# CEER-B-065

BIOMASS: AN ALTERNATIVE ENERGY SOURCE

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AES-UPR and CEER-UPR Bionass Energy Progras

Presented to the

CUARTO CONGRESO DE !NVESTIGACION CTENTIFICA

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Contributed By

?The UPR Center for Energy and Environment Research

Rio Piedras, Puerto Rico

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BIOMASS: AN ALTERNATIVE ENERGY SOURCE

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ABSTRACT

Bionass is organic matter in which solar energy has been stored in the forms of fiber and fernentable solids. In this context plant materials are viewed as solar energy collectors in which photosynthesis is the decisive process for conversing sunlight to usable energy forme. Although not very effictest, plants are the only form of solar collector that has ever worked at any appreciable level of magnitude, with any appreciable economy, for ny appreciable period of tise.

As renewable energy sources terrestrial plants are grouped into two categories: Voody (trees and other perennial foras) and herbaceous (prinarily anmual piants). Mesbers of both groups can be managed as cfop plants, and each grour has numerous wild species that produce bionass without the aid of san. ?Whatever the species, the energy content of this biomass will be about, 7500 BTUs per oven-dry pound. There are many ways of recovering this energy. ?The two most imediately practical recovery methods are direct conbuation (or electrical power production) and fermentation to alcohol (for motor fuels and chenical feedstocks).

Bionass energy production as an agricultural commodity or a salable Forest product requires land and water resources in addition to a warm growing season and suitable species. Puerto Aico is blessed with a year-round growing Season and adequate sunlight for both woody and herbaceous plant foras, but land and water are Limited. 4 very careful analysis of land-use potentials

Is needed to arrive at the correct trade-offs between food and energy crops in a small island urgeatly in need of both commodities.

Puerto Rico's outstanding biomass resource today is sugarcane and related tropical grasses. These plants make optinal use of the vam climate in producing both fiber and fermentable solids on a year-round basis. Puerto Rico"s historical experience in producing cane, raw sugar, and molasses spans four centuries. More than at any time in Puerto Rico's past, sugarcane is needed foday as @ boiler fuel and a source of fermentation substrates for alcohol. Sugarcane molasses is also needed with mounting urgency to meet the denands of Puerto Rico's rum industry. Current and past research by CEER-UPR on bionass energy production is outlined in this presentation.

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BIOMASS: AN ALTERNATIVE ENERGY SOURCE

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## INTRODUCTION

## BIOMASS IN PERSPECTIVE

Bionass is solar energy stored in the conveniently manageable foras

of plane tissues (cellulose, hemicellulose, Lignin) and fermentable solids

(sugars and starches.? In its fresh or ?green? state it can be converted

anaerobically

methane (1). When sufficie

y dried it can be burned

Airectly aa a boiler fuel or it can be conpacted and stored for later conbus-

tion (2). With suitable technology it can be converted to Liquid fuels,

seseous fuels, oF a broad range of chenfcal feedstocks (3,4,5,6). There is

strong evidence that dried ané powdered biomass can be fired directly in the

existing of1-burning power plants of electrical utilities (7).

Literally thousands of land plant species?both herbaceous and voody?

are potential energy sources. They are both a renevable and a donestic resource.

For nations blessed with @ tropical climate such species can be managed on 4

year-round basis as agricultural or forest commodities, In this context a

whole range of enploynent opportunities is opened for both skilled technicians

and an unskilled Labor force. An oven-dry short ton of biomass represents

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about 15 x 10° Bits of stored energy. The direct incineration of one such ton, in a stoker furnace with high-pressure boiler having a 70 percent conversion efficiency, would displace about two barrels of residual fuel ofl.

Sone species also produce sugars and polyglucosides in sufficient quantities fo justify extraction and sales as fermentation substrates. Alcohols produced from bionass fermentable solids have a groving denand in the motor fuel and

uv

chenical feedstock markets, not to mention alcoholic beverages !/ still other

species store energy in the nore highly-reduced forn of nature) hydrocarbons (8,9).

TERRESTRIAL FORMS OF BIOMASS

Onty © snali fraction of the earth's lasd plants have been examined closely 5 potential energy-supplying connodities. Woody species used as fuel over thousands of years vere sainly a gift of nature. fven in modern times forest

species management has been primitive by agronomic st.

