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PLARNING AND INETIAL ACTIVITIES FOR THE UTILIZATION OF

RENEKABLE ENERGY SOURCES

IN THE SOUTHERN UNITED STATES, PUERTO RICO AND THE VIRGIN TSLAKDS

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Juan A, Bonnet, Je. and G. Barry Graves

ABSTRACT

This paper presents a sumary of goals, planning, and initial

Program activities aimed at achieving the 20% solar energy goal in the

southern region. Special attention is then given to Puerto Rico and

the Virgin Islands where heavy dependence on inported oil and high en-

Fay costs pose a real threat to social, economic, and governmental

stability. The point is made that Puerto Rico oil imports represent a

very significant portion of the total eil isporte for the entire southe

fern region. An asses:

went of renevable energy choices ia then presented

for these Caribbean territories, vith attention to the potential for

OTEC, biomass, photovoltaics, wind, and solar thermal technology. The

seneral conclusion is drawn that pranpt action in developing altera.

tive energy sources is essential fron the standpoint of both the Carib-

bean island communities and the United States which should have a strong

interest in the long term well-being of the entire Caribbean region.

The ase

venent for Puerto Rico is based on a comprehensive

energy analysis prepared by the Center for Energy and Environment Re~

Search of the University of Puerto Rico.

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PLANING AND INTTIAL ACTIVITIES FOR THE UTILIZATION oF

RENEWABLE ENERGY SOURCES

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Juan A, Bonnet, Je. and G. Barry Graves

EXTRODUCTION

Planning efforts for the utilization of renevable energy technologies in the U.S. Caribbean are being undertaken both by Puerto Rico ang the Virgin Islands, as vell as the Southern Solar Energy Center.

?This paper reviews sone of the planning activities concerning the SSEC Fegion and discussion will ensue regarding the situation in Puerto Rico ?and the Virgin Islands, drawing upon work done by the Center for Energy and Environment Research of the University of Puerto Rico. Limited observations are also included concerning other portions of the Caribbean. ?The general conclusion is dram that proapt action in developing alternative energy sources is essential fro the standpoint of both the Coribbean island comunities and che U.S. Planning and programmatic activities must reflect both the unique prioriti

diverse island communities.

and constraints of the

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gional centers operated for the U.S. Departuent of Energy.

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The Southern Solar Energy Center is one of four regional. or-

Banizations responsible for helping te accelerate the practical appli-

cation of solar and related conservation techniques, In planning the

initial activities of the Center, considerable attention has been given

to examination of goals whi

fight be achieved through the use of vari-

ous types of renewable energy sources. One objective of this effort

has been to obtain a perspective of the problem and to have a basis for

Program planning and for measuring progress. This is certainly a begin=

?Ring point which must be continueusly reexamined as technical develop~

ments take place and other factors influence the proce:

?The southern region consists of the 16 southern states, the

The

stateside area extends through Texas and Oklahows, and includes Arkan-

Sas, Kentucky, West Virginia, Virginia, Maryland, Delaware, and those

District of Columbia, Puerto Rico, and the U.S. Virgin Islands.

es Lying to the south of this line. With the availability of «

Feasonable base of data on the continental portion of the region, it

was pos

the SPURR model (Reference 1) which was developed for the Enerny

Department by the MITRE Corporation.

ible to

ike analyses through the use of computer models such

Consideration of the situation in Puerto Rico and the Virgin Islands is a sonevhat separate matter, Island planning is éifferent

than stateside planning because of the special characteristics of ts land communities. Also, in the

se of the U.S. Caribbean Islands, there may, in the future, be very important reasons for comparing their ?energy situation with other countries in the Caribbean. We mention the ?importance of this because of the natural Linkages throughout the Ca ribbean and the fact that the econosic and social development of the entire a

is important and interrelated. With the extensive back- ground analysis that has been done by the CER, energy data and systens studies for Puerto Rico were available. Also, the Energy Office of the Virgin Islands has contributed significantly to the understanding of the special problens of the Caribbean area.

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GOALS AND INITIAL PLANNING ASSESSMEatTS

Initial analyses indicate that the southern region's avail~ ability of resources, favorable economics, and relatively high growth rates may enable it to provide alsost 40% of the national goal of 18.5 quads! from renewables by the year 2000. Table 1 shows the contribu tion by census region projected by the year 2000, Tt should be noted that, in this estimate, 7.5 Quads of renewable energy are projected

for the region, This table does not include the energy element repre

mnted by Puerto Rico and the Vicgin Islands. While the azounts of energy are not large by comparison, it will be seen later that the eco- nomics of the Caribbean Island:

energy dileema are extrenely serious

Table 11 is an estimate of the breakdown by technology area and user sector. Biomass is expected to be a large contributor because of the very significant forest and agricultural resources in the region, with approximately 1.22 Quads now being utilized. This, of course,

primarily in the form of wood combustion by the pulp and paper indus try, One observation that can be made fron Table IT is that every

major technology element is expected to make a contribution, including additional hydroelectric generation (with low head applications). We Fecognize that the timing for the various technologies is very depen dent upon progress in current research and development efforts. Thus, fone can expect the mix to change with time. However, this type of

analysi

?8 helps place the problem in perspective and is needed to examine Just what is required to obtain the needed impact.

