-
titicamente aplicables. Antes debe realizarse un estudio de facto-

res tales como: costor locales de mano de obra y costes de los

materiales, condiciones del me

?ado del producto 0 productos,

tamafo de la planta, métodos eléetricos y agua; tiempo de disponi-

bilidad de le plonta adaptada; tiempo de retencién de los sélidos en

la digestién anserdbica, ete.

Como se dijo antes los erédites van # variar en ura y otra

aplicacién. Por ejemplo en el desarrollo propuesto para la ganaderia

Ubarri los posibles beneficios cconémicus se deseriben segin la

Tabla 1.

---Page Break---

TABLA 1

POSIBLES CREDITOS PARA SISTEMA INTEGRADO EN GANADERIA UBARRI

ACTIVIDAD / MRJORA DESCRIPCION DEL CREDITO

Molinos de Viento

Reduceién consumo Kw-hr por empleo

de bombas de trasiego de agua

Gepésitos subterréneo y agua de las

chareas,

Reuso del agua de actividades Reduce costos por uso de agua en el

limpieza ge sales de ordefio ¥ proceso anaerébico.

agua de dilueién

Produccién alimentos - Aprove- Reduccién de los costos de alimenta~

chamiento residuos sélidos cién de animales.

estubilizudos com complemento

fertilizante.

Adicion sistema absoreién Reduceién consumo Kw-Hr actualmente

eritico con el sistema refrigeracién

DX para mantener calided de 1a

leche.

Tratamiento biolégicos anaeré- El beneficio se coneibe en base a y

bico y deposicién de desperdi- los ahorros que en costos se obtendria

por empleo de materiales quimicos y por

consumo de energia que el tratamiento

y manejo de desperdicio no estabili-

zados requeririan

Mejora Calidad producto 6. Aumento de ingresos por mejores

mereados.

Uso biogas en maquinaria y T. Ahorros por consumo de combustible

sistemas transportacién Viquido.

Ventus de subproduetos 8. Material fertilizante, heno, ete.

Los resultados finales del estudio serviran para corroborar estos cré:

ditos y el tipo y magnitud de gastos e ingresos.

---Page Break---

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

By

Harry M.C. Kaspers

Senior Lecturer in Environmental Pollution Control

and Sanitary Engineering

University of the Netherlands Antilles

and

Sixto A. Wout

Senior Lecturer in Control Engineering

University of the Netherlands Antilles

---Page Break---

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 fon a global scale.

It is apparent that if wastes could be considered as @ 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 waste water cen be considered as a potential source of energy. But it is well to point out that the discharge and treatment of waste waters, using present technology, consume significant amounts of energy, as can be seen in Table 1.

st

---Page Break---

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

Oxydation diteh(Pasveer)

type ot 0,85 25

4) 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 @ BOD of $4 g Op/day. Another approach Is to define p.e. in relationship with the

chemical oxygen demand, whereas the organic waste is chemically oxidized to conform with the K,Cry0, method and with the amount of Kjeldehl-nitrogen (TKN) present in the discharged waste.

Assuming the relationship COP

Bop

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 = 185 g O,/day (without nitrification) resp. 135

+ 4,87 x 10 = 180 g Op/day (with nitrification)

b) Conversion factors

1 Btu = 1.06x10°5

1 therm = 10° Btu

---Page Break---

It is assumed that the total energy consumed in the U.S. for

Gomestic municipal waste water processing costs more than $130 mil=
tion annually. The secondary und 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 of the capital Willemstad (100,000 p.e. excluding industries) would probably range between $145,000 - and $365,000 ~ depending on the type of sytem. This is about 16 percent of the total annual cost for waste water treatment.

One should understand that snother 60 percent of the total costs are caused by capital Unbilities, Therefore, it seems that there are more important budget items than ?energy? to save on. Furthermore, it should be noted that in the Caribbean huge amounts of energy are consumed for purposes other than waste water treatment, In the Netherlands Antilles, for instance, annual energy costs of alr conditioning are estimated at $23 million. A Aramatic decrease will be achieved by @ more climate-adapted design ?and construction for tropical housing. (3)

However, because of the large capital investment needed for waste handling and the increasing energy costs and consumption, alternative processing methods should be sought and tested. Prior ity should be placed on those processes with which not only energy conservation but also energy production and a reduction of capital costs may be obtained, The University of the Netherlands Antilles (UNA) storted research into anaerobic waste water treatment by ?means of an upflow anaerobic sludge bed system (UASB) at the end of February 1982, If the investigations prove successful, the UASB

---Page Break---

system will become a substantial part of an integrated waste processing scheme,

The high costs of waste handling pose a problem to Curacso because of the small scale of the different facilities for waste Gisposal. Under the proposed scheme, waste water treatment and solid waste handling facilities are joined to one processing plant in which waste recovery might become feasible. Valusble materials like glass, plasties

cipal) s

nd serap should be separated from the (muni waste for local manufacturing or export. The organic fraction will be converted into compost together with the surplus Sludge derived from the waste-water treatment unit. Only © small fraction of the original volume has to be discharged as sanitary Jand6itl, This compost and treated effluent will be used in agri- culture. 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 searce and expensive. The valve of a "second quality? water like treated effluent will amount to $0.60/m°.(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 woter treatment techniques. This has led to the development of the Upflow Aneerobic Sludge Blanket Reactor (UASB). It was during. experinental work on a continuous anaerobic process at the Wogeningen Agricultural University in the Netherlands that the dogree of sophistication required for practical commercial use was achieved. (5) The main part of the UASB system consists of @ re- actor tunk in which a mixed bed of bacteria is located. This microbial population is composed of facultative and strict anaeroble

bacteria which utilize chemically bound oxygen. In the UASB ays~

60

---Page Break---

tem the raw wuste water passes through the reactor in sn upward

direction and pollutants are absorbed by the microorganism.

?The digestion is, in essence, u sequential process. Complex

orgenie matter is hydrolyzed and, subsequently, acid forming bac~

teria converts the hydrolized compounds into simple molecules, vix.

volatile fatty welds (VFA), COp, Nig, and ll. The VA and other

ntermediates In turn serve as substrate for methane bacteria and

fare mainly converted into Cll, and CO,. In a balanced digestion

Process, however, the separate steps take place simultancously at

fan optimal temperature of 33°C (90°F), The gus produced risk

the surface at the top of the reuctor where it is carried off via a to

gas globe and a water seal, Also st the upper area of the reactor the separation of sludge and effuent takes place,

A disadvantage of the UASB process is its sensitivity to dis turbences if certain limits in the fluctuations of pH, loading rate and temperature are exceeded. Another possible disedvantage may be that ansero!

treatment must be considered as a primary bio- logical treatment facility. Residual pollution, the presence of vaonium and anserobie conditions, compel subsequent aerobic bio- logical treatment of discharge to sewage. In moderate climates the Process temperature is sometimes « problem too, and the system is self supporting only if strongly-polluted waste waters are proce

sed. In the Caribbean, nowever, there is no need for an external heat supply since temperatures are almost at @ constant and optimal level of 27°C (81°F). This implies that the system may also be

?energy self-supporting even in cose of processing weakly-polluted

waste water.

Some advuntages of the anaerobic upflow process are:

Substrate loading reactor: the anaerobic biomass can take care

of heavy loads (10 kg COD/m® day) because of the high

a

---Page Break---

Tempo

100,00

Biological trestrent including

Le J*LWSB processing

TS

30, 0008/99]

NEW recovery

Sanitery Vanafit) rond construction /~

[eon

?ethan

eroney,

ED

2

|_|

ng

Windrow oF serated

???_ ?statie pile

ween composting. fact ity

Anreclaimed

tan

Trento

effluent

Flare 1

CONGIPT OF AN INTECRATED WASTE: PROCESSING SCHED,

POR CHICA

---Page Break---

Treated

Effluent

A,

Sludge O

Blanket O

°

?yt vw

VA LLL 11,

ad

Mi, 47, Sludge tye

A,

7

ao SULIT,

Polluted Waste Water

FIGURE 2

UASB SYSTEM

---Page Break---

Fig. 2: Process flow diagram vase

AC

Centritugat pump, in tine capacity $800 mt/n

vessels, $004,

In Hine capacity $ 800 m/n

Gosmere

Worerseal (waterpressure co, 2")

UASB-reactor, SOOL

Timer conteatier for o

Filter

nal oiternating suming

---Page Break---

Sludge retention of the reactor, viz. 25-30 kg VSS/m?, and the fairly nigh specific bio-aetivity of the sludge, viz. 0.7-1.1 kg COD/ky VSS/duy at 30°C

As a result of the high loading rate, short hydraulic retention times, (e.g. six hours) are possible,

Smali-sized facilities and aren are required. Therefore, in many cases angerobie (pre) treatment has proven to be finan-cially competitive with aerobic treatment and other anaerobic treatment facilities. (Table 2, Table 3).

Sludge quality and quentity: the sludge is well-stabilized, settles casily, end has a high dry matter content (Sludge Volume Index 10-30 mil/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: asa consequence of the low sludge production in the anaerobie process, less nutrients (nitrogen and phospho-Pus) are required compared to aerobic processes.

Energy: since ambient temperature in the Caribbean is almost optimal for the process and sinee energy is only required for

pumping, an energy surplus should be expected.

65

---Page Break---

ENERGY PRODUCTION

From a given amount of average type waste having @ general

composition of C, H, 0, Ny a rough estimate of the producible

methane can be obtained from the formule:

3 aH,0

42434) CO, + ann,

B+3 2 3

The COD of the sane 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 O,/ mol cHy.

?This is in accordance with the equation:

chy +20, 0, + 2h,0

From this one can caleulate that oxidation of 1 grammol Ci, (22.4 1 at 0°C/760 mm Hig) demands 64 g Oxygen, or 1 kg COD equals 0,35 m? (°C, 760 mm Hg).

---Page Break---

The relationship between CH, and COD is given by the for-

mula:

. 3

Vong = AY) 0,85 b coy cnn)

cop

with

Yous is methane production (m®, 0°C, 760 mm He)

Y is yieldfactor: fraction of removed COD

used for development of new bacteria (sludge

growth), in general 5-158

Lcop 18 waste load expressed as kg COD

Ncop 18 processing (removal) efficiency of COD

or

---Page Break---

---Page Break---

(VS ?ERD SAMMOVERL HKETIS GLUNALEW OnEIY @Y SSEKRLL-AV OADM 4O S190

?eam

---Page Break---

OMDITY Y SSONKI-ISVN SLIDERAW 49 SLD

© rene

---Page Break---

Since the generated methane is a fraction of the total produc-

tion of biogas, there is u slight variation in energy-content.

Depending on its ?purity? biogas hes @ heating value of

7000-8500 Keal/Nm? methane Ctiy or 29-40 MI/NaP CH, (740-2060

Bru/tt®) which means that an equivalent of about 3 kWh/Nm?CHt,

(r gy 80-40%) can be obtained). At Curacao presently 1 kWh costs

80.145 (April 1962).

APPLICATIONS AND IMPORTANCE OF ANAEROBIC WASTE WATER) TREATMENT

Becouse the development of modern snserobie systems, especially the UASB-type, is rather new, only a relatively small number of industriai-seale plants are in operation, Most of these plants operate in rx like the Netherlonds, West Germany, Sweden, and the U.S.A.) Since high biogas production ?allows internal energy supply for heating, there are substantial

Jerate climate countries

UASB processing has general applications to a wide variety of ?agricultural snd related industries. Also the treatment of other waste waters from industrial and non-industrial sources have proven to be feasible.

Some examples of waste-waters tested on pilot-plant-scale and/or tested on industrial-seale are outlined in Table 4.

n

---Page Break---

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 ground. water.? Laboretory 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 Nm*/kg removed COD (57% Cli). An extra advantage is a removal of metals from the effluent up to 98% eificiency,

TREATMENT OF WASTE WATER FROM SLAUGHTERHOUSES AND

MEAT PROCESSING INDUSTRIES

This application is tested now with a 30 m® reactor in the Netherlands. ?Subsidiary aims are? energy generation and. protein recovery.

TREATMENT OF WASTE WATER FROM STARCH-INDUSTRIES

Several starch industries in the Netherlands are equipped now with UASB-systems, e.g. a maize starch-industry (60,000 p.e.;, capital costs US 16,70/p.e.). At potato starch-industries, ?waste water (COD 18 kg/m3) is ircated at loading rates up to 18 kg COD/m3-4. At loading rate of § kg COD/m3.d. (40 p-c./m3) # biogas-production of 8,5 ~ 7,5Nm3. (71-774 CH,) per m3 treated effluent is obtainable, as weil as u pollution réhoval efficiency of 954 as COD respectively 98% as BOD. The net surplus is used for starch procossing.