és and directed to

conventional tinber and wood products rather than fuels and feedstocks. A

slightly larger number of herbaceous species have been studied as domestic

?Acong the latter are tropical grass species of

» Sorghum,

and Rennisetue which were recognized for their high yields of fiber

and fermentable solids Long before the petroteu

ceabargo of 1973. However,

there is good reason to believe that woody plants once fully developed could

supply greater quantities of energy than crops such as sugarcane. Tadeed, the

R&D emphasis of the US Fuels From Biomass program has been heavily slanced

toward silviculture in recent years.

A/ For exanple, Puerto Rico's rum industry consumes about 40 a{llion gallons
of molasses each year, more than double the nolasses output of the island's
sugareane industry.

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A majority of terrestrial plants have never beon cultivated for food, fiber
for fuel (10,11). In warm elizates wild grasses such as Sorghum halepense

(Gobnson grass), Arundo donax (Japanese cane), and species are border

abu

jes where occasional use has been nade of their high productivity of dry

hatter. In cooler climates, self-seeding herbaceous plants such as reed canary

Brass, cattail, wild oats, and orchard grass may be vieved with mixed feeling

by landowners unable to cultivate more valuable food or forage crops. 5}

such as ragveed, redroot pigveed, and lanbsquarters are recognized for their

Persistent growth habits while otherwise regarded as common pests. Nonetheless

the fuel value of such species is rising dranatically as fossil energy foras

becone increasingly costly.

Evaluating the long-term energy potential of silviculture (forest) species

Ae a more tine-consuning task (12-16). Most of our information on wood produc

tion relates to wild forests or extremely narginal cultural managenent regines.

Moreover, conventional tinber and wood products continue to command a more

we

tive market than fuels and feedstocks, even with today's rapidly-escalating energy values, Mood conversion to fuels is essentially confined to lover-quality species, forest residues, and residues from conventional tinber harvest and milling operations. However, two concepts are gaining acceptance as means of capitalizing on forest energy potentials: (a) Woody species sust be renoved from the purely wild state and "nanage: a8 crop plants, ie, in forest ?energy plantation: and (b), maximum yields can be obtained through coppicing (Frequent Tecutting of shoots from established stumps), Both concepts are under investiga~ tion on the US mainland (12,13,14,15) and in Puerto Rico (16).

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PUERTO RICO"S BIOMASS RESOURCES

Fornost anong the Island's plant rescurces are sugarcane (S:

harum spp.)

and related tropical grasses. First as the "noble" canes (3. of ficinarum selections)

and later as interspecific Saccharum hybrids, sugarcane has been planted here for over 400 years (17, chap. 1). The highest recorded yield was 36.4 oven-dry

tons/acre year (about 105 green tons) obtained in 1979 (2). Wild Saccharua

species ($. spontaneun, $. sinens

are presently found on the Island

robust

bot all are post-Cotumbian imports (18). Other cultivate! tropical grasses

?include sveet sorghun (Sorghus vulgare), napier grass (Peanisecun purpureum),

ané "Sordan? (a sveet sorghum x Sudan grass hybric). The latter yield lower

tomnages than sugarcane but produce excep

Sonal growth for short periods of tine.

Several wild tropical grasses are also being studied as biomass resources. Johnson grass (Sorghun halepense) originally developed as a cattle forage and imported for this purpose, "escaped" on the Island and is widely regarded as a

Noxious weed by local farmers. Banboo cane (also "Japanese cane") growing wild

fon the semi-arid south coast, is an Arundo species formerly used in the produc~

tion of wind instruments.

2. Moody Planes

Puerto Rico's forest or silviculture species also have large biomass

Potentials; hovever, chese potentials have never been defined in an ?energy

plantation" context where total dry matter (cellulose, henicellulose, Lignin)

is the prefereneial product. Data gathered by the USDA Institute of Tropical

Forestry in Rfo Piedras have related mainly to quality wood products and tinber from minimum tillage operations (19,720,271). Hence, the production of silvicul~

coral biomass

a renewable energy source offers a new and significant challenge

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for Puerto Rico's forest industry. In this context woody species would serve

98 4 partial substitute for imported fossil fuels (valued at $1.20 billion in

1978) rather than a substitute for imported timber (valued at $0.25 billion ia

1978). Anong the most promising forest genera having larze bionass potential

in Puerto Rico are Eucalyptus, Cassia, Albizia, Leucsena, Casuarina, Syzygium,

and Pinus (29,20,21) .