Table TIT is an estimate of the types of action vhich must

Yone quad equals 10'5 srv or 180 million barrels oil equivalent.

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ceeur in the future if we are co make a reasonable transition to re nevable resources as a part of our long term energy strategy. This table simply indicates the numbers of installations which are required based on present concepts of aystems for individual residences, con sercial applications, and industrial use. This is the result from one of the modeling efforts and is helpful in understanding the scope of the task. Of course, for this or some equivalent mix of renewable use to take place, the technology must be available, the economics must bbe sound, and the regulatory and institutional situation must encourage

the actions to happen. If you will think carefully about past major

transitions in our society, you vill recognize that changes such as these normally require a very long time span. Thus, a concerted ef- fort by both government and the private sector will be necessary to achieve an effective transition in the limited time which is actually available.

Te should be noted chat the actual implementation of renevable energy systems on the scale indicated by Table ITT vill require signi~ Ficane amounts of capital. Various estimates of the capital required for meeting a national goal of 20% fall in the range of 700 bslion to one trillion dollars. This vould be a significant part of the private investment capital available during the period and could be on the order of 15% of the total. For the south, the capital requirements could be approximately 350 billion. This, of course, is only an estimates how- ever, it does provide another method of placing the matter in perspec tive. It also helps one realize that the risk must be reasonable, and that the private sector can be expected to be properly cautious shout fechnical performance and the resulting economic benefits as compared to other energy options.

With che initial estimates as show in Tables II and IIL, further study was undertaken to develop a viable approach for the near tera, An examination wae made of the following key factors:

Current technical status

?Ultimate potential impact

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Economic viability

?Status of the industry

Knowledge and current acceptance by users.

With the current situation, as generally recognized by those

presently vorking in the field, this resulted in targeting near-term

Programs within the region in the folloving approximate order of priority:

Passive designs for buildings

Active systens with enphasis on solar hot water for

domestic and comercial applications

3. Bionass applications with enphasis on wood combustion

and gasification techniques

4. Industrial process heat applications

5. Small wind systens

It should be recognized, hovever, that these near-term prior-

ities are weighted tovard comercial readiness which is now concentrated

in the buildings market. Such technologies as ocean thermal energy

conversion (OTEC), large wind turbines, high temperature solar thereal,

and photovoltaics may hold even greater future promise for displacing

conventional energy sources if and when technical and cost goals are

by ongoing research programs

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PASSIVE DESIGNS FOR SUILDINGS AS_AN EXAMPLE

To provide insight into the initial progran activities being under- taken in the region, Let us consider the matter of passive designs for buildings. With reference to Table IIT, it is estimated that a total of 3,600,000 passive applications are needed by the year 2000, with an interim goal of 100,000 by 1985. One rationale for achieving these goals is illustrated in Figure 1, A multiplier, or branching effect, is used to influence the building industry. We assume that for every direct faction taken by SSEC, such as design participation and technical assis~ Fance, some nusber of additional projects will be undertaken by builders ?who becone convinced of the feasibility of passive design concepts and Proceed on their om. The multiplier used in this instance is five. As depicted in Figure 1, SSEC will be directly involved in the design, construction and monitoring of a small number of passive houses per year. By focusing this direct assistance tovard larger builders of both conven tional and sanufactured residences, supported by heavy education and design tool ats

jenination, it is anticipated that exponential grovth ia both the supply and demand sector will result.

It is important to recognize that the process is tenuous and that

early progr

is absolutely essential if there is to be a reasonable

impact by 1985 and a total of 3,600,000 passive applications (primarily residential housing units in thie example) by the year 2000. Accompli- ?hing this goal requires a wide range of efforts, including:

= The development of a range of proven and marketable passive designs

to meet the various climatic needs of the region. For example, @ minimum of 120 basic designs are needed to illustrate the options

Wilable for residential and light comercial construction in the

widely different geographic areas which are involved.

~ Interaction with a large number of design professional

?and governments] organizations in an effective manner, such a:

individuals,

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General contractors and developers (For example, a

Ay 660 firms account for 20% of the new construction in the region).

Desiim professionals, including the 15,400 architects and over 1000 mechanical designers. Also, over 25 architectural schools and 900 vocational-technical institutions in the region

should becone involved.

3. Abroad range of financial, real estate, insurance and code officials. For example, there are over 2,100 key financial institutions, 615 insurance companies, 1,400 key code officials, ?and thousands of real estate organizations which need a better understanding of what can ba achieved through passive design.

As a first tej

include open inspection periods for professionals and the public in a

SSEC has initiated passive buildings projects which

wide number of locations. Sound progross is being mde in getting the best available design tools assenbled and in the hands of the user commu= sity, Figure 2 shows the initial project activities throughout the Fegion. A number of structures are now being completed and activity is underway or iminent at all of the locations which are shown. You will easily recognize the need to properly treat the different clinate and other site-specific requirements over this area.

As a somewhat separate means of evaluating the program pleaning strategy, one can examine the number of building starts which are projec ted for the region and ask what the impact might be from this perspective For example, industry estimates indicate that betueen 7.0 and 7.4 million housing units

ire Likely to be constructed in the region during the next decade. If a large number of these housing units can be built with good Passive features, then the results will be very significant. With an optimistic view of reaching one-half of these units by 1990, the energy savings would be, at a minimus,the equivalent of 27 million barrels of of annualy. Of equal, or perhaps greater, importance to the occupants Would be the savings in costs for heating and cooling.