BEETSUGAR-INDUSTRIES

iny beetsugur factories in the Netherlands are equipped now with

USAB-systems. Loading rates 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

Jn 1981/1982 the construction of the world's targest industrial

Ihaerobic waste ?water=trentnent complex at 6. Helenan Beatie

Company at La" Crosse, wisconsin was ?cone pleted Tila breweng

brodtces over 1 milion? bbI (150 milion A, per sear. ?The plete

Scsigned to progeas ver 10000" ml/0"(S_ MOD)? of brewers weafe

water? with "polltion rate of 1800 g_ BOD/m os 2880" e: CODInS

?otal towd? amounts 347000 kg BOD! £78-000 ibs HOD! dal) eu to

54,300" kg COD! (180,000 Toe COB,) ov more than 0,008 p-0.

?oad ?reduetiof! of #58 BOD "is expébteg. ?Meunane producto Ss

?

---Page Break---

(Continuation Table 4)

galculated at 17,600 m3/d (621,600 ft3/day) with a heating value of

7130 keal/m3 (900 BTU/f2). Options for using the bio-energy are either electricity generation or bollerfuel. ?The gross value of the biogas is estimated at (1981) $816,870 per annum (40/therm).. The operating costs (personnel, utilities, chenicals, maintenance and sludge removal) are estimated at (1981) $240,000/year or $492,288/year including process heating. Net operating benefits amount therefore $324,582/year. Capital costs (exclusive of sewer or street work, or outside utilities) would be $6.5 million as of the ath quarter of 1981, ?Based on the projected reiurn on bio-energy this would imply a 20 year pay back; however it is expected. tha as energy prices inevitably rise, the rate of return will increa: 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 65 - 85% COD reduction Was obtained at temperatures higher than 6°C (43°F), ?The biogas Production amounted 220 1/kg COD (at 20°C or 68°F). Expected is a net CH, = production of 7,6 - 9,1 Nm3 CHy/p.e./year (1 p.c.

equals 544g BZV/m3d). During rainfall ina combined. sewerage

system however, COP redue- tion is expected to diminish to 50-756,

---Page Break---

?The climate in the Caribbean offers an ideal condition in which to use the UASB process as an energy producing ut Since temperatures are in yeneral higher than 24°C (75°F) and since there are only small fluctuations on the average annual temperature, no heating of the reactor will be required. Produced biogas can therefore be used for other purposes. In this respect waste waters from local food processing industries (cane sugar, distilleries, meat Processing, ete.) are undoubtedly promising energy sources.

In the Netherlands Antilles there are only @ few food proces

sing industries. No pollution loads are known for these industries since an overall study of environmental pollution has not yet been completed and the following pollution figures ure only rough esti-

ate

A rum distillery is located on St. Maarten, but no production figures are available yet. Because of results at other fermenting and distillery industries @ high pollution rate and therefore # high gas-production may be expected. (E.g. with molasses industries,

10 kg BoD/m®,

HOD/COD = 0,8, expected gas-production 4Nm°CH,/m? treated waste water.

expected figures are: pollution ratio.

The Amstel brewery on Curacao produces 132,000 hl beer/ year. Breweries, like most food industries, do not operate in an identical manner. Some use Lauter turns, others mash filters; some recover liquor, others do not; some use corn grits, others rice;

and 50 on. Consequently, the amount of waste and the pollution load of the sewage may differ considerably. Waste water volume varies 20-40 hi./hil. beer produced. Pollution rates range 500-1800 ? BOD/m® or 940-2900 ¢ COD/m®.

Assuming the same sewage characteristics as for the Heileman-brewery (see Table 4) the pollution loading rate

estimated at

?4

---Page Break---

38,500 p.e. with a gas-production estimated at of 1460Nm° (51600 1°) CHig/day will be obtained. This volume equals « heating value o 49x10 my Caoxt0® BTU or 464 therms) Téey. This energy way be used as o fossil fuel substitute for steam generation. If elec~ tricity were genevated from this biogas, an annual production of

1,600,000 kWh with a local substitute value of $232,200 (or $6.93/p.e.) can be estimated.

In this situation not only an energy credit is obtainable, but also reusable water is a possibility, Because of the arid climate in the Netherlands Antilles, the main fresh water source is distilled Sea water; price range of this water is $2 - $4.50/m°. In the beetsugar 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, 3901 sheep, 1512 goats, 14 turtles ond 18 other animals. The pollution loading rate is estimated at ca, 8000 p.e, or 1400 kg COD/m*.d, This equals a twethane production of 400 Na®/day or 75,000 Nm*CHy/year, meaning a substitute value of electricity for the amount of ca. $92,700 or $4.10 per p.e. per year.

Presently industries in the Netherlands Antilles are forced by law to purify waste water or they are taxed for discharging waste water. Consequently, up to now industries have been interested in

waste water treatment only if @ positive income is obtai

Process. Even then, however, waste water treatment probably will

be considered "branch-foreign" unless high energy credits are

1d from the

obtained.

With respect to domestic waste water, the Curacao government

Plans to construct several waste water treatment plants for the town

of Willemstad within a few ye One aerobic activated sludge

---Page Break---

plant (4000 p.e.) is under construction now. Because almost all

construction materials are imported, capital costs of « plant of this size are very high (up to $140/p.e.).

A waste water 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 one singe activated sludge systems being planned.

for tne tons of willmstad (100,00 psc.) a gross energy pro: duction of 800,000 No*CHy/year with ® heating value of 2.39 x 102° xdlyenr (2.26 10° therms/year) may be feasible and would pro- vide an electricity generation of 2.4 X 10° kWh with a local value of (2982) $348,600 oF $8.49/p.0. Estimates of investment costs and running costs of s one-stage serobic waste water treatment plant and # two stage UASH facility are made in table 5.

---Page Break---

?TABLE 5

COST ESTIMATE OF 100,000 P.E TREATMENT FACILITIES

1 Stage aerobic 2 Stage treatment

activated sludge UASB + aerobic

treatment tivated sludge

Load 100,000 p.e. oF 13500 kg CD/day

(0° aay) 10,000 10,000

Loading rate, 1° stage 10 p.e./n® 40 p.e.ia? oF 5.4

kg ODin®.,

stage: - 10 p.e. in?

Efficieney 1° stage ost 708

26 stage: ast

werall 258 958

2 2

Volume 1° stage: 10,000 2,500 a

2° stage: - 3,000

Mothune produet ion 800,000 No® year

Capital costs (x10008)

Sefoottrentiment » seat

tientation * sludge drying 000 3350)

TAS + gusholdor M400)

Gual-fuel generator - 100

Total 00 0 ay)

per p.0.$ 80 48.50

Annual_costs (10008)

investment costs 920 587.8 (11,58 of 1p)

raintensnce #0 38.5 of 1)

- 19.6 (1,308 of

1

Vor 200 200

contingsneies 160 97 (2b of 1)

So eee Ho 1o0's Ref TS

Riergy production (electricity) "= minus 248.6

Total 1600 2

costsyper pac. (_) 16 7

per a rested etftuent (> ? 18

NB. Egtimute does not include net revenues from effluent. sales:

$0,56/m" or $1,63 million/year (water losses assumed 208). In that

cose i-stage aerobic activated sludge plant in financially. self-supporting and 2-stage waste water treatment plant has a net re~

venue of $964.000/year, which ean be used for operating the inte-

Grated waste processing scheme (fig. 1).

n

---Page Break---

From these calculations one can see that:

Investment costs of the two stage (UASB + activated

sludge) facility are 39 percent lower than for the one-stage

activated sludge facility.

2. Annuol 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 » 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 te 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):

---Page Break---

1. Centrifugal pump for optional influent supply to storage ves:

Sels and optional discontinnous, automatically time controlled,

sludge water recirculation in the UASB reactor (cep. 800 1/h).

2. Storage vessels (400 1),

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

4. Gasmeter

5. Watersea!

5. CASB-reactor (500 1) composed of two ofldrums and a tilted

Plate interceptor with gas globe, welded together. Waste

water treutment ond methane generation proceeds as follows:

substrate contoining influent is made to flow upwards through

the reactor by means of the pulse pump. The gas produced in

the process carried off via the gas globe the top of the reac~

tor, the gasvolumemeter 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

Feactor vessel and the treated effluent overfiows 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 recirculation system.

9, Devices for waterflow indication and manual control and tempe-
ature meusurement.

?The installed flow scheme has the following processing options:

1, Raw influent is periodically pumped to the storage vessels and iter that the UASB reactor is fed during # 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-renctor is fed simultaneously. Return flow of the

---Page Break---

treated effluent to the storage vessels and/or sludge water mixing are optional.

?The installation was assembled at the site of municipal waste water treatment plant "Klein Hofje". This plant consists only of @ facility for primary sedimentation (Dortmund-type) and anserobic digestion of primary sludge. Partly stabilized sludge from this digester was used to start the UASB-reactor on February 28, 1982. Average composition of the initial sludge in the reactor was ca, 12 kg TSS/m?; 806 vss.

RESULTS

A sludge edaptation period of six weeks was projected. However, the pilot-test experienced several technical break downs 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 waste water from a separated sewer is discharged. Based on a daily discharge of 50-80 1/cap. day and a lowd of 54 g BOD or 125 g COD/cap. day, a pollution-rate of more than 1500 g COD/m? was expected. The pollution rate, however, was never more than @ disappointing 486 g COD/m',

This low value cannot only be explained by assuming biological

?oxidation during long hydraulic retention time in the sewerages. Probebly 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 phenomena is that even after start-up and sludge adaptation, the UASB reactor will not operate at ® maximum loading rate because hydraulic retention time will become the limiting factor.

---Page Break---

Shortly after the first start-up, it turned out that @ raw waste water supply directly to the UASB reactor was not immediately pos- sible because of clogging effects in the influent system and centrifugal-type pump. For that reason waste water was periodical- ly 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 wis not released very well from the sludge par- ticles unless the resctor can be brought into vibrations. Forced Fecirculation 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 overage COD-removal efficiency is still low; however, on some days @ COD-removel of 60 percent and more was obtained, On Mareh 18 the pulse pump was damaged and had to be re-

Placed. The subsequent test period was characterized by @ biogas

production which decreased from 22 1/day to less than 6 1/day.

Finally vs production stopped. Sludge content proved to be very

low, and the reactor was refilled with new sludge.

On April 8 however, the packing of the centrifugal type pump

started @ leak so that providing a supply of raw influent was no

longer possible. This pump st:"! has not been replaced and tests are

temporary stopped.

a

---Page Break---

TABLE 6

?TEST RESULTS

March March March April

Period 27 Bld 16-28 1-708)

Pollution ratio

influent gO /ni? 325 S27 3008

Effluent gO in? 7370s

efficiency % 7 48 ag

Load geuD/4 n? 0.455 0.916 0.600 0,389

Gas production

theoretical No?, /period 61.5 138.5 55 60 ay

measured ni* biogas/perioa 192.4 232.2 16 98.4 (5)

Gi, ratio 5668 a 6B)

Hydraulic vet. tine average day 1day 1 day 1 day

Recirculation rate a7? 4 4 oo4

(2) Assumption Gi, production 1s 0,35 Q-¥) ¢ezyy L(GAV) with y=0,10

(2) Sludge content during test periods March 2-14

12 kg TSS/o°; 818 VSS

(8) Initial studge content of test period April 1-7:

14,6 kg TSS/m?; 89% VBS

(4) Probably inaccurate

(3) Average temperature 30°C

(6) Correction for temperature; no corrections for solubility of gas in

waste water

---Page Break---

CONCLUSIONS

1, UASR processing of industrial w

te water represents a cheap

land promising method of waste removal and energy recovery.

2. Climatic conditions in the Caribbean are pre-eminently appro-

Priate to obtain an optimal net energy production.

It is expected that domestic waste water can be treated with a

wet energy yield. Further feasability studies, however, are

necessary

A higher benefit from waste water treatment can be obtained if energy production is desired and if the treated effluent is re-used ue process-water for industries or for irrigation.

Acknowleagements

We wish to thank the Sanitary Department of the Isle of Cura-cvo for its support of this research,

?The assistance of Mr. Joop Willems, Mr. Franklin Fecunda end Mr, Arthur Eliza of UNA are greatly appreciated.