Areas least suited to biomass production are the non-irrigable zones of

the Island's semi-arid south coast. Even here, species of the Euphorbiaceae and

families appear to have important potential as sources of plant

Asclepiadac

hhyérocarbons. In all, sone 65 species from ten fanilies have been identified

45 potentia! hydrocarbon-bearing plants for Puerto Rico (22).

Mininus Tillage Biomass

One ether group of plants deserves mention as a biomass energy resource for

Puerto Rico. These are the ?low tilt" species whose inportance stens not from

their high ylelés but rather fron their ability to produce sone biomass under

Barginal conditions unsuited to conventional agriculture. Members of thie group

tend to cross conventional taxonomic and ecological boundries. A common

characteristic is that they propagate solely in the wild, or are agricultural selections sufficiently close to the wild state that no special care fron nan is

needed for survival, They are usually self-seeding and often have specialized

features such as long tap roots or an ability to fix

rogen, oF anatomical

features designed to conserve moisture or to resist extrene tenperatures and natural enemies. Typical exanples in teuperate cliates include ragueed, rede Foot pigveed, tansy, ragwort, lanbsquarters, cattail, and reed canary grass. Examples in Puerto Rico include such herbaceous species as wild sugarcanes

(S. spontaneus), napier grass, and Jobnson grass, and voody plants such a:

Albizia, Leucaena, and Calotropis.

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In sone cases mininun tillage may include a low level of agriculture where seedbed preparation and one or two irrigations are provided to aid species establishment. At the other extrene no tillage of any form is ever given aside from such operations as are needed to prevent plant takeover of a given property. A good example of this is found in Puerto Rico's autopista and coad right-of-ways where wild plants are periodically cut back a8 a part of nomal highway main-tenance and beautification. The cut materials are ordinarily left on the road= side or trucked to the nearest sunicipal dunp. The author estimates that about 2200 acres are thus occupied in autopista borders and dividers alone. With an average anqual yield of four oven-dry tons per acre, the discarded material would represent soxe 12,000 barrels of fuel oi, worth about $530,000 at this writing (Feb., 1980). This conservatively represents less than ene percent of the wild bionass refuse that at some future date could be trucked to a bionass-fueled

incinerator for the production of electrical power.

[BIOMASS AS AX AGRICULTURAL CossfoDiTY

¢ Considerations

Under suitable circumstances a case can be made for biomass energy planting

fas an agricultural commodity in sost of the earth's croplands traditionally planted

in food and fiber conmoditis

Bur to obtain the maxinun biomass yield possible

fon a per annus basis two factors are needed: (a) A climate sufficiently warn to

sustain plant growth throughout the year, and (b), available plant species capable

of continuous growth throughout the year. Hoth factors are unattainable in all

regions of the US mainland, Each 4:

happily present in Puerto Rico and most

other tropical areas of the world.

In addition to warm tonperatures there is an obvious need for soil, water,

fond Light resources to sustain plant growth. None of thee is quite so limiting

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for plant growth as temperature, especially minimum night temperature, Even in Puerto Rico the "Winter" grovth of sugarcane stackens to less than 20 percent of the summer growth rates (2). An example of a very good biomass yield in temperate climate conditions is the 10-12 dry tons/acre of cattail (Iygha spp.) obtained by Pratt and Andrevs (23) in Minnesots. This yield was produced in the

?-nonth interval June through September. Exper

ental sugarcane in Puerto Rico
hhas produced over 36 dry tons/acre year (2). This is roughly equal co what northern

cattail would yield if it grew continuously throughout the year.