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ACTIVE SYSTEMS, BIOWASS, INDUSTRIAL, PROCESS NEAT, WIND AND PHOTOVOLTATCS

In the previous section, the application of Passive Design Technology vas used to illustrate the basic planning approach and the rationale used to establish plans for meeting long-term goals. Similar steps have been taken for the rensining technology areas vhere action is now feasible, The following discussion is intended to provide a brief overview of the initial program activities with comments on gone of the practical reali-

land challenges which are evident.

Active Systems for Buildings:

?As is generally recognized today, the application of solar techniques

for water heating in domestic and commercial applications is techoically and economically feasible. Figure 3 presents the estinated economics of Using solar domestic hot vater systens in the southern region. It should be noted that the key factors which influence the economics are the federal

and state tax credits and the utility rates. In fact, it is the relative

dy high urility cates of 9.3 and 12.1 cents per Kuh in Puerto Rico and the

Virgin Islands, respectively, which create the favorable econoaies for solar in these locations.

As an initial step, the SSEC progran efforts were concentrated in Florida and North Carolina because of the favorable economics, the market size and the existence of welt

veloped industry infrastructures in these states at the time. With the recent passage of the tax credit in Oklahoma,

this state has become one of those with the most favorable economics,

SSEC progran efforts have been primarily associated with marketing assis:

tance and promotional activities to

id industry, make the public avare of the potential, and help encourage reasonable consumer assurance and

Protec tion steps by industry and by the normal agencies which deal with consumers. As an exanple, a series of avareness campaigns has been udertaken in Florida, They were conducted with the cooperation of the state

encies and the Florida Solar Energy Center.

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Figure 4 sunmarizes the key program activities which have been under- taken to date. With regard to the media-type promotional cempaigas, it should be noted that upwards of 9.0 million msilers were distributed in ?cooperation vith other organizations such as utilities, and over 10,000 radio and TV public service announcements vere included. With the evolu tion of the industry base, it is recognized that a continuing sound working relationship with industry ig needed. The SSEC role is that of « catalyst, leaving the marketplace to work with saximun freedom,

With regard to donestic solar hot water systems, it is important to Rote that there is need for industry to continue its efforts to achieve high performance systens and to lover costs wherever feasible. With the advent of dedicated heat pumps Co produce domestic hot water, this is especially important. From the preliminary data available, dedicated heat Pumps appear to offer a coefficient of performance (or COP, defined as the ratio of the energy delivered to the energy supplied by electrical input) of 2.0 or greater at moderate cost. Thus, if solar systens are higher in cost, they must offer a higher COP to be competitive.

OF course, service lifetime and projected energy cost increase also

high performance solar designs,
Possibly with reduced costs, appear to be needed for the future,

enter into the picture. Nevertheles

Biomass, including combustion, gasification, and other proce:

Such as microbial or enzyne techniques to produce fuels, is one of the ?most important energy sources available ia the region. Today, wood combustion and gasification techniques are economically competitive in

44 wide range of industrial, comercial, and even utility applications

Other agricultural products, including sugarcane, napier and sordan

Brasses in the case of Puerto Rico, are equally important sources of

energy.

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?The initial activities within the region include the following:

= A cooperative effort with a state forestry commission and TVA to

evaluate pilot wood yard supply methods.

= A general supply system assessment in Virginia as a pilot state,

= A pilot effort with an "assistance tean" working with potential

industrial users in North Carolin

= An in-depth case study for a typical brick mnufacturing operation

in South Carolina.

~ Technical

ized

ristance in the development of @ moderate:

downdraft gasifier to operate a stationary diesel generating

unit for a municipal utility.

~ General information activities to encourage the use of wood waste

4 combustion fuel.

In order to recognize the potential for wood as an energy source, fone factor to consider is the amount of wood waste that is now disposed

of at an economic cost within the region. Figure 5 indicates the results of one estimate (Reference 2). It is very important to recognize that this is but a small fraction of the wood materials that are potentially available for use. For example, in the case of Virginia, Figure 5 indicates that the total amount of waste that is disposed of by lumber finishing plants and other similar users is 1.4 million dry cons each year.

This waste , which aust be deliberately disposed of, has the energy equi-

valence of 3 million barrels of ofl. Reasonably conservative estimates

indicate that there is easily the potential in the state to use cull wood,

other res:

lues, and the stock associated with sound forest managenent to

Produce as much ss 26 million tons. This is equivalent to over 60 aillion

barrels of oil.

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In the state of Georgia, an asse:

ment made by the state Forestry

Commission indicates that if only one-fourth of the logging waste,

?excess grovth (10 million cords annually), and cull trees are used for energy, they could replace 42.5 million barrels of of1 annually.