References

1, Koot, A.C.J.; Behandeling van efvalwater, 1980, Delft-Netherlands.

Jewell, Wad., 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 Agricul ture, Animal Husbandry and Fisheries, 1982

5. Lettinga, G'etal.; Several publications, e.g.

@) "Feasibility of anserobic digestion for the purification of

83

---Page Break---

industrial waste waters," 4th European Sewage and Refuse

Symposium EAS Munich, 1078,

b) "Anaerobic treatment of raw sewage,? HO (14) 1981, nr.

10; 214, UDC 628,356.6 (in Duteh)

Kaspers, H.M.C., et ale:

f) ?Anaerobic treatment of leachate from controlled tips of

NSW," Sth European and Kefuse Symposium EAS Munich,

1981,

b) "Accumulation of metals in biological sludge from anserobie

treatment of leachate," H,0 (14) 1981, nr. 3; pp 43 (in

Duteh) .

Richards, E.A.; "Bio energy from anaerobically treated waste

water," 1981 (not published), RME associates, 9305 N 124th

Strect, Brookfield, Wisconsin 53005, (414) 783-5406,

Keenan, John, U.; Iraj Kormi; "Anserobic digestion of brewery

by-products," Journal WPCF, Volume 53, Jan. 81, pp. 66

ry

---Page Break---

EL ILN.RLA 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

---Page Break---

Es preciso que desde el comienzo seftalemos las preocupaciones del Instituto Nacional de Investigacién Agronémica en el campo de la biomase, Segiin Chartier la valorizacién energética de la biomase, mds que cualquier otro medio energético, se encuentra en interac~ cién permanente con otros sectores de actividad (produccién de alimentos, produecién de madera), es decir que los problemas macroeconémicos deben considerarse detenidamente.

Por consiguiente se ha procurade organizer las investigeciones Girigidas por el I.N.R.A, en una Comisién de Energia Biomdsica Para asegurar especialmente la definicién y la evaluacién de los Programus. A la misma vez, se han designado delegados regionsles Para Io energia. Una de sus responsebilidades es dar a conocer mejor les actividades de 1.N.R.A,

Fn el Gitimo informe de actividades de In Comisién de Energia Blomésica se presentaron los programas en proceso bajo tres drens:

Los Recursos. Bases de la producción, potencialidad de

Produceión del territorio, mantenimiento de la naturaleza renovable

de la produeci

+ impacto ecolégico, y carecteristicas de las dife-

rentes biomasas y de su movilizacién.

Las Transformaciones. Celulosa, fermentacién alcohélica y

fermentacién metinica,

Anélisis del Sistema de Producción_y de_tos

?Transtorma

Medios de

. penetración de medios energé

ticos en los sistemas de producción agricola y forestal, y estudios

eeondeicos.

. Balance energét

FL 1.N.R.A. mantione un centro de investigacién en la regién

Antillas-Guayana, Naturalmente

ste centro es parte del esfuerzo

Beneral de las investigaciones. Pero también ha habido dentro del

cuadro una reflexién especial del Comité Regional de Economie Ener-

Sética y del Comité de Técnica Solar de Guadalupe. Ademés esa

Politica regional se define de comiin acuerdo con los otros territorios

---Page Break---

franceses de ultramar. Se ha legado a tomar en cuenta, de manera

relativa, los recursos y las necesidades energéticas, el nivel de sensibilizacién y las realizaciones previes.

Una de tas primeras etapas fue el examen de ta situacién local.

Guadalupe consumié en 1980 cerca de 300,000 toneladas de productos

etroleros desglosedas on las siguientes proporeiones:

= transporte por carretera 38.28, de los cuales aproximads:

mente 1a sited fue gasol

~ produccién de electricidad 27.1%

ndustria 1.8%

= avincién 22.68

= otros 9.38,

Se ha hecho también un inventario preliminar de potencialidades de energia renovable. Se ha encontrado que el problema mayor consiste en Io nevesidad de reconsiderar en parte el modo actual de Produccién de onergia. Es necesario pasar de une politica de con- centrucion @ un sistema civersifindo de produccién de energia y al ils bajo costo.

Le sgricultura es un sector favorable para aplicar tal politica Notemos desde el comienzo que los insumos de energia {ésil tienen eseasu Smportancia en in agriculture local, La mecanizacién, la invigacién, el uso masivo de abono nitrogenado, son pricticas toda via poco desarroliadas. Es por esto que se ha estimado que Ins Recesidades de los cultivos se suplen solo en alrededor de un 508 mediante Ja aplicucién de diferentes abonos.

BI objetivo principal es, pues, aumentar la productividad de la agricultura y de le erfa en Guadalupe. Fs necesario, sin embargo, Procurar desde shora racionalizar el uso de los abonos, del agua y de los productos fitosanitarios.

---Page Break---

Esta politica también se ubica en el marco del mejoramiento de os recursos locales de biomasa. En efecto, con una irradiacién

?solar incidental del orden de 1,800 KWh/m? y suponiendo una efi-

ciencia de In fotosintesis de alrededor de 0.4%, el equivalente

energético de Ia biomasa producida junto @ la Guadalupe es de mas

de 950,000 TEP, es decir més de tres veces el consumo actual de

productos petroleros.

Los programs de investigaciones del I.N.R.A. en esta zone

geogrificn se derivar de observaciones

hay un proyecto para la medicién de la irradiacién solar en Guada-

lupe con miras u construir un mapa de yacimiento solar y un banco

de datos. Estos trabajos se llevan cabo en colaboracién con

diversas contros de investigacién locales,

interiores. Para comenzar

No se contempla por lo pronto envolverse directamente en cul-

tivos energéticos, ain cuando se estén Mevando a cabo ciertas

investigaciones agronémicas con la cafla de azicar, una planta que

genera un excelente rendimiento fotosintétice. Pero en otros cen-

tros del I.N.R.A. se han estado acumulando datos sobre ol jacinto

de oun, las biomasas de hidrocarburos (euforbidceas) y las oleagi-

Muchos de Jos proyectos tienen que ver con el uso racional del ?ogua. Citamos en particular Ia tolerancia de plantas hortenses Seleceionadas por Is sequeded y la valorización éptina de les pre~ Cipitaciones del agua y la irrigacién. En este Gltimo caso, le estacién de bioclimatologia ha Nevado a cubo por muchos afios una intensa actividad. Se han venido realizendo en forma continue estudios interdisciplinarios sobre: el comportamiento de los. suelos ?hacia Ia irviguclén, la seleceién de cultives capaces de asegurar la mejor valorizacién del agua, In determinacién de las necesidades especificos de las plantas, y la influencia de la irrigacién sobre la fertilizacién.

---Page Break---

Continda In preocupscién en torno al aumento de la produetivi~ Gad agricola. Actualmente se estima que uno de los factores de Progreso seria, sin duda, enfocar el cultivo de leguminosos. A la misme vez, también conviene valorizar al méximo la biomasa residual de origen agricola 0 de otra procedencia. En el primer caso, el bugezo representa el volumen, el substrato més interesunt vesiduos reservados son considerudos en segundo plano.

Las destilevias y las centrales azucereras tienen su autonomia enorgéticn gracivs al bagazo. Los equipos de investigactn de Gua~ Galupe quieren nejorar lu transformacién energética. Ellos pronos~ ican utilizar I gasificacién y la pirolisis en vez de la combustién, En este caso habré

un excedente muy importante de bagazo que Podré utilizarse para el mejoramiento orginico de los suelos. I.N.R.A, persigue conjuntamente con varias otras organizaciones un Programa de este tipo para el cultivo de productos comestibles. En esto lu estacién agronémice juega el papel principal. Esta. cltima Fecalen que el contenido de materias orgénicas es particularmente importante pare el terreno. En nuestro caso donde los suelos & veces son pobres debido a le actividad de los microorganismos, le No-restitucién de las materias orgénieas del terreno ocasionaré una baja on le fertilidad. Tales consideraciones han servido de base para emprender los trabajos pare 1a fabricacién de compuestos derivados de desperdicios y el uso del lodo de las estaciones urbanas de purificacién de aguas.

La industrinlizneién en Guadalupe es escess pero la contamine-ci6n causada por las vinazas de las distilerias conlleve malas con-secuencias para el plan ambiental, El tratamiento de estas vinazas por via serobin consume mucha energix. La fermentacién metiinica 8, pues, una mejor solucién para reducir la contaminacién. Esta es la alternativa por la cual se ha optado rectentemente en los pro-

gramas de investigacién de 1.N.R.A.

89

---Page Break---

Antes de terminar, es necesario decir algunas palabras sobre

el programa de cooperacién de I.N.R.A. en la regién del Caribe.

Existe uns preocupacién constente por dedicar mayores recursos fi~

bancieros © estas gestiones que nos permita cultivar relaciones con

el mayor nimero de paises. En estos momentos, sin embargo, el

4mibito de la energia biomésica ha sido poco explorado.

HL programa de investigaciones de 1.N.R.A. sobre los usos

energéticos de ln biomass se sustenta sobre la necesidad de satis~

facer las necesidades de productos y sobre el cuidado de una pro

Suceién menos contralizuda de la energia, La proteccién de ambien

te ¥ cl mantenimiento de la naturaleze renovable de la produccién

son también una de nuestras muyores preocupaciones.

0

---Page Break---

BIOCONVERSION OF STRONG ORGANIC WASTE STREAMS

TO METHANE GAS:

THE BARCARDI CORPORATION'S ANAEROBIC TREATMENT PROCESS

Presented at

UNICA WORKSHOP ON BIOMASS AS AN

EKFRGY ALTERNATIVE FOR THE CARIBBEAN

San Juan, Puerto Rico

April 28-29, 1982

By

Dr. Michael Szendzey

Project Manager

Bacardi Corporation

Catefo, P.R.

---Page Break---

?The Bacardi Corporation has investigated numerous disposal

and treatment alternatives to find the most acceptable method for

Gisposing 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 oxidation of mosto, the use of con centrated mosto or "CMS" us a boiler fuel and the anaerobic digest- ion of mosto were all investigated. As a result of an agreement entered into between the Bacardi Corporation and the U.S. Envi- ronmental Protection Agency in late 1979 which required # 75 per- cent BOD removal from its mosto waste stream, the company decided, because of its previous studies, to utilize an anaerobic biological treatment process.

The Bacardi rum distillery, the largest in the world, has, like other distilleries, a waste stream thet is high in organics. Based ?on the information developed during the evaluation of various treat- tent technologies, Bucerdi decided that anaerobic biological treatment wus 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,
cop	85,000-105 000

ss 4,000- 5,000

Nitrogen (Kjehidahl) 790- 1,480

Phosphorous (Orthosphate) 59-98

2

---Page Break---

?The reasons for choosing the anaerobic process can be summa~

rized as follows.

1. The process is suitable for high strength organic wi

?The waste is hundreds of times stronger than domestic

wastes and stronger than many industrial wastes.

2. © & Mt costs are low. Aerobic treatment would require as

much as 8,000 horse power for aeration elone.

3. The process generates energy in the form of methane

ges. Aerobic treatment doce not produce recoverable en

corey.

4, There is a minimal studge production. Aerobic treatment

would produce @ large emount of sludge requiring han-

dling und 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. De-

pending on the strength and characteristics of the waste
land the level of treatment required, the retention time
and the design of the process can be custom tailored.

Another reson for choosing an anserobie process is that
Puerto Rico is an ofl importing country; therefore, any process that
replaces imported oll is beneficial to the economy. ?The practicality
of anaerobic troatment 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
from u few hours up to a day.

?The advontages of an anaerobi
are as follows:

1, Loadings are not restricted by oxygen transfer. The loa-process over an aerobic one

93

---Page Break---

ings echievable in anaerobic systems are much higher than in aerobic systems. In anseroble systems the loa dings are determined by the viability of the bacteria to the loading and by possible material handling limitations such a8 pumpability, Given enough time, anaerobic bac teria capable of performing efficiently under extremes of organic concentration can be developed.

2. The naerobfe process is not restricted by the high cost of oxygen transfer. It takes a significant amount norse-power for aerators or an expensive oxygenie plant to treat waste serobically.

3, There is usable end product in the form of gas. Aero-

bie Weatment only produces Coz, water and large volumes of shudge to be disposed of.

4. Less biological solid is removed per pound of BOD. In the annerobic treatment approximately 90 percent of the de-graced cxgunies are converted to gas and only approxi-mately 10 percent go to solids.