## Botanical Considerations

Tt is generally recognized that both woody and herbaceous species have charecteristic yield potentials for bionass. However, for economical production, the energy planter must give careful attention to his crop's growth and saturation Profile, This profile is particularly inportant for herbaceous species such as sugarcane and other tropical grasses. For such plants a miscalculation of

harvest date by as Little as two weeks can defeat the grower's best intentions.

A given specie's growth and saturation profile can be plotted as an S-shaped curve (Figure 1). Typically, the early-juvenite plant will experience a relatively ong period of tissue expansion, followed by a short period of tissue maturation, ?The plant's visual size increases markedly during the expansion phase, but Little

dry matter is sccunslated and in fact these tissues consist mainly of water. The

ation phase involves little outward change in plant size but dry matter increases drastically (Figure 1). For the energy planter this dry satter is his Principal salable product. le aust resist the tentation to harvest his crop

when growth has appeared to cease, for by vaiting just a little longer his yields Bight be increased several fold, and without connitting any additional production

inputs.

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While the S-configuration is characteristic of aost grovth profiles, the magnitude of this profile will vary enormously anone species over a time course of one year (Figure 2). Hence it is necessary to categorize available species in accordance with the time interval neeéed to naxinize biomass yield. As illustrated by Figure 2, a ?short rotation? species such as Sordan 704 will naxinize its dry matter yield within about 10 weeks after seeding. This is an excellent energy crop for tropical regions where a given site is available for energy cropping only 10 or 12 vecks (as for exauple between the harvest of one food crop and the planting of another food crop). If a longer tine-frane is available for energy cropping. say 4 to § months, a superior species would be rapier grass or sone other "intermediate rotation" plant chat maxinizes dry natter yielé sonevhat later than Sordan 708. If a full year fs available neither Soréan 70A nor napier grass vould be sown. Im this instance the eneray planter would turn to sugarcane or sone other ?Long-rotation? species whose finest yield attributes are expressed a year or more after seeding (Figure 2).

[As described above, the concept of tailoring crop selection to the correct maturation profile is alnost an over simplification. Yet, it is a botany-oriented concept not readily grasped by non-botanists or others unfaniliar with the principals of energy planting. A persistent error by authors evaluating biomass potentials for the United States is on assumption thet biomass enerey planting is essentially comparable to planting conventional food and forage crops. Hence, workers in Florida (24) still recomend that sugarcane be harvested

several times per annun; similarly, in a recent testimonial (25), it wae recom mended that sugarcane yields be increased with varieties suited to two harvests

per year. While such programs are based on good intentions, they

re contrary

vo the botanical capabilities of sugarcane and inpose unnecessary constraints

on the energy planter.

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3. Production Costs and Energy Balances

?The ?energy plantation? concept for biomass production has received wide

spread attention since the mid 1970"

Cost figures for energy plantation

operations are, at this tine, mainly projections based on conventional agricul

tural operations, Baseline data for sugar crop management for energy have been

Bathered since 1975 (5), but these also are heavily reliant on figures supplied by the cane sugar industry. Meaningful production cost dara for herbaceous

Plants a8 a whole may require several decades of research by Literally hundreds

of contractors. Baseline cost data for silviculture species has also been Published in Limited quantity (15). Many years will be needed to compile produc tion costs for the world?s forest species sanaged as energy crops.

Production costs for sugarcane managed for energy in Puerto Rico are fairly well known, oving largely to production research sponsored here first by ERDA ant tater by the DOE Fuels From Bionass Systens Branch (2). Because of the ?esphasis given to energy products (boiler fuel snd molasses) rather than sucrose the term ?energy cane" has been adopted by the CEER-UPR bionass energy program.

Preliminary cost analyses for energy cane production vere performed in 1979,

on the basis of firet-ratoon yields from three varieties planted at two row ?spacings (Table 1). These figures pertain to a family-owned, 200 acre operation yielding 33 oven-dry tons of biomass per acre year. The nost expensive equipment itens (a whole-cane harvester and low-bed truck) would be hived from the FR Sugar Corporation together with the equipment operators. In an energy cane industry such items would probably be family oxned?in which case

ne operation and main~

Fenance costs would be appreciably lover. Both water and fertilizer charges are

conservative; actual data showed then to be lower in the ecological zone vhere

baseline data were gathered. Total costs, including delivery to the milling

Site, anount to $25.46 per oven-dry ton, or about $1.70 per eillion BTUs. By

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way of reference, Puorto Rico is presently paying about $4.30 per eillfon BTUs

in che form of residval fuel ofl.