So there is little question regarding the potential; however, the matter is still not simple, Land and forest omership is diverse, the Fequired harvesting methods are vel! understood but not widely practiced, the user is not neces

wily convinced that the supply systen is viable, ?and the wood combustion and gasification equipment is not a faniliar

item to many users, Even with favorable economics, considerable effort

vill apparently be necded to encourage industries and utilities to convert to wood as a fuel source. The benefits are very real. As a matter of interest, the comparative equivalent fuel costs in the Richmond, Virsinia area in June 1980 vere as follows, with the cost referenced to an equivalent barrel of oil:

oa $35.00/B01,

Natural Ges ($3.42 Mot) 17.90

Coal ($45.00 delivered) 9:90

Palpwood ($35.00 cord) 23.

Dry Waste ($20.00 ton) 133

Moist Sawdust ($10.00 ton) 5:50

Im addition to wood, agricultural products and vastes have significant Potential. Combustion {s often the best process at hand. However, ra! tively simple updraft gasifiers can be used to supply lov Btu gas for many existing users with relatively simple modifications. Domdraft gasifiers offer good potential for the operation of fixed diesel plants, but careful attention is needed to gas clean-up techniques and other aspects of each specific application.

Industrial Process Heat

As an initial effort within the region, a Linited nunber of applications case studies have been initiated in industries which utilize

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relatively large anounts of moderate-temperature process heat. Wherever Possible, applications which are representative of a continuous process are looked at first since costly storage subsystens can be avoided. Efforts are presently restricted to the food processing and textile ?industries. A total of 17 case studies are in process, with the current work focused in Texas, North Carolina and Georgia.

Although results are not yet available, preliminary indications are that the payback periods are sonevhat greater than industry users normally accept, There is a clear need for further development efforts with a view toward simpler, lover cost, or higher performance systems. In certain cases it is expected that sone industries vill be interested in smaller sized applications. In part, this is with a view co the future, but there fare some instances vhere the user has had his energy supply disrupted, and the solar IPH option can be seen as a justifiable backup or supplement in the case of emergencies.

In the case of wind systens, primary attention is upon small to poderate sized systens. With the recognition of ongoing experinental work through the DOE Rocky Flats facility, emphasis is presently on ?special situations, The Virgin Islands is one exanple. Here, the current

objective is to examine the wind resource at sites which are both accessible and re:

jonable for interconnection with the existing pover aystem ©F @ user. The approach being caken is to apply the best available mode- Jing sethods for a preliminary analysis of the major islands, and to work closely with the Virgin Islands Water and Power Authority and the local

Bovernment. The current effort is receiving expha

because of the relatively critical situation in the Virgin Islands. With imported of] as the sole fuel source, electricity is now at a preniua, and is being

required for water desalination as well as other ust

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Applications work concerned with photovoltaics has not yet started

because of the research nature of the DOE program at this time. Neverthe-

ese, sone start up activity is expected during the coming year. With

the current progress tovard meeting the ultimate cost goals of array

prices at 70 cents a peak watt in 1986 and reduction to the range of 15

to 50 cents by the 1990-2000 time frame, some preliminary steps will take

Place during the next year. These are not well defined at this tine.

However, applications with utilities and in situations such as Puerto Rico

?and the Virgin Islan

should receive attention at an early date. Other

efforts will undoubtedly involve the residential area, including exanina-

tion of the option for povering modest sized cooling systems in structures

where advanced passive and conservation techniques can be applied.

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THE SPECTAL CASE OF PUERTO RICO AND THE VIRGIN ISLANDS

In the preceding sections the planning approach and initial activi-

ties being undertaken by SSEC have been de

hhas been done in Puerto Rico and the Virgin Islands; however,

?ribed, Some initial analysis

ause of

their particular characteristics, additional major efforts are needed in

sntial since both Puerto Rico and the

Virgin Islands are almost entirely dependent upon imported ofl for all

theme offshore areas. This is

their energy needs. The econonic impact is far and above that present in

the continental United States. In fact, che econonic survival of these

?areas depends upon rapid and positive action to alleviate the current

situation. Thus, it is important to give this matter proper attention.

?The Islands in Profile

Puerto Rico and the U.S. Virgin Islands are part of the Les

Antilles, the crescent shaped chain of islands stretching from the Domi-
ican Republic to Trinidad as shown in Figure 6, The Carib Indians
occupied the Lesser Antilles in the period 1000 - 1500 A.D.; however,
with the spread of European influence che islands were conquered and then
went through a succession of rules by the French, English, Dutch, Spanish

and Danes. These historical events have created a diversity of cultures,

tions, Language

+ and loyalties which have for many years impeded

effective direct communication and cooperation; a situation vhich contine

ves, to some extent, even after many of the islands have achieved self-

sovernnent.

Although Puerto Rico and the Virgin Islands are neighbors and both

territoris

of the United States, they are quite different in size,

culture, denographics, and economy. Puerto Rico hes approximately 3.3

million inhabitants while the Virgin Islands has just over 100,000. Puerto

Rico experienced rapid industrialization, hich begun during the 1960s;

the Virgin Telan ind a fow industries.

Both territories have low median fanily incones, relatively high

are largely dependent on tour

?Me

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?unemployment and are dependent on outside sources of capital investnent. The cost of living is generally 25% higher and wages 202 lover than on the aainland,

A Critical Reliance on oi1

One characteristic unfortunately shared by Puerto Rico and the Virgin Islands, as well as most of the Caribbean, is an almost exclusive depen~ dence upon imported of1, the cost of which has increased 30-fold since 1973, With imported petroleum fuel cost equalling 20-25% of GNP for Puerto Rico and the Virgin Islands, there is genuine concern over potential onetary problems which may affect tho bi

sic economic system of the of f= shore areas.