Most of this is possible becuse the onaerobie biological filter, invented by Dr. P. MeCarty, is a grest improvement over the con= ventional anaerobic contact digestor.

Unt the development of the anserobie filter, it was difficult at best to develop and maintain # 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 recireula-tion and nixers, it only requires very low horsepower to Wivide recirculation. A total of only 12 horsepower is required in our 8.25 nillion gallon angerobie filter.

---Page Break---

5.

There is a smaller tankage needed due to the higher to

dings. Although anaerobic plants may be more capital

intensive because of the methane handling equipment

required for energy recovery, the high loading rates and

swuller tunks require less space,

There is a more stable, larger inventory of attached orga:

nisms. This is one of the most important advantages of

the anaerobic filter. Not only is the snaerobie filter

system more stable, bet this large inventory of attached

ites to be achieved than

are possible lr the contuet process. Also, no clarification

organisms allows higher loading ra

is required; thus capital costs are increased and operation is mode simpler.

Not only is a higher loading rate possible in the anaerobic filter, but higher BOD and COD removals ure achieved, leading to a more highly stebilized effluent.

The fuct that only about 10 percent of the organics re moved from the waste yo to solids is # very important advantnge. Also, the solids appear to be more settleable thon those produced by the contact process since the solids produced in the anaerobie process appear to slough off the filter media in larger pieces. ?The importance of low solids production ean be appreciated by those responsible for aerobic treatment plants because solids disposal fs one of the most difficult problems to solve. Cities like

Philadelphia ond New York "ocean dump" via barges as ho other vieble disposal method available,

Fost "restart" after prolonged "resting" periods. Based fon observation made by Dr. MeCarty and others and con-there

firned in our studies, it is possible to stop "feeding" on anaerobic system completely for months and to restart it in 9 matter of « few hours or days by initiating feed and by bringing the tempersture to the normal operating hunge of the system. A leborotory anserobie unit was

---Page Break---

held dormant at an ambient temperature for six months ond was restarted within matter of a few hours by initiating feed and raising the temperature to ca. 37°C, ?The ability to maintain an anaerobic system dormant for long periods is very important for maintenance and other types of plant shutdown. Aerobie systems cannot be lallowed to become dorment for long periods of time because they will lose their activity and must be restarted fas aerobic bacteria will auto-oxidize if aeration is con tinued oF die from lack of oxygen if aeration is halted.

?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 coniplex 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 slso 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 diffe-rent micro-organisms must be present for efficient waste stebiliza-tion and methenogenesis to occur.

One disadvantage of anserobic versus aerobic treatment can be suggested indirectly. An aerobic system can generally be devel-oped rapidly by seeding with aerobic plant clarifier bottom effluent: fan anserobie system requires months to acclimate and is very slow to develop and stabilize. Sced for anaerobic plont startups must be carefully selected and often must be developed in Inboratory oF pilot

Plant cultures. The fact that methanococcus bacteria divide once every three to five days while aerobic bacteria do so every few

96

---Page Break---

hours elso contributes to the very slow development and stebiliz tion of unacrobic systems. The anaerobic culture used at the Bocurdi plant was developed from fresh cow manure and has accli- tuted to the point that it can withstand large variations in waste characteristics and concentrations and is not affected by hydrogen Sulfide concentrations twice as high as those reported to be fatal.

Until now we have concentreted on the BOD removal or waste stabilization aspects of anaerobic treatment. As we have noted

earlier, the anaerobic process also produces s methane rich gi Which can make a significant contribution to the energy require- Ments of the plant using it. In fuct, 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 vegete-
ble and plant material to an easily handled, transportable end fuel may very well become a significant energy source of the future. Auwerobie processes have not been studied carefully and significant technical xdvances

will be made in the next decade to direct more and nore attention to it as @ potential energy source.

The patented Bacardi Corporporation's anuerobie process was first tested in three pilot scale units. Some of the pilot plant findings have becn incorporated into the full scale plant while others are expected to bo incorporated the second phase of the anaerobic plunt. The seed used to startup the full scale plant was developed in the units which ure used to test modifications and improvenients,

The potential to produce significant amounts of energy was one of the key factors that led Bacardi to select the angerobie 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 removsl, It is obvious that the potential for replacing fuel ofl

---Page Break---

with sicthane will represent a significant savings. Unfortunately, the micry organism population in the first phase of the unaerobic plunt is stil 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 anserobie Slter,

?The process schematic of the enaerobie plant can be summa-Fired quickly. Mesto enters the holding tank and is fed at a con-trolled rate to the unique anacrobie filter nutrients. Then pit control chemicals are added and the mosto is cooled during the transfer to the anaerobic filter, The treatod anaerobic filter effivent will be pumped into a deep ocean outfall for final disposal. The methane rich gos produced is either fed to the boilers, stored in a pressure sphere, or Mared off if it cannot be used or stored.

---Page Break---

HIONASS ~ A POTENTIAL EN!

GY SOURCE FOR JAMAICA

Presented at

UNICA WORKSHCP ON BIOMASS AS AN

EXERGY ALTERNATIVE FOR THE CARIBBEAN

Sun Juan, Puerto Rico

April 26 - 29, 1982

by

Lilieth H. Nelson

Ministry of Mining & Energy

Petroleum Corporation of Jamaica

Kingston, Jomsica,

---Page Break---

JANAICA AND THE WORLD ENERGY SCENE

Since 1973 Jamaica has been spending increasingly larger percentages of export earnings on oil bills, Jamaica paid 18 percent export earnings for oil in 1973 and 48.1 percent in 1979. ?This has contributed te Jamaica's bulonce of payments problems. In 1978 while off contributed approximately 50 percent of the total world energy con

?uniption, Janice depended on imported petroleum for approximately 90 percent of its total energy supply. The other 10 pereent was from bagasse used in the sugar industry (9 percent), and a small anount of hydre power (1 percent). Currently, the suger industry, which wus previously self-sufficient in terms of energy, because it used bagusse for process steam and clectricity.

generat

energy supply.

is depending on petroleum for nearly 45 percent of its

Jonaien has experienced a very high level of per capita energy consumption. Even when the consumption by bauxite/aluminum see- or is exchided, Jamaica per capita consumption levels are higher nan those of other oil-inporting developing countries. While the world average Hbl/eapita is 9.5 fuel ofl equivaent (f.0.c.), that for

?veloped countries is 28.9 f.0.c. und for developing countries is 1.8 f.0.e, Only some cil-exporting developing countries have lower Fer cupitw consumption than Jenaiea, which enjoys about 8 BbI fee. per capita,

Because of the Venezuela/iexico Accord of 1981, Jamaica is importing crude oi! from Niexico and Venetucla and continues to import from Curacao, ?Trinidad and Aruba. While volumes of impor- ted oil have not varied much, there has been « steady

?Tho Curibbean Development Bank sponsored the author's partfefpa- Yon ut the Bionase Workshop.

100

---Page Break---

and overwhelming increase in costs. Thus 16.1x10° Bbls cil impor-

ted into Jameics cost J$44x10° in 1972, $931x10% in 1978 and

481028410" in 1981. Potroleum consumption by sector in 1980 is

retlected in the following table,

TABLE 1

PETROLEUM CONSUMPTION RY SECTOR

vortan (x10? Bois)

Aviation	765	4.92
Bunkers	236	1.52

Bauxite /Aluni num 8234 52.93

Sugar 145 0.93

J.P.st 2681 17.24

Cement 195 1.25

5.0.8¢ 55

Railways 28

Others 3221

"J.P.S. ~ Jamaica Public Service Company (Electricity)

4.0.8. ~ Jamaicn Omnibus Service Company

In 1980 the Jamaica Public Service Company used

2.41x10° Bois fuel 011 and 0.21x10° Bois automotive diese!

oil to produce net electricity generation of 1.27x10° kwh.

km the sane your the sugar factories used 45x10 RbIs fuel

oil to produce 242 x 10° tons of sugar.

---Page Break---

?The above fucts indicate thet the present situation must be changed if Jamsica is to proceed with Its development. This is so 98 there is a close relationship between energy consumption and economic growth. Jumsiea, ke many other countries, can no Jonger base putterns of scientific, technologicel, industrial and economic expansion on the availability of abundant, cheap petro- Teum. The question is, where does Jamaica turn for its energy

IOMASS - A POTENTIAL SOURCE?

The first ettempt which parullels the search for oil and gas is the quuntification of all resources which can provide an alternative to imported petroleus.. Of great importance also is Jamaica's focus op conservation, which can result in « saving of 10 to 15 percent of fuel costs.

Highest priority should be given to the exploration of such

Guantified resources which reflect

lity of cheup technology, especially where the use of local material is possibl

») possibilities for low operational and mointance costs;

©) abundance and "renewability

4) iininum searce skills requirement and maximum use of

technological know-how which olready exists on the

islene or which can form the base for rapid modern

a) availa

" of the resource:

tion oF transference of more efficient techniques;

©) optimization of foreign to local expenditure ratio, so that

the former is kept us low us possible:

1) non-competition for food, especially proteins

6) optimal protection or preservation of terrestrial, aquatic

und atmospheric environment (in benefit ratio).

---Page Break---

Based on the above eritera, the high priority and short term

options for Jumsica tie in exploitation of its smull-seale hydro, blo~

and low-cost solar, wind, urban and industrial waste potential.

In the medium term Jamaice can plan for the best use of its

Proven peat resources, while in the medium to long term the

development of such potentials us OTEC, large-scale hydro, solar

and geothermal resources con te pursued. This, of course,

assumes that the country persists with its avid scareh for off and

gas. However, it must be realized that even if the finding of

commercially viable quantities of ofl becomes a reality, the use of

this potential will still decrease in the medium to long tere

A projection of possible diversification of the energy supply

mix by 1990 is shown below

TABLE 2

PERCENTAGE NATIONAL ENERGY SUPPLY MIX

198008) PROJECTED 1990 (%)

-0

-0 (if feasible)

0

5 (Conservative)

Bagasse =O

Other* : ?0

Hydro 1 ?0

Solart* Minima) °

corre - 3

+ "Estimates - Inc

ides wood and charcoal currently used,

and fuel alcoho!, urban wastes, biogas, ete. projected.

** Includes low and high temperature solar for erop dry-

ing, water heating, electricity generation and cooling.

---Page Break---

The evidence is that at least another % percent of the energy bill could be reduced if focus within the next five years is placed fon development of Jaruica's biv-resource potentiol for energy. Even if she oil bill were to level off over this period, a somewhat optimistic assumption, there would be a few million dollars uvailable fer 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 life styles of the population and the expansion ci industry in the vurul areas.

?There is growing ttention to bio-energy usage in developed countries which: have ft

plenented programs a) to improve productivity of plnts that could be used for fuel, b) to increase effi-Giency with which plant matter can be converted te liguid and Bascous fuels, ond ¢) to develop improve methods of converting sold bio-fuels.

The Ministry of Mining and Energy in Jameica embarked on a program in Murch, 1981, to quantify all the biomass resources on the islond. The project summary, an outline of the framework within wld

fhe survey was conducted, and an abstract of the first report are attached to this paper. (See Appendix)

In August 1961, the status of blomuss utilization ond bio~

conversion technologies existing in Jamaica was assessed. The

most significant users of blows were the rural and tow- income

urban household secter (firewoud and chaveosl) and the sugar

industry (bugasse). AL the end of the first phase of the survey,

there were indies

ms for research and developmental work aimed

at harnessing other biomass resources such as erop and forestry

Tesidues, urbon wastes, agro-industrial wastes and animal manures

for energy.

---Page Break---

14 Units throughout

the island

rural and Urban

Factory,

Field und Faetory

Sites Islandside

Agro-Industries

Urban and Rural

2 Sugar

Foetories tstund-

wide

Other-Crban ane

Rural

Crban avens

Tetundvide

Mostly Coastal

TABLE 3

CURRENT BIOMASS UTILIZATION IN JAMAICA

HEasTOOK

Auiout Nanure

vp Residues,

surpluses:

ody Residues

Tingasse

Food Processing

Ty-Products

Municipal Sotia

oste (Carbon-

bused)

Seomage Sludge

Aquatic Plants

* SIATIS © P= Planning; & = Design; ©

capacity

(anplooy = GuANTITY stamus*

Anwerobie 6 - 7a? Bo

Digestion ore potential = 1-1

?quantified

Vomentation Not avai lable P

Digestion

Direct ?vor 24x108 PD

Canbust ion yearly potential

Casi fication

a

Direet Apprex. 15x10! o

Conbust Lon ?Tons/year

Fermentation Over 8xi0° T/¥r P

Anaerobic Potential

Digestion 5

Direct Conbustion Approx, 3x10" P

?Tons yearly

potential

Annerobie seo! Tver. P

Digestion potential

Digestion NIA P

Conbustion; © = Operation: I = Inactive.