In an energy cane scenario about 6% percent of this dry matter would be burned as boiler fuel. The remainder would be extracted as fermentable solide during the cane devatering process and later sold as constituents of high-test molasses. The fermentable solids from one acre of energy cane (ie, with a yield of 33 dry tons/acre year) would be valued at around $1,800 if marketed today as high-test molasses. The PR rum industey is the logical first buyer of this byproduct since run is one of the island's Leading sources of revenue.

Donestic molasses is also in extrenely short supply. Although Puerto Rico was

fone of the world's major exporters of molasses in 1934 (76), she had declined

to an 88z dependency on foreign suppliers in 1979 (25).

A preliminary net energy balance was performed on PR energy cane in

Jansary, 1980 (27). The energy balance is of decisive importance to all

candidate species for bionass production, since an appreciably greater amount of energy must be recovered from the crop than that expended in its production ?and processing. Authors vary considerably in their derivations of a net energy balance oving in part to the difficulty in selecting and defining the paraneters used in their respective models (28). Zeiners (29), for example, divided the energy content (higher heating value) of dry harvested material per acre by ?energy input per acre. The output/input ratio ranged from 3.3/1 for Hissours, corn to 10.7/1 for South Dakota alfalfa, By equal treatment PR energy cane has an output/input ratio of 8.2/1 (27) ! A core neaningtul energy balance is the ratio of usable stean recovered per acre to the energy expended per acre. By this standard the output/input ratio for PR energy cane is 6.2/1 27).

A/ Assuning that the extractable solids (about 640 pounds per dry ton) are Fenoved during the devatering process and are not credited to boiler fuel,

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Period of

Tissue Maturation

Day MATTER (4)

Period OF

?Tissue Expansion

ACE oF SPECIES

FIOURE 1. A schenstic representation of he maturation profile of Plant apecies. Wich the visibie growth phase (Cioove expe sentially covpleted, the energy plaster will gain such wore dy satter by alloving a brief addicional tine {aterval to elap DSefore harvest!

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DRY METER (29

8

Sugarcane

?apier Crass

16 30 30 « 30

AGE OF SPECTES (WEEKS)

FIGURE 2. Relative saturation profiles for Sordan TOA, narier

?and sugarcane over a tine-course of one year. The

Representative of the short, intermediate-y anti

cropping categories, respectively.

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TABLE 1. Dry utter Production Costs tor Firat-Ratoon Sugarcane Managed

as an Energy crop 1/

Land Area? 200 Acres

Production taterval! 12 Months

DH Yield" 33 (Oven-Dry) Shore Tons/Acres Total 6600 Tons

Prelininary Cost Analyse

teen coat ($/¥ean

A. Land Rental, at $0.00/Acre 10,000

2. Seeddod Preparation, at 15.00/Acre 3,000

3. Warer (800 Acre Feet at 15,00/£e) 12,000

?ater Application, at 48.00/Aere Yeas 9,600

5. Seed (For Plant Crop Plus Tue Ratoon Crops),

V Ton/aere Year at 15.00/t99 3,000

6. Fertilizer, at 180.00/Aere 36,000

7. Pesticides, at 26.50/Acre 3,300

8. Marvase, Tacluding Zquipnent charges,

?Teulpment Depreciation, And Laser 20,000

9. Day Labor, 1 Man Year (2018 hrs at 3,00/ne) 2/ 6,048

10, Cultivation, at 5.00/Aere 1,000

11, Land Preparation 6 taintenance (Pre-é Post-Harvest) 600

Delivery, at 7,00/Ton/20 Méles of faut 46,200

13, Subeoest: 152,766

14, Managenent: 10% of Subtotal 15,275

15. Total Coot: 168,023

AJ DOE contract no. DE-AS05-76E120071.

2 Labor vhich Is not included in other costa

Total Cost/Ton: (168,023 + 6600): 25.46

Total Cost Million BTie: (25.46 -+ 15)! 1.70

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