In both territories a large share of inported petroleun is consuned by the utility companies. For example, Table IV compares clectric utility data from Puerto Rico and the Virgin Islands to the two southern

states having the heaviest dependence on oil for power generation and Louisiana. Although Puerto Rico's total power production is far less than these states, its oil use is relatively large. In fact, Puerto Rico's ofl consumption is

very significant portion of the total imported oi1 used in the southern region. According to a recent survey

of electric utilities using more than Five million barrels of oil annually, the Puerto Rico Electric Power Authority (PREPA) ranks among the top ten utilities in the United States (Reference 3). To the Commonwealth of Puerto Rico, this represents a current annual outflow of approximately $1.7 billion per year, with projections that the outflow could exceed

$3.0 billion per year by 1985.

While the Virgin Islands of1 use is snall in contrast to Puerto Rico, its energy problem 4:

by no means less significant. Not only are electri-

the highest in the southern region (12.1¢/kih for residential) ,

but service reliability and generation efficiency are poor. During Sep-

tenber and October 1980, St. Thomas and St. Croix aver:

Per month, lasting 15 minutes to 24 hours

cal rats

ed 14 power outages

oas

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This obviously affects the tourisn business and makes it difficult

to attract industry to diversify the economy. Power outages also cause

water shortages, since many residents rely on electric punping from rain-

water cisterns. In addition, the public water aystem serving the

venaining residents is provided by desalination units operating constantly

ear capacity. Alternative energy sources are needed for both electricity generation and desalination.

Energy Resources

Even though the area is nov primarily dependent upon inported of1, there are substantial renevable energy resources available in both Puerto Rico and the Virgin Islands, including energy from the ocean, the wind, and bionas

Following is a brief sumary.

?Tidal movenents in the Caribbean Sea are small, partly because of the enclosed nature of the retion. The tides range up to two feet but average only one foot. Surface ocean currents pass strongly through the Caribbean from the Atlantic and continue with increasing speed through the

Yucatan channel. The main current flows at an average velocity of about

fone mile per hour. Also, temperature gradients between the ocean surface

fand 1000 meters depth are more than 40°F (22°C). Great sources of unt:

Ped energy exist in these currents and temperature gradients. The

?maximum depth of the Caribbean Sea, south of Puerto Rico, is 6150 meters,

?about 160 km offshore in the Muertos Trough. However, as close as 2 km

southeast of Puerto Rico, depths of 1000 meters exist. Consequently,

Puerto Rico is one of the best possible sites for the development and

application of Ocean Thermal Energy Conversion (OTEC) technology. The

Virgin Islands also offer potential sites for OTEC applications. Punta

Tuna, in the southeastern coast of Puerto Rico, is a prine site for an

OTEC plant; its di resulted in it having being chosen for

42 CEER floating OTEC laboratory for Biofoulin

irability hi

Corrosion and Heat

n16-

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transfer studies, The floating Laboratory and proposed OTEC site Lies 4 ke, southeast of Punta Tuna. Ta this area, the insular shelf extends about 2.5 km offshore and the bottom slopes off steeply into the Virgin Islands Basin. The 1000-m contour lice about 3 km offshore. This fact, along With the closeness to a large electric grid and the nearby convenience

of the deep port of Yabucoa, testify to Punta Tuna"s advantages.

Wind Energy,

sn Sea. The vinds

The northeast trade winds prevail over the Caribbi

blow consistentiyfrom the east or northeast more than 60% of the time at wean velocities of about ten miles per hour, Because of this favorable

n installed by the

U.S. Department of Energy and the Puerto Rico Electric Power Authority

condition, a 200 kilowatt wind power generator has bi

fon Culebra Island and this energy source is being evaluat.

Solar Radiat

?The solar radiation in the Caribbean region is on the order of 2000 Kith/meter?/year. Average air temperature varies from about 7é° in February to 83°F in September. Sunlight and mild temperatures are tvo valuable as:

ts of the tourist industry and the first is also a great diffuse energy resource. As an example, Barbados received solar energy 426 times greater than the anount of comercial energy consumed in 1977 (Reference 4).

Puerto Rico and the U. S. Virgin Islands have ideal conditions for

solar research and development and for the comercialization of solar and

Fenewable energy technologies. Six (6) climatic zones exist, ranging

srt to tropical rain forest, all with basically high insols

Tngolation data on the Islands compare favorably with that of the

a

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Because of the high cost of electricity in the U. S. Caribbean, many

of the solar technologies vill becone competitive sooner than on the main

land.

Bionas

Some potential exists for biomass fuel consisting of dried or partial~
ly dried forages, grasses, cane and other ageicultural products which can be used for combustion and perhaps for gasification. Bagasse has tradi tionally been used as a supplemental fuel in sugar refineries in the Caribbean. However, given the shortages of useable land, biomass appears to have only Limited potential in the Virgin Islands. Significant

attention is being given to Puerto Rico's biomass potential, and it is

ecotimated that sugar cane, sordan and napier grasses can yield energy at Jess than one-half the cost of imported oil at today's price:

However,
only a portion of the island's needs could be met under current Land use planning.