---Page Break---

The move to realize the maximum potential from biomass in Jamales should be accelerated subsequent to the articula- tion of certain policy decisions concerning exploration of bio-resourees in Janaica, relinble technical economic feasibility studies, and valid research ond Gevelopment in converting the wide variety of feed~ stocks availoble or the extraction of fuels from energy crops.

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-preduel

usable for fveds/feods, fertilizers and fibres.

---Page Break---

Works Consulted

Bente, Paul F. = Introduction to THE INTERNATIONAL BIO-ENENGY DIRECTORY, Isio-Energy Council, 1981.

Department of Statistics, Jamaice - STATISTICAL YEARBOOK OF JAMAICA 1979,

Food and Agricultural Organization for UNDP - WOOD FUEL ENERGY STUDY for Janice, 1975.

ivod und Agricultural Grganization - THE FUELWOOK SITUATION DEVELOPING COUNTRIES, 1981, Institute for Industrial Research, Ireland - INVENTORY OF

NATIONAL AND INTERNATIONAL BIOMASS R und D RESEARCH

PROGRAMS, Vols. 1 ane 2, 1981,

Ministry of Atining and nergy, Jamaica - Papers prepared by the

Econonie Planning Divisicn, 1979-1981,

of Mining and Energy, Jamaica - NATIONAL ENERGY

ws,

National Academy of Sciences - METHANE GENEI

HUMAN AND AGHICULTURAL WASTES, 1977.

TION FROM

National Planing Agency ior Govt. of Jamaica - ECONOMIC AND

SOCIAL SURVEY JANAICA 1980,

Nutionat | esearch Council - Supplement, ENERGY FOR RURAL

DEVELOPMENT, USA, 1981

Petroleur: Corporation of Jamaica ~ THE NATIONAL ENERGY

OUTLOOK 19811986, 1981

?own Planning Dept. Ministry of Finance Plora

RATIONAL ATLAS OF JAMAICA, 1971,

United Xetieus Eavirane

SOUKCE

ental Programe - NEW AND

OF ENERGY, ?THE ENVIRONMENTAL DIMENSION, 1981.

107

---Page Break---

APPENDIX. I-A

OUTLINE OF BIO-RESOURCE ACTIVITY

Biomass Survey - Istundwide.

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)

und transportation uel.

Devetopment of a Seenaria of Options

for iomass Utilization for energy in

Samaive

DESoRIPTION

Phase 1 (a) fdentification of Types of Biomass re

Sources in the Island, Location and

uantity of each type? white

?or energy.

Ts avai lable

Phase 1 (b) Optimization of Biomass Conversion Tech-

nology for particular resources identi-

fied, taking into account nature, quan-

tity, tecution and demands of particular

sector. Estimation of present, future

Menands for By-products of Biomass Conversion Technology eg. Feeds, Fertilizers, Fibres and other chemicals.

Phase 11 Planning and execution of experimenta: and developmental (pilot) projects on a small seule to demonstrate effectiveness of the processes and validate them to private snd public sector Institutions in the society.

No previous overall assessment of Biomass sources of energy has been done in domaien. this 18 a necessary prerequi-Site for the formulation of @ range of policy options for harnessing and con= verting particular biomass resources for specitie? fuel ond uses. Such policies, would set the framework within which business ventures proposing to use these resources would he assessed, as well as guide government investment or encourage-

108

---Page Break---

mont support to local private sector in

projects which will use these resources.

?TOTAL ESTIMATED

cost:

Phase 1 = Year I ~ 3$20,000.00

Phase I~ Year Il- J860,000.00

109

---Page Break---

Phase 1 (a)

APPENDIX 1-B

Biomss Quantitification Survey

[_Potentiat for mena |

Residues /Wastes/Surpluses

Agriculture and Silviculture based

on Land Utilization Patteme and

Policy

Aquaculture based on identifiable

indigenous species

fresh

= brackish

= salt

Crop Residues /Surplus

Major Crops

Banana

Sugar

Cocoa

Coffee

Coconut

Pimiento

??+-4]

Tin]. [one roc

anival

= Urban Wastes - Manures/

= Agro-Indus- Sewage

trial Wastes - Refuse

Woody Residues

~ Field

~ Fuetory sites

?4n additional survey was conducted on a smtl sample, in order to verify certain pat-

tems of charcoa! and fuel wood consumption implied? in the results of the Household

Sector Survey in 1979, and to indicate current and future trends in Biomiss. fuel

(Charcoal and fuelwood)

supply/demand patterns.

uo

---Page Break---

Phase 1(b) - Assessment of Conversion Technology available

for converting biomass to energy was carried out

under the following headings

Conversion Processes

? fp

worbieeees MOWICL

; . nen

Digestion Petletization Cenbustion

Fermentution/Concentration Chipping Pyrolysis

Hydrolysis Pulverization Carbonization

Mixing with of) Gasification

Densification

Ligui faction

Synthesis

Based on ~

a»

b> 1

© 41D

® WV)

2»

assessments of the State of the art with respect to the above

processess

location and quantities of specific bio-resources identi fied

assessment of demnd of products and co-products in ench sector

implications for collection, transport and storage of raw materials and

co-products

availability of skills, equipment and miterials to effect or adapt the technology.

A scenario of options for Bio-resource utilization in Jamaica was constructed.

a

---Page Break---

APPENDIX 1-¢

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 islandwide 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

snimal residues ond surpluses as well as other organic wastes

Je and combustible

constitute the largest percentage of ferment

sources of energy in Jamaica,

It is estimated that munure from esttle, pigs and poultry has ?the potential to supply over 800 nillion Kwll per year. Another interesting estimate is that local sewage can supply some 40 milion Kwil per your.

Ih addition, large quantities of crops residues and surpluses in Jamaica, Banana prepared for export for example, hes 0 ejection rate of 70 percent and of that 20 percent is completely wasted. Cocoa pods, pimento residue and coffee husks all amount to quite substantial wastes that could be productively used for fucl. The survey ulso showed that thousands of existing coconut trees, unsuitable for lumber because of thelr decayed condition, could be used for fuel.

exist

---Page Break---

Although there are relatively small quantities of residues from vegetable, root and fruit erops, these could be used in bio-gus digesters as it has been found that the combustion of vegetable and onimal feedstock enhances yields of biogas (in conjunetion with other factors such as optimal temperature and pressure).

Large quantities of woody residues with consideruble fuel potential ure eiso wasted both in the field and at the factory sites. Estimates show ut upward of 1,000 tons of woody residues from factories and workshops are wasted every year.

?The survey also indicated that, as far us charcoal and fuel-Wood consumption is concerned, unless serious attention is paid to @ re-forestation program, the situation will become eritical in a few years time, especially if the nation takes the call to use more

bio-fuels seriously and increases the demand.

Phase J of the survey also involved an assessment of conversion technology available for obtaining energy from biomass.

The processes full under three main headings

@) Microbial Conversion; eg. Fermentation and digestation,

») Thermal Conversion; eg. pyrolysis and gasification and

©) Mechanical Conversion; eg. 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 the society.

ua

---Page Break---

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

---Page Break---

INTRODUCTION

In 1980 the Caribbean Research Institute began @ 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 $.86 gallon and could be used by farmers or coopera~ tives. It was evident that @ larger cooperative could make use of @ continuous fermenter, @ stock-pile and materials, and could add both flexibility and efficiency in using or marketing many of the side products, To develop this idea further, the Institute postulated a hypothetical farm cooperative with sbout $38 million in assets and a desire to get into the biomass fuel/by-products field. The hypo-?thetical cooperative was located on an imaginary Caribbean island that, frankly, was modeled after St. Croix, U.S. Virgin Islands. It had suitable land and shipping, tax incentives, and some indus~trial structure,

?The feedstocks considered were molasses, grain (corn or sorghum), and a combination. Ethanol versus butane! production ?and the use and price of by-products such as carbon dioxide gas (CO,), hydrogen (H,), distillers dry solids (DDS), and chemicals Such as acetone, acetic acid and formaldehyde were also evaluated.

Since 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 feed-back loops. This formed the basis for the model.

ns

---Page Break---

DATA AND RESULTS

A 25 gallon a day alcohol system costing $3,000 and using "free" agricultural wastes (spoiled cattle feed, yams, and cassava) ean produce ethanol for $.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 @ small farmer to got enough waste for 25 gallons of fuel. More than economics and technology are required to make the propost- tion work; stability and diversity must also be present.

ALCOHOL PROPERTIES

The basic properties of the most important alcohols are sum-

marized here. ?The following classes of properties are presented:

Physiochemical properties

Fuel properties

Economics of production

?The physiochemical properties are basic information available {in all chemistry handbooks. ?The tabular form of presentation # lows rapid comparison among the alcohols of different chain Iengths, ?The fuel properties are a mixture of information on heat

content, ignition temperature, and the like, For comparison pur-
Poses, note thnt available information has been presented for iso-
octane (gasoline). The rationsle for isooctane (gasoline) is
obvious since it is @ fuel replaceable partially or totally by
aleohols.

---Page Break---

Ethyl oleonol_(ithanol)

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,
Bencrated by its users. For these rensons and because of the
carly 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 uifference between the boiling points of water and ethanol are 80 great that this has been a traditional method for separating mixtures of the two. Hecause of its "waterlike" polarized chemical charactor, it has a limited solubility in oll or gasoline if any water is present.

The energy value of ethanol is about 73.4 to 84.0 Btu per gallon compared 115 to 124 KBtu per gallon for gasoline. However, the octone ratings are about 99 for ethanol and 90 for gasoline and 8 for ethanol. ?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 ofl must freely reach all parts. The octane and Btu rating is too low for efficient diesel operation. In addition, two eycle motors cannot luse ethanol without complex schemes to add oil, These and other factors make it advisable to look at other alcohols and process

Coproducts. 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 fan animal feed or feed supplement for years. Marketing these co-Products is essential to the economies of ethanol production.

ut

---Page Break---

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

Market for Coproducts. The tota! market includes oilseed, animal protein, and other sill products. As a polnt of reference, a 50-million gation ethanol plant will produce about 177,000 tons of DDG por year, i.c., about 45 percent of the 1976 market for thet commodity. A 600-million-gallon ethanol program, & near-term objective in the United States, will produce almost two million tons of DDG, or about seven percent of the total 1976 feedmarket and

about five times the amount of DDG sold in the United States in

1976. tn the 1963 to 1976 period, the domestic market for all

?nimsl feeds increased at an average rate of about 1.2 percent

annuity. ?The market for soybean meal (with which DDG is more

Uirectly competing) expanded at a rate of about 3.5 percent over

that period. ?This expansion wos not quite sufficient to absorb the

expanded fuel production. Some substitution between DDG and

soybean may take place and, ax a result, some readjustment of

agricultural production patterns will probably take place 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 fuel supplement in dual

arbureted diese! engines.

us

---Page Break---

dots bel be wo? ip) rouooty Aang-aaay,

oxo

soz iat vere Se iBw) ?_taweory ng-081

ots 260'09 iD wD WD 4D

088

? 80460"

ols

? 09-9» Sn

WT 9579 okfo0z)?eeaze wip Counay

68 2610 Towoory AMON.

ru) ymisog aay

rurod ounssoug wwi9%

ela ods, avjmooqaqy .

---Page Break---

1

1

©2000)

1

1

"266

1

(2901/01)

it ec ene cmap os

(otse-)

020° 400° uM uaBOUDAL 44

? = tout Sw ou

Puy

j0g samy

oanssaug 0108 Auraeag aon

todo, Burton __o1y 19044 12521 ~

---Page Break---

Ethanol also is used as a chemical in the perfume and pharma-

ceutical industries. Esch of these potential markets for ethanol

hhas some constraints which bear on the decision making process of

Producing ethanol. Some of these constraints result from the dif-

ferences 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

Flanmability Limits

(Volumen Percent) 1.4 to 7.6 9.3 to 19

1a

---Page Break---

Buty! Alcohols

?The four monchydrie butyl alcohos are: n-butyl alcohol, isobutyl

alcohol, sec-butyl alcohol, and tert-butyl aleohol.

Five methods for the production of n-butyl alcohol are:

2) fermentation, (2) a process based on aldol, (3) the oxo pro-

cess, (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 welght return of 60 percent n-butyl aleohol, 30 percent acetone, ?and 10 percent ethanol, Vacuum removal of the acetone during fermentation muy increase the butanol yleld, as acetone is the main

toxin for the bacteria,

?The aldol process utilizes either ethyl alcohol or acetylene as a Faw material with crotonaldehyde appearing as a chemical interme @iate. The yield in this process is about 8 percent of the theoreteal.

The butane-propane oxidation process is @ Fischer-Tropsch process.

?The Ziegler process was commercially developed by the Conti-ental Oil Company in 1962 for the production of even-numbered carbon aleohol. N-butyl alcohol as @ Cy 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

---Page Break---

production of acetaldehyde using butane or propane as a feedstock. Isobutyl alcohol also is w major component; 74 percent in molasses

4nd 12 to 24 percent in corn, of the aleohols present it tusel oll

resulting from the fermentation procese. Its major use 1s as iso-butyl acetate in the Incquer industry.

To form sec-butyl alcohol, butylene is absorbed by sulfuric acid, forming butyl hydrogen sulfete which is reacted with steam, Its principal use is as chemical intermediate to the production of tmethy! etyl ketone, a solvent. Seebutyl aleohol is also used as a solvent und a coupling agent in hydraukie brake fluids, paint removers and industrial clean

1g 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 sulfurie acid forming isobutyl sulfate which is steamed to form tert-butyl alcohol.

Tert-butyl alcoho! is very miscible with many organie com-
Pounds and becomes useful as a blending agent. Some of the uses of this alcohol are as follows: as o selective solvent ond extraction agent in the drug industry; for the removal of water from com-
Pounds and substances; in the manufacture of perfumes (artificial

musk); in the purification of chemicals by recrystallization; and as 4 chemical intermediate. Tert-butyl aleohol is an authorized dena:

turant for proprietary ethyl alcohol and for specially denatured alcohols.

Whereas all the alcohols mentioned to this point have the same Physical appearance, tert-butyl alcohol has a freezing point close to room temperature and in a pure state often appears in crystelline form,

---Page Break---

?The basic problem with the butanol fermentation is the produe-tion 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 gr solvent/100 gm fermentable sugur). The pro-blem 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 un extrac tive separation while fermenting, thus removing the toxic end pro-duet. However, economics will contro! this possible production from sugar. Therefore, only @ 28 percent improvement is theoretically possible, To uchieve this the Hy produced must be recycled to insure the 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 oll 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 oll but @ mixture of propyl, amyl, and butyl alcohols, Most investigators suggest that it not be re~ covered; rather, savings could be taken by utilizing a two-column distillation system and letting the fusel oils go over in the alcohol product. This may be all right 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 dlesel fuel and wore approved recently by the EPA. However, for industrial or spirits grade aleohol, the fusel oil must be recovered.

Acetic Acid

Acetic acid as such cannot be considered as # liquid fuel but is an important chemical building block in organie synthesis. The

two major uses for it are as vynil acetate (latex paints, plastics and

---Page Break---

adhesives), and acetic enhydride (cellulose acetate, esters

vents).

Total acetic acid production in the USA was around 3.0 billion

Pounds in 1974, representing sbout 0 percent of total world pro-

duction.

?Table 3 summarizes and Figure 1 pictures the different proces-

ses presently used for its production. Note the following points:

(1) Practically all acetic acid is produced from petroleum.

(2) 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. Besides, 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.

In Figure 2 the various alternatives for acetic acid production

from biomass are illustrated. There are two distinet possibilities:

(2) Biological process (fermentation)

(2) Thermochemical conversions (pyrolysis)

---Page Break---

---Page Break---

08 sprig

WN 66-08 oe swe-sut

ste rast

uN a6 00". osz-ore

sr opog

any, 36 o 99

ues 86 ost ogi-ser

oor mse

ors osoumap osmyd

Pinbrt puarsina (@

oo ara

ae wor (ar wreppD

801m 19 aemud

Pinbyy ouing-u (#

assure

VS) HL NI SSOM doy OLN WIRED

ea uML

---Page Break---

ECONOMY OF ALCOHOL PRODUCTION

Table 4 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 MARKEY ?CURRENT PRICE/

PRICE 10% Bru

Methanol 38-49 J gallon $5.99 - 7.72

Ethanol $1.04 - 1.14 gallon $12.29 - 19.47

n-Propy! Alcohol $1.87/gation $16.98

Isopropy! Alcohol 63 - 70 /galion $6.93 - 7.70

n-Buty! Alcohol $1.25 - 1,69/gallon $11.95 ~ 15.18

Isobuty! Alcoho! $1.27 ~ 1,67/gallon $10/42 - 14.39

See-Butyl Alcohol $1.43/gollon $13.72

?Tert-butyl Alcohol $1.75/gallon $17.34

---Page Break---

TABLE 5

BASE RAW MATELIAL AND BY-PRODUCT PRICES IN 1980 DOLLARS

Raw Material

corn

Grain Sorghum

Wheat

Potatoes

Sugar beets

Beet molasses

Staren

By-pro

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

s20/r

sa0/t

$.36/ ga

$.08/1b

siz0/7

s120/7

siz0/T

so/T

sees

sisit

∘

$3./100¢

$5./1008

---Page Break---

?vad :90snog

pue owwiog /T

vy oat 6 oo 1s 809

rmpzoyan mea 39N,

zo ° 9 0" ww se" st roumne 1e/§

nays ot vonpoad

aoreToAIND

° wyoet sopad yonpoud- fe

oer a" 3809

repsopan wea 1TH

0 ues navoe's aye rouge 1a ioraTenRe

08" woe rayos'2 nayas'e sao 1100, aopad

verso ye ng

sosswray wang sie0qSoommeg 189 unggzog use) smn wi

sing um, urna)

SSIVTION o86T NE As9D VRE ANE aN

9 ara,

? ? +. . .

---Page Break---

By-Produet

?The possible by-products from these processes are numerous, Possibilities include CO, or Hy, animal feed, lignin, fuel credit solids, pentoses (zoylose), furfural, and fusel oil,

The CO, is produced in quantities of roughly one pound per Pound of ethanol in a relatively pure by-product stream. At the resent time, there is no industriat use for this CO, in the volume it would be manufactured. Poesible future uses include industrial gases, dry ice, carbonation of beer or drinks, and as a supplement to increase green house production

Of alt the by-products, the animal feed derived from the dried Gistillers 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 possibiility of extracting the solids in order to recover @ high quality of human protein. In the short term the use of the solids for animal feed is the most realistic as this is current practice and needs no testing. If alcohol fuel were to become a serious proposition, over 100 plants of Greater than 25,000,000 gallon capacity each would be required. ?Such @ capacity could yield 2 - 5 million tons of high protein animal feed per yeor, This would be a significant by-product, andr

Search is needed to establish its economic feasibility.

The unfermented solids consist largely of lignin materials. Hignin has nearly twice the energy content of cellulose and hemi-cellulose. Present technology envisions burning the solids for fuel value in the process. Research is warranted on ways to convert the lignin to liquid fuels or chemical feedstock; aleohol solubilized lignin, fractionation of lignin to yield a polymer grade material, end conversion of lignin to pheholies are a possibitites..

a1

---Page Break---

by-Produet Prices

A distillers drieu grein base price of $110 per ton for corn, sorghum, and wheat distillers dried grain was used for the esti-mate. ?This price was based on the average prices for corn distil-Jers dried grains ut Cincinnati whieh ranged trom $89.56 to $139.22 er ton and averaged $110 per ton in terms of 1977 dollars over the period. Typically, distillers dried grain at Cincinnati trades in the range of 60-85 percent of soybean meal (44 percent protein) at

Decatur. Distillers dried grains have # total protein content of about 27 percent which makes then @ substitute high protein feed for certein livestock, principally beef and dairy cattle.

?The following distillers dried grain price forecasting equation has been estimated by Wisner and Gider (1977) 1/:DDG =

3,8825 - 0.022227 (DDG) + 0.265566 (SIM,) + 0.168753 (C,) + 0.518049

x)

3.21) aa2.81) (2.92) «a.98)

where:

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

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

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

G, = Gom price in cents per busher

BG, = Cattle numbers in five major Furopean protein feed inporting countries

7 Wisner, KER- and 4.0. Gidel, "Econamic Aspects of Using Grain

Alcohol as a Motor Fuel, With, With Emphasis on By-product Feed Morkets." Iowa State University, Eeonamie Report Series No. 9, ?Appendix. IV, Tune TOT, Moonee Report Series No. 8

?This equation indicated an clastic demand for distillers dried grains; & 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) cor prices, and 8) cattle numbers in five major Euro

---Page Break---

ean 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 « significant proportion of total high protein feeds available, then the demand price relationship would bocome price inelastic: a large percentage price decrease would be required to clear the market. Under such conditions by-product credits to net cthanol 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.

---Page Break---

SVEA/SAVU DCE (A) 000°000"07) NIFENOS JSEINS NWO NDLIONEDRE TOMINT SUCRE

LER.

---Page Break---

188/$_ 3800 soorspoag

188/§) "1809 wor ranpoad

anons

NIV WOU ONVHIA ONION YM SOMONE ESV LS

8 HM,

---Page Break---

Sweet Sorghum or Sugar Cane Juice

The alcoholic fermented products from cane juices are immediu-

tely associated with rum. In tropical countries rum has either

Dlackstrap molasses (left over trom sucrose crystallization) or

virgin syrup (concentrated sugar cane clarified juice) as its raw material.

More recently, ane 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 lused cane juices as the fermentation raw materiel

In these factories part of the sugar mills have been converted into rum production facilities. From the practical point of view this situation has worked well under very specific market condi-tions

however, it has a drawback because what is optimum for sugar crystallization or for rum manufacture is not necessary optimum for ethanol fuel.

Here is the method used to process cane. Clean sugar cane Stalks from the field are cut and the juice extracted in a standard roller milling unit. The juice is treated with chemicals, precipitate, and the supernatent is filtered in rotary vacuum filters. The clarified juice is sent to the evaporators where it is

solids

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 efter 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

---Page Break---

wash, separated yeast can be recycled to the fermentor in order to inereuse ethanol productivity. A 95 percent (w/v) ethanol product is produced by straight rectification/distillation and absolute ethanol by areotropic distillation.

Stillage, filter muds, and wash waters and fuel oil are wastes, Yeust is a byproduct. The bagasse from the milling operations is burned to provide the total power requirements for the operation. Hence, the facility Is energy selfsufficient. Moreover,

spent electricity 1s usually available.

Sweet Sorghum

For a long time it has been known thet some varicties 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 (4978) made 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, suger crops may have a three way potential.

Although sweet sorghum has an enormous potential, this erop has not been studied cither 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 eventually could be ?added to corn to be converted into soluble sugars by enzymatic or acid hydrolysis and then to ethanol by anaeroble yeast fermentation. Alternatively, the stalk could be processed by employing new technologies like the Tilby separator or the Ex-Ferm process.

---Page Break---

In any event, sweet sorghur: needs to be processed in con-Juction with another crop, either sugar cane or corn. In this capscity crop harvesting and availability could be extended, storage problems minimized and operation days of the alcoho: plant increased.

Aleoho! from Molasses

?The process using molasses is typical of those materials in which the carboliydrate is initially in the form of sugar. The molasses used is generally bluckstrap molasses, a byproduct of Sugor sunufacture. In making sugur, the juice squeezed from the Sugar cane is concentrated and sugar is crystallized. After two or three batches of sugar crystals are obtained, the impurites in the

?mother liquor are so concentrated that further sugar crystallization is impracticel. ?This remaining mother liquor is blackstrap molas~ ses. Another important materiel is invert or high test molasses. This is produced by adding dilute acid to sugar cane juice, inver~ ing 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. Saccherine materials used in minor anounts include pineapple waste, sorghum cane, citrus waste concentrate, waste from fruit canneries, pineapple juice and corn sugar syrup. The molasses process is essentially @ 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 I1) in the United States until the early 1960's when the

138

---Page Break---

Preliminary calculations suggest thet a piant designed to consume epproximately as much stock as would produce 25 x 10° gallons per yerr (82,500 tons per year) of ethanol would require 1.1 x 10° bushels of grain per year, and would produce 6750 tons of nixed 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 u total investment of approximately $20 x 10°, and the cost of production would be about $0.65 x $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 thet produced by conventional petrochemical means, For example, present production in the U.S. of these solvents is given in the following table slong with 1978 prices.