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ENERGY OPTIONS FOR THE FUTURE

With the high cost of conventional energy in the Caribbean,

several renevable technologies have potential viability for Puerto

Rico and the Virgin Islands. In this section, ve will attempt tore

view some of the key options and will focus on Puerto Rico since CEER

has recently completed a thorough ase

wealth, While no such thorough assessment has yet been made for the

ssnent of choices for the Comon~

Virgin Islands, observations regarding potentials for the Virgin Is-

lands are included.

Puerto

In order to identify and implenent research programs and other

initiatives to develop energy alternatives which could take full advan=

tage of the unique resources and conditions in Puerto Rico, the Center

for Energy and Environment Research of the University of Puerto Rico w

?blished in 1976. This Institution, from which both the United States and Puerte Rico are benefiting, vas organized under a contract between the University of Puerto Rico and the U.S. Energy Research and Develop- ?ment Administration which is now the Department of Energy (DOE). The University, with an enrollment of more than 52,000 and a faculty of 5,000, has ten campuses in different locations in the Island. It is fone of the largest and most diversified institutions of higher learn- ing in the henisphere and is a menber of the National Association of State Universities and Land Grant Colleges of the United States (iASULGC) 5 the Oak Ridge Associated Universities (ORAU); the Association of Caribbean Universities and Research Institutes (UNICA); and the

Unién de Universidades de América Lotina,

In May of this year, CEER completed a comprehensive study entitled Energy Analysis and Socio-Economic Considerations for Puerto Rico (Reference 5). The study indicates that electricity produced by expensive by 2 si of one and one-half to two) than the electricity produced by commercially

available coal plants. The study shovs that the cost relationship will

be maintained for the rest of the century and beyond. Conservatively

nuclear plants is le

nificant factor (on the order

high estimates of nuclear plant capital investment and fuel costs vere

taken from available comercial dat

Coal plants are recognized as 2 viable alternative in the study,

and, in fact, the cost of electricity produced by coal burning plants is

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used as the cost criteria which must be achieved by other energy aiterna

tives for then to be considered as attractive for development and com

Rercialization, The impact of coal inportation on the Island's econoay

versus the impact of other energy alternatives such as OTEC, biomass and

direct solar energy provide sone socic-econowic credit in favor of these

renewable energy alternatives.

Biomas

Excluding nuclear plants, the lovest predicted cost of electricity

results from pover plants burning bionass. With assumed escalation rates

until 1985, the average production cost for the first year

of electricity from a biomass fueled plant is predicted to be 4.58 cents

of 82 per ye:

per Kh, With an assumed escalation of 5% per year beyond 1985, the

of the plant (

per Kitt. By contrast, the corresponding levelized cost of electricity during the Lifets: sumed

to be 35 years) is 7.13 of

costs for a coal plant equipped with Flue Gas Desulfurization System is 6.35 cents per kit for the first year of operation (1985), and 9.59 cents per kh levelized cost for the lifetine of the plant (1985-2020). The corresponding cost of electricity from residual fuel ofl burning plants shows costs on the order of 160% and 3202 of those for the coal burning Plant. (O11 fuel costs of $57 per barrel are assuned for 1985 and there

is a 9% per year escalation thereafter.)

?At the request of the Government of Puerto Rico, a major one-year study was conducted by the National Acadeny of Sciences (Reference 13) to determine Puerto Rico's options for alternative energy sources.
Bionass Program presently being conducted by the CEER Bionass Division is in conformity with the National Acadeny of Sciences? recommendations for

The

biomass research in Puerto Rico. Anong their recommendations, we quote the following:

"Of all the alternatives discussed, biomass cropping based on the present sugarcane industry, has probably the large Te could jectricity, with bagase

produce a significant fraction of the tsland as fuel, by the year 2000..."

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?ALL in all, energy cropping say in the internediate term be for Puerto Rico the most important renewable energy source. Given vigorous: development, it might provide 10 percent oF more of the Island's electric ity by the year 2000. Ethanol produced as a coproduet could eliminate the Puerto Rican rum industry's dependence on imported molasses and also

supplement gasoline supplies"

orec

?4n Ocean Thermal Energy Conversion (GTEC) plent of 250 MM capacity is shown to be economically competitive with coal by the middie of the next decade. An initial OTEC pilot denoastration project of 40 si capacity, scheduled to begin operation in 1985, is show to be non= competitive with coal, but it will have electricity costs mich lower than

the costs of electricity produced by oil fired steam plants.