TABLE 9

PRICES OF SOLVENTS *

Price

Sikg si S/gat

n-butanol 046 0.2n 0.95

acetone ost 0.17 0.90

ethanol (958) ost oar 0.86

Based upon current prices, the price of the mixed solvent

produced by fermentation should be $0.43 per kilogram, which

?compared to the estimated costs by fermentation greater than $0.60

+~ 0.70, The following tables give additional information:

---Page Break---

ove" tat

ovz's

009° 96

sum 09

Burky nr90y ?opsyepLy

wos ywiuautag 9 Buy%00

Surrpum spy

NIV® (WHT ORVILLE JO NOLLONODAKE JHE OT SONVIVT ADRES TVIMSOONE CHIVALEST

or aw

---Page Break---

002" ev 08't02

BurAug ures ionpoug-kt

?uoH ayua0U0D prnbry

?Buy ipa ae TTS»

oro uautag,

suoyiwaedarg *Buryoop *Burpuys

?Huysseooag Sure *Z

Sumureg ?1

tr idinsuay ABI

?aNMU 496 JO NDTIVD Ga ALT

wo Jo rousng 404 tounyy

29K Taq Shaq

9K sag [ou (4 aun

fu SUOT TAD OE

got X oF

AIMALIS YATTHROS ~ NOOO WOAH TOWWHIS JO NDLIQNOOR SEAL YD SONWIVT ADEE

1 avs,

---Page Break---

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

2, 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 CO, are evolved with the ethanol (a weight ep- Proximately 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 take the CO, off separately from the ethanol. Second, the yeast alcohol fermentation operates best at 3037°C. At this temperature @ vacuum of one Ib./sq. in, would be required to boi {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 bacte- rum, Clostridium thermocetlum, is being studied that will produce aleohol 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 succeds, then vacuum fermentation may be an important technology.

---Page Break---

REVIEW OF SOLAK DISTILLATION

In ora

to save energy as fuel in distillation of ethanol-water nuxtures, solar energy could be considered applicable.

Solar distillation hes been used mainly to obtain potable water from sea water, the process being actually ar evaporation unit operation. The solar cnergy collectors employed have been of many varied but simple designs without costly energy concentroting devi-

The average valucs of water evaporated have been in the order of 0.10 gal/sq ft/day. With this figure and assuning heat effects of the same order of megnitude, the distillation columns of ethanol 50,000 gallons per day factory would need reboilers of around five million square feet of surface. This type of application in not then recommended for what has been commonly known as solar distillation or sea water 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 «

distributed system. Both collect and concentrate direct sunlight to

heat © working fluid, which could be water, steam or oil. The

feeling at this point is that solar heating for industry unit oper-

ations like distillation is viable yet not economical. Current costs

fare two and one-half times that of the systems they would replace.

However, collectors costs can not come down until they are mass

produced.

as

---Page Break---

6.

10.

nL

a2,

13,

* Fatories-(rg6zy??

REFERENCES

Stark, W.H., "Alecholic Fermentation of Grain" in Indust
Fermentation, Underkofler and Hickey, eds., Volume Ts Chose
ter 2, 1950.

_ + "The Production of Industrial Aleohot
By Fermentation", in Industrial Micobiology, S.C. Prescott and
C.G, Dunn, Chapter 4, New York, MeGraw-Hill Book Co.,
Ine. | 1959.

Hiodge, H-M. and F.M, Hildebrandt, "Alcohol Fermentation of

Molasses" in Industrial? Fermentation, Underkofler and Hickey,
eds., Volume T, Chapter 3, 1080,

Ethyl Alcohol, New York, Enjey Lebo-

Arnold, L.K. and L.A. Kremer, "Corn As A Raw Material for
Ethyl ?Alconoi?, lows ?Engr. Expt, Sta. Bull. 167. 48 (42),

Mareh 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).

Schelier, W.A. and B.J. Mohr, "Production of Ethanol and Veg:
etable Protein by Grain? Fermentation", presented at 169th New
tional Meeting ?American Chemical Society, Division of Fuel
Chemistry, Philadelphia, Pa., April 9, 1978.

In Lipinsky, E.8. et al., Sugar Crops as a Source of Fuel
Volume It: ' Processing? and-Goiversion Weseurehe rel
Ye Department of Hiesey Agus TOTES
Lipinsky, E.8. et ala, Sugar Crops as _A Source of Fuels
Volume ti: Processing snd? Conversion? Rasearehe Titel Peso
Te Dopartaient of Energy. AUpUSE AT TOT

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 Etha-

nol 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 Ferment

tion of Grain",? presented at International Symposium on

us

---Page Break---

Aleohol Fuel Technology-Methanol and Methanol and Ethenol,

Wolfsburg, Ger., November 21-23, 1977,

14, Scheller, W.A., ?Energy Requirements for Grain Alcohol Pro-

duction", presented at Symposium on Economies of Fermentation

Processes, American Chemical Society Meeting, Miami Beach, FLA., September 10-15, 1978,

15, Mappel, J. and D.C. Jordon, Chemical Process Economies, New

York,? Marcel Dekker, Ine.," 1675.

16, Peters, Si.8. and K.D. Timmerhaus, Plant Design and Econo-

nics for ?Chemical ?Engineers, New York, ?MeCPaw-Hll- Book

11, Kespert 1.G., 8B,

Sadek, and D. Wise "An Economie Analysis

of Fuel Gas "Production from Solid Waste", Resource Recovery and Conservation 1:95 (1975).

18. Horsely,, L.H., "Azetropic Data III", Adv. Chem. Series 116: 15 (as73)

19. Othmer, D.F., Azetropic and Extractive Distillation", in Kirk Other? Encyclopedia of Chemical Technology, 2nd. ed., Volume 1, pp. BOP C1863)

20. Katzer, R. ot al

3,990, 952 (1976):

"Alcohol Distillation Process", U.S. Patent

21. Katzen, R. et al.,

patent 3,449,345 (1968).

US.

22, Weizmann, Ch. et al., "Studies in Selective Extraction and Ad~ sorption.? TI. The Adsorption of Acetone, Butyl Alcohol and 2:3, Butylene ?Glycol from Dilute Solutions,", J. Soc. Chem

Ing. 67:225 (1948)

23, Nature 271: 12 (1978),

24, Remalingham, A. and R.K. Finn, "The Vacuferm Process: A

New Approach to Fermentation Aleohol", Biotech, Bioengr. 19

583 (as77).

25. Cysewski, G.R. and C.R. Wilke, "Rapid Ethanol Fermentation,

Using Vacuum and Celi Recycle", Biotech/Bioengr.19: 1125

art)

26. » "Solar Energy Gets Up Steam for Chemicals".

?Chem, Week: ?37, February 7. 1

---Page Break---

Report on

Biomass as an Energy Alternative for the Caribbean,

Workshop

Sen Juan, Puerto Rico

April 28-29, 191

UNICA Commission on Science and Technology

---Page Break---

BIOMASS AS AN ENERGY ALTERNATIVE

FOR THE CARIBBEAN WORKSHOP

SUMMARY REPORT

It is the opinion of the UNICA Selence and Technology Commission that the April 28-29, 1982 San Juan Workshop on Biomass as an Energy Alternative for the Caribbean was a greater success than the first Workshop on Wind because of many cizcumstances. Some of the ?most favorable conditions were the familiarity of the UNICA contact Persons among themselves and with the project, which stimulated direct interest in their involvement and commitment to its success. Also the workshop followed the Fuels and Feedstocks for Tropical

Biomass I Seminar which provided the UNICA contact persons unique opportunity to become acquainted with the subject.

Again, following the formet of the Wind Workshop, the group was seperated in three working sessions: Education and Training Needs, Research and Development Needs, and Demonstration Needs.

It may be gathered from the recommendations that biomass is perceived rs one of the energy alternatives for the Caribbean which could be utilized faster based on the agricultural experience and Knowhow of the region. Consequently, a generalization of the recommendations can be formulated as follows:

(Q) Securing funding to establish research, development and Gemonstration projects of specific nature in the region on bio~ mass as an energy source should have the highest priority.

(2) In order to implement the above recommendation, educstion and training programs to prepare the human resources needed

{in tropical biomass for the region are « must.

---Page Break---

(3) UNICA should play a vital role in technology information,

disseminsting, R&D projects evaluation and technology transfes between their member institutions.

(4) ?The UNICA Foundation role of securing funds for imple~ mentation the above is essential and indispensable to carry out ?such programs.

If the sbove recommendations are implemented the science end engineering capabilities of UNICA member institutions in biomass matters would be greatly enhenced. Also, the role of the universities and research institutes as providers of solutions to society Problems would be strengthened.

The UNICA Science and Technology Commission wishes to thank all the UNICA contect persons for their participation in their workshops end in particular the moderators of the session who drafted the workshop reports. Also, we are deeply grateful for the funding Support from the National Science Foundation, Exxon Education Foundation and the UNICA Foundation.

---Page Break---

FOR THE CARIBBEAN WORKSHOP

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

WORKSHOP SESSION, GROUP NO. 1

EDUCATION AND TRAINING NEEDS

Report by

Dr. R.L. Sullivan, Moderator

General

Participants in the Education and Training Workshop session included:

Dr. Jairo Lascarro (University of Puerto Rico)

Eng. Gerardo Manan Peniagua (INTEC, Dominican Republic)

Mrs. Lourdes Iturralde (Universidad Simén Bolivar, Venezuela)

Mr. William Chalmers (Caribbean Development Bank, Barbados)

Dr. Glenda 8. O'Brien (University of the West Indies, Jamaica)

Mr. Gerald Lalor (University of the West Indies, Jamafca)

Dr. R.L. Sullivan (University of Florida, USA)

Recommendations

(@) UNICA should decentratize the work of the Commissions into technology working groups and increase the number of contact people.

(2) To fund the increased activity stemming from the new structure UNICA should actively seek new additional funding for @ three

year budget.

(8) Each working group should be encouraged to submit budgeted

---Page Break---

Proposals to the appropriate Commission to fund specific acti-vities e.g., workshops, continuing education programs, etc.

(4) Each working group should establish communications and data collection procedures.

(5) UNICA should fund exchange programs among Caribbean uni-versities as 4 means for improving the transfer of new tech nology knowledge in the region.

(6) UNICA should sponsor a special workshop on education with em=

phasis on university curriculum development and communication

techniques aimed at improving the region?

various new technology options.

awareness of the

(1) Each working group should publish an edited volume deseribing,

the state of the art of its specific technology for each country

in the region.

(8) Each working group should be responsible for promoting its

specific area of concern within the Commission,

(8) Video cassettes should be made for each technology to promote

fits development and use among teachers and public officials.

---Page Break---

BIOMASS AS AN ENERGY ALTERNATIVE

FOR THE CARIBBEAN ?WORKSHOP

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

WORKSHOP SESSION, GROUP NO. 2

RESEARCH AND DEVELOPMENT NEEDS

Report by

Dr. Al Binger, Moderator

General

It is the general view of the working group that there is a Ereat need for collaboration and exchange of technological know-how between member institutions. It is felt that UNICA must address {itself to the development of a mechanism to allow for such transfer. It is also commonly felt that there exists in the region various technologies which are needed in other countries.

The efficiency of UNICA members is being affected by:

(21) Imadequacies in the procurement and dissemination of in-formation

(2) Obstack

tutions.

Preventing collaboration between regional insti-

UNICA could be an efficient organization in the development and Propagation of science and technology in the region if it could overcome some of these problems.

Research and Development

These are short term recommendations aimed at stimulating Gevelopmental work for various UNICA members and at addressing

certain problems which some members are presently having.

---Page Break---

We interrelate our project goals in energy with those for the Protection of the environment and construct our project proposal in order to take advantage of all funding which exists in other areas such as environment protection, agriculture, etc. Attempts should be made to have joint projects developed whenever possible, realizing that projects must be specific nature for the sites involved. One of the main potentials seoms to be for the utilization of cocoa and coffee waste in generating biomass. We should recognize that duplication can be both good and bad. However, duplication should result in nore efficient use of funds.

Wherever possible UNICA should speed up the distribution of funds coming into the region for RaD and whenever time allows before importing foreign technology we ask UNICA personnel if such technology had been previously tested in the region and with what Fesult. Projects aimed at utilizing biomass as chemical feedstocks should be given priority. The orientation of such projects is more technologically and financially demanding but they ere potentially more feasible. It is therefore recommended that all such projects be

undertaken in collaboration,

The UNICA representative in euch 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 this service for cost-benefit analysis so as to deduce the benefit of project. In developmental work, all pertinent data from the region should be supplied so as to allow analysis for site and regionol applicability and potential. That U.S. AID policies in the region should be evaluated to see how they promote:

(@) regional collaboration

(>) developing expertise within the region

---Page Break---

As there is a present funding shortage, it is suggested that UNICA solicit funds in an effort to act as » source of interim financing for collaboration projects with regional application.

Closer working contacts should be maintained with research and velopment institutions in the region us these institutions usually have more funds, personnel and equipment to assist the development fal phase of projects. UNICA would therefore seek funding for the actual development of collaboration of regional projects.

We accept the offer of collaboration from French Overseas Uni versity Progranis offered by Professor J. Renaux of AUPELF. UNICA should make representation to funding agencies for funds to aid in organizing this information service and to provide the required training to allow the transfer of technology from this source to the countries where it can be utilized,

Until an intormation machinery is in place for the dissemination of information, person-to-person communication should be vnder-taken. Since the existing questionnaire is viewed as being difficult to comply with, it is suggested that each person supply his present project with his immediate needs for information and funding in order that UNICA Secretariat can provide whatever short term assistance it

UNICA should include in its current publications @ section on research projects stating: institution, persons, projects in progress and current status, projects in planning, projects i tions are secking collaboration, funding availability and requests for assistance from members. This will allows UNICA contact per-sons to be aware of funding availability for research and distribute this information to people whom they think can benefit from this.

whi

institu

UNICA should consider providing the following:

(@) information update

---Page Break---

(1) the ongoing R&D projects in energy within the region

(2) the requirements of our individual institutions from UNICA

(8) proposed methods which UNICA will employ to nieet these needs.

In addressing the first question we realized that such infor~ mation was extremely limited and the steps instituted by UNICA in the past by means of survey had not had the anticipated results, As a@ short term solution it was proposed that some time before the conclusion of this session all persons actively involved give @ brief report on whot they are pursuing and state whether they are inter ested in any form of collaboration.

?The second requirement was for education, In institutions where technology is developed for the masses (e.g, charcoal pro- ject) in association with R&D we recommend that UNICA's know-how be provided to inform bureaucrats and potential users as to the Need, ns well as the operational techniques, for that technology.

The social factors involvea in giving new technology to our people cannot be overlooked.

In order to meet these needs we proposed that UNICA consider the establishment of a program for educating bureaucrats, and then 4an associated demonstration programme for the populous in the need and utilization of such technology.

Our second recommendation for UNICA, which is in the unique situation to identify and assess regional needs with regards to socio-economic parameters and then solieit the funds and award these fon the basis of competitive grants for institutions or a combination of institutions to achieve these needs, is that such activities be done in collaboration with other bodies in the region which share UNICA's concern for technological development in the region.

---Page Break---

It is recommended 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.

---Page Break---

BIOMASS AS AN ENERGY ALTERNATIVE

POR THE CARIBBEAN? WORKSHOP

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

WORKSHOP SESSION, GROUP NO, 3

DEMONSTRATION NEEDS

Report by

Dr. Modesto Iriarte and Mr, Salvador Lugo

Moderators

Goneral

?This workshop was attended by a small group (six persons) re-Presenting Guyana, St. Lucia, Jamaica, Netherlands Antilles end Puerto Rico.

At the outset the group decided to establish the following eri-teria for the selection of demonstration projects: (1) availability of biomass on @ commercial scale; (2) this biomass would be in un existing commercial activity; (3) the projects would be of such nature that they could be done elsewhere in the Caribbean (tech-nology transfer); (4) projects should be culturslly acceptable to the region und the countries involved,

With this criteria in mind, a discussion was held of the various biomass related activities being carried out in each of the regional fareas mentioned. Various projects with a potential for developing into "demonstration" stage were discussed. Several were identified ?96 needing further RAD, others were ruled out because enough com-mercialization has already been developed or because they were not within the general interest of the majority.

While sifting the options, the countries borne in mind in terms of biomass potential were Guyana, Jumaica, St. Vincent, Haiti,

---Page Break---

Dominican Republic, Venezuela und Colombia. There could be others.

Only one demonstration project was identified and discussed at length for implementation. Discussions and 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 and hendling ond use offers advantages even over Liquid fuels. The suggested project could start with a conference workshop sponsored by the University of Guyana and producing pyrolitic gas from the management of the forest industry. The gasifier has been developed by a German firm.

The conference at Guyana would include # 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 in the

Gevelopment of this project. The task force could proceed as

follows: (a) make an initial assessment of the process, the logistics

and management, and outline » plan based on a selected site;

() prepare a proposal for securing funding from private and

government agencies; (c) implement the proposal when funding is

secured.

Other Projects Discussed

GQ) Direct burning of biomass was discussed. ft was concluded

that for small capacity boilers there is a long history of commercial

---Page Break---

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-

as. This project was discussed and it was concluded that it is

feasible but that there is not now too strong an incentive in

developing a demonstration project.

(3) Sea weeds as a source of biomass. This was discarded because

it requires R&D before a demonstration unit can be attempted.

(4) Need of data bank in biomass for the Caribbean. ?This wus dis~

cussed and it was concluded that UNICA has a seperate project on

this,

(5) The need to determine:

(@) Bio-fuel consumption in the Caribbean

() Charcoal uses

(e) Fire wood uses

?This can help in identifying further demonstration projects.

Other Recommendation,

For consideration ot 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 biogos from the expansion of pork and poultry Production, In Dominica explore possible use of wastes from coconut users and from food processing.

---Page Break---

LIST OF PARTICIPANTS

1. Mir, Quitvio Cabral

INTEC (Instituto Tecnolégico de Santo Domingo)

Avenida de los Préceres, Gali

Santo Domingo, Republica Dominicana

Tel: 567-9271

2, Dr. Howard Harrenstien

University of Miami

Coral Gables

Florida, 39124

Tel: (305) 284-3301

3. Mr. R, Sullivan

University of Florida

Gainesville, Florida "$2611

Tel: (904) 992-4961

4. Mr. A. Derek Fairclough

Scientific Research Council

P.O. Box 350, Kingston 6

Jamaica, West? Indies

Tel: 092-4777-1

Mr. Anthony Francis

Caribbean Development Bank

clo Ministry of Finance and Planning

Castries, St. Lucia

Tel: 2611 Ext. 215

Dr. Patrick St. Louis

Caribbean Development Bank

W.1., Barbados

7. Mr. RB. King

Tate & Lyle Ent. Inc.

2121 Ponce de Ledn Blvd.

Coral Gables, FLA. 33124

Tel: (805) 448-2845,

Mr. John Kadyszewski

AID

1617 Cole Biva.

Golden, Colorado 80401

Tel: (303) 231-7009,

9. Ms. Lilieth Nelson

Caribbean Development Bank

Ministry of Mining and Energy

2 St. Luela Avenue

Kingston, Jamalen

Tel: (926) 9170 to 6

---Page Break---

List of Participants

10. Mr. 3. Renoux

?AUPELE

173. B.S! Germain

7506 Paris, Frances

Tel: 2229838

1. Dr. Al Binger

Scientific Research Co.

Kingston, Jamaica

Tel: (809) 927=4471-4

12, Mr. Aubert Parfait

INRA

INRA Petit Bour

Guadeloupe

Tel: 852040

18, Mr. LM. Szendrey

Bacardi Corp.

GPO Box 3549

San Juan, P.R. 00936

Tel: (808) 795-1560

14, Mr. Kerby F. Fannin

Institute of Gas Technology

5424 S. State St.

Chicago, IL 60616

Tel: (312) 867-3941

15. Mr. Homero de Poo!

Instituto de Estudios Superiores

?Ave. México

Santo Domingo

Tel: 688-0159

16, Mr. M.3. Canoy

College of VI

St. Thomas.

Tel: 774-8200

11. Mr. Sixto Wout

University of the Netherlands

Jan Noorduynweg 11 Antilles

Curacao

Tel: 84422

18. Mr. Carlos F. Dierolf

Universidad del Valie

Apartado Aéreo 2188

Cali, Colombia

Tel:? 393041 Ext. 137

161

---Page Break---

List of Participants

19, Mr, Luis F. Sanz

Universidad de los Andes

Calle 189A Cra 1E

Bogotd

Tel: 2849911 x210

20. Mr. Marcelo Laproa-Bigott

Universidad de Oriente

Pto. La Cruz, Venezuela 6023-A

Tel: (081) 665743,

21. Bir, Alexis Jacques Edouard

Universited Etat d'l Haitf

32, Rue BonnoFol, P-au-P

?Tel: 2-4592, 2-8310

22, Mr, A.M.B. Sankies

University of Guyane

P.O. Box 10 1110

Georgetown, Guyana

Tel: 54841 (Work)

69066 (Home)

23. Mr. Gerardo Maflan Pani

INTEC, Los Jardines, Galé

Tel: 67-9271

24. Dr. Glenda So'Brien

University of West Indies

St. Augustine, Trinidad

?Tel: 662-5511, Ext. 4

25. Mrs. Lourdes Iturralde de Ande

Universidad Simén Bolivar

Venezuela

Tel: 9621101 al 09

26. Dr. Jairo Lascarro

Depto. Ingenierfa Mecénica

University of Puerto Rico

Mayaguez Campus

Mayaguez, Puerto Rico 00708

Tel: (808) 832-4040 Ext. 2366

21, Mr. Francisco J. Gutierrez

Universidad Central de Venezuela

Ciudad Universitaria - Caracas

Venezuela

---Page Break---

List of Participants

28. Mr. Gerald Lalor

University of the West Indies

Senate House, Kingston 7

Jamaica

Tel: (809) 927-0762

29. Dr. Eloy Pérraga V.

Rector - Presidente

Universidad Rafael Urdaneta

Maracaibo, Venezuela

Tel: T1619

30. Dr. Miguel Fazaneli

RUA Marones de Itt 58

Seo Paulo SP

Brazil, CEP 01223

31. Mr. William Ocasio

CEER

.parra Heights Station

San Juan, Puerto Rico

Tel: (808) 767-0350,

32. Dr. Juan A. Bonnet, Jr.

Director, CEER

Ceparra Heights Sta

San Juan, P.R.

Tel: (809) 7

0350

33. Dr. George Pytlinski

Head, Solar Division

CEER

Mayaguez, Puerto Rico

?Yel: » (608) 832-1480,

34. Dr. Donald Sasecer

Head, Energy Section

CEER

Mayaguez, Puerto Rico

35. Eng. Pedro Sarkis

CEER

Caparra Heights Station

San Juan, Puerto Rico

Tel: (808) 767-0321,

36, Dr. Thomas Mathews

Instituto Estudios del Caribe

Universidad de Puerto Rico

Rio Piedras, Puerto Rico

Tel: 764-0600

---Page Break---

a,

38,

39.

40,

a.

a.

4a

?a

45.

46.

Dr. Modesto Iriarte

CEER

Ceparra Heights Station

San Juan, Puerto Rico

?Tel: (809) 767-0358

Mr, Salvador Lugo

CEER

Caparrn Heights Station

jan Juan, Puerto Rico

Tel: (809) 767-0321

Dr. Angel Lépex

Solar Divisi

Mayaguez, Puerto Rico

CER

Tel: (809) 832-1480

Mr. Gary Martin

Fom

GPO Box 2380

San Juan, Puerto Rico 00936

Tel: (803) 763-0820

Mr. John Zebrowski

CHER

Caparra Heights Station

San Juan, Puerto Rico 00995

Tel: (609) 767-0338

Mr. Lewis Smith

CEER

Caparra Heights Station

San Juan, Puerto Rico 00995

Tel: (808) 767-0938

Mr. Luis C. Sarmiento

Col. Regional de la Montafia

Box 1499)

Utuado, Puerto Rico 00761

Tel: (809) 894-2828

Mr. William Eilers

Agency for International Development

Washington, D.C.

Mr. Chalmers

Caribbean Development Bank

Eng. H.M.C. Kaspers

University of Netherland Antilles

---Page Break---

47. Mr. Renato Nunez

Universidad Catélica Madre y Maestra

jantiago, Rep. Dominicana

48. Sir. Andrés Salient

Universidad Nacional Pedro Henriquez Urefia

Santo Domingo, Rep. Dominicana

49. Mr. Peter Earle

Institute of Gas Technology

Chicago, 11.

---Page Break---

---Page Break---