Photovoltai

A 250 Yi photovoltaic central power installation with electric battery storage project for operation in 1993 is shown to be highly competitive with coal burning plants. Photovoltaics is energing as a very attractive possibility for the Puerto Rican scenario and offers @ very good energy source along with the OTEC approach. Before this study was undertaken, the competitiveness of photovoltaics was thought to be 20 oF nore years avay; however, rapid progress under the DOE research program

He now seeus that photovoltaics may reach economic competitiveness within ten years. If chis does occur, the results will be very significant. For example, all of the electrical energy generated last year in Puerto Rico could have been generated with solar photovoltaic facilities equipped vith electrical storage and a total cell surface collection area of less than 12 of the area of the Island at costs predicted to be similar to coal ang initially lower than the costs predicted for OTEC power plants. The technical problens associated with photovoltaics appear rather sinple when

vith the technical problems associated vith OTEC marine plant

Also, a photovoltaic manufacturing industry would be nore

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feasible for Puerto Rico than vould an OTEC manufacturing enterprise. On tthe other hand, OTEC has no impact on the use of land resources which is fa great advantage for Puerto Rico, The economic attractiveness of these two alternatives, plus the particular advantages of each, point tovards @ decision to explore both technologies.

wing

Evaluation of wind data compiled at several coastal pointe shows that Puerto Rico's location in the path of the trade winds gives it a

high potential for using wind energy. The trade winds are notable for the steadines

of their speed and direction. Measurenents on the off shore island of Culebra, for exanple, show that the wind velocity exceeds eight miles an hour 85 per cent of the tine. Testing and evaluation of ?the 200 Ku NASA wind generator on Culebra will provide additional know Ledge and experience for the further development of wind energy in Puerto Rico at other sites. The results of this experience can be shared with

other nations in the Caribbean with similar favorable conditions.

?A study has been made by CEER of the possibility of integrating

large windpower generators to the existing PREPA theraoelectric network

in Puerto Rico. Climatologically, one vould expect the highest potential

for vind pover utilization on the north and east coasts because the sea

bes

of wind power density for other regions, especially the mountainous

facts to intensify the prevailing winds in those regions. Estimates

Interior, indicate that no

feciable advantage is found i the mountains

over the eastern coastal plains.

A station on the e:

st coast, Roosevelt Roads, vas chosen for

detailed analysis. Applying the design characteristics of the General

Flectric 1.5 and 0.5 MV generator to the wind speed distribution for this

station reveals that an average power of 288 Ki and 236 KW respectively, could be generated throughout the year.

With @ theoretical systes of 25 turbines, total power costs were estimated at 138 sill/kih. Three major factors account for such an

elevated productions cos

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1. the wind power potential is moderate
2. the capital fixed charges is very high
3. land costs are extremely high

vas the

Making # 40 year economic projection, the largest it.

escalation of the already high land cost. If land costs could somehow be minimized, che equivalent cost of each barrel of oil saved could be around 60-70 dollars for the next 25 years, a price that could becone

competitive in the foresceable future. The study, therefore, shows the central wind power system to be suitable for fuel oil displacenent, but

hnot as an economically viable base (with storage) energy system,

Overall Assessnent of Electric Renewables

Figure 7 illustrates the predicced production cost of electricity from the alternatives reviewed above. The levelized cost indicated is

the ?average? cost during the Lifetine of the facility with the inflation of operating costs and fuel costs taken into consideration,

If the current dependence on conventional energy continues, of1 price increases will severely worsen the economy of Puerto Rico. Cost

ss to industries such a5 cement, electricity production, con~

struction, mining, alcoholic beverages, transportation and business

rvices will be very large. Analysis shows that the largest impact is in the important industries in terns of output generation and job creation. This study shows that, all prices constant, the increase in ofl prices from 1973 to 1979 (assuming @ conservative price of $21.00

se barrel of crude in fiscal year 1979) will induce or hae already induced an increase of sore than 130% in an estimated producers price

Lies double-digit inflation

in other prices. This increase has

resulted in an estimated loss of $8,000 jobs and $1,328.2 million in productivity.

index, excluding industry mark-ups. This i even when there

In contrast, for two 300 I bionase plants and one 250% OTEC

power plant the study indicates an increase in employment of 67,145

workers and an increase in productivity of $1,387 million. This assumes

that the reduction in imports will improve the balance of trade, which in

ae

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turn will increase domestic final demind. The unemployment rate, with

other factors constant, could be reduced by about 7% from its 1979. level.

Recommended Scenario

Based on these econonic analyses, alternative energy scenarios vere

Prepared for the rest of the century, with corresponding RSD prograns and

funding requirements. Fro the present state of development of the

various technologies and fron the predicted potential of the various

alcernatives to compete economically with coal, the following program has been suggested:

1, Bionass ~ A strong effort to make the first (300-450 si)

power plant operational by 1986.

2. OTEC = An experimental plane (40 ¥) by 1985 and first

commercial plant (250 *4) operational by 1991,

3. Photovoltaic ~ Large demonstration project in operation by

1993, or earlier if feasible.

4, Wind Power Turbine Generators - A program coupled with the

operational experience of Culebra's Wind Turbine

0 that a 12.5 Mi wind turbine farm can be placed

in operation by 1988, for fuel oi1 displacenent.

Based on estimated needs for additional electrical generation

capacity and the econonic potentials of energy alternatives, a possible

scenario vas prepared. This scenario is indicated in Table V.

?Three coal burning plants, one with a 300 MY capacity in 1985 and

evo with 400 MY capacity each for 1989 and 1990 are included in the scenario which is shown in Table V, It is estimated that bionass burning plants could be placed in operation as early as 1986 and 1987. Wo additional bionass plants are indicated because of land use uncertainties at this time, The two 400 MH bioma:

plants will require the planting and harvesting of approximately 75,000 acres of land, about the Land acreage actually devoted to sugar cane in Puerto Rico. Coal and biomass plants should be designed to burn either fuel.

No more than 500 Yi of pover from photovoltaics is shovn in the

?scenario because Land use policies are uncertain. It is estinated that

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the two 250 MM photovoltaic installations will require approxieately 10,000 acres of Iand. To generate with photovoltaics all the electric ity produced in 1979 in Puerto Rico a total land area of approxinately 100 km square or 25,000 acres would he required.

A wind power farm also has the sane type of Land requirements. The 12.5 Mi wind power installation which is evaluated in the analysis vill require approximately 3,000 acres. For these reasons the scenario depends heavily on the OTEC alternative. However, not all of the efforts are placed on this alternative because there are still many questions to be ansvered. The scenario does not present any fixed alternative to be followed, but rather provides a reference alternative on vhich to base development prograns.

Te is very important to recognize that the total fuel of1 consump tion for electrical generation between the year 1985 and the year 2000 is estimated at 681.9 willion barrels and thet the savings proposed by this scenario represent only 22% of the energy consusption during the period. This further indicates that che energy situation is so dependent on ofl that heroic efforts are required to make significant reduction in oil importation during the present decade.

Non-Electric Renewables

?Thee principal non-electrical generation energy alternatives are addressed in the Puerto Rico Office of Energy Document "Polfticn Energé tice de Puerto Rico", (Reference 14):

1, Solar industrial steam and hot water

2, Fuel synthesis

3. Conservation measures, mainly in transportation

Consideration has been given to these topice in Preliminary Report on R&D Program Needs for Energy Alternatives in Puerto Rico (Reference 6).

Te is estimated that ethanol and industrial solar steam can play a substantial role in reducing oi1 fuel imports. An electric generation Project based on photovoltaics can be designed as a cogeneration project

(olar steam production and electricity), Tt has been estimated that a

250

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250 ti electric photovoltaic cogeneration project can produce enough industrial stean to save the equivalent of 3.7 million barrels of oi per year.

Industrial stean can be produced separately by adequately designed solar concentrators, with estinated production equivalent to the savings of six million barrels of ofl per year.

Ethanol offers potential help for the transportation industry. ?An ethanol project at a pilot rum plant is under consideration. The Project can be economically designed as a cogeneration facility to provide steam for its rum production and to generate electrical eneray from bagasse. Preliminary estimates indicate that a savings of 7.5 million barrels of oil per year can be achieved. Energy conservation measures in the transportation industry also require special attention. It is difticule to assign specific figures to thie progran. However, it could reach savings as high as 4-107 of oil imports.

Table VI indicates the combined total savings which could be obtained through the proposed scenarios and an aggressive R&D effort. Im the electrical sector the reduction in fuel ofl consumption is over 26%, and for all sectors the fuel ofl equivalent reduction is approxi- ately 21%, When conservation measures in transportation are added, probably @ 9-10% additional reduction can be achieved.

Te is important to point out that the energy renewable resources scenario concurs in general with the Puerto Rico Energy Policy document (Reference 14), the Puerto Rico Energy Conservation Plan (Reference 15), and the U.S. National Acadeny Report (Reference 13). Tables VIT and VIIT include a comparison of the scenarios.

ALL of the above indicate that a renevable energy program supported by a strong RAD effort in Puerto Rico can achieve an approxinately 1/3 reduction in oil dependence while still maintaining the sane level of ?economic development.

The Virgin Islands

With 1/30th of the population and an even smaller fraction of the

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land mass of Puerto Rico, the Virgin Islands requires a much different approach to renewable energy. Tt has been estinated by the Virgin Islands Energy Office that 12 ile of renewable energy capacity would be desirable in the near term for reduction of fuel coste and improvenent of power production reliability, Unfortunately, when discussing renewables it is Rot that simple due to varying capacity factors, resource availability

and load match requirenents. A much more intensive renewable energy plan- ?ning process, combined with practical field denonstration projects, appears to be needed if near~ to mid-term solutions are to be found for the Virgin

Ielands" energy dilema,

Such program should, at 2 minimum, address the following matters:

1, Resource assessment, principally solar insolation and

wind energy.

Utility interface, including load match, buyback, etc.

Unique requirements imposed by the Caribbean climate,

4, Initial engineering experiments to refine the technology.

5. Land and environmental inpacts,

Economics assesenent and financing.

Although available data is sparse, it is possible to draw some

Preliminary conclusions regarding the best renewable choices for the

Virgin Telands. They ar

aw

While some discrepancies exist in available wind

Gata, it does appear that sites exposed to winds fron the

southeast and northeast possess good potential for wind

energy conversion systens (WECS). SSEC's current

ment of the Virgin Islands! vind resource should enhance
our understanding of this resource. The economics of WECS
as denonstrated in Figure 8, would be attractive for sites
having average wind speeds of 13 aph or higher. While the
?economics of WECS in comparison to conventionally generated
electricity are better than many mainland locations, the
initial capital expense may impose real barriers to wide-
spread decentralized use. In addition, the small land

Ue

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Ea

?mass combined vith steep topography may impose some
restrictions on location and size of WECS,

Sol

Hot Solar hot water heating has economies which compare quite favorably to the mainland staces of the southern region. As depicted in Figure 3, cash purchase (with 40% tax credit) of a solar water heater Providing 502 of hot vater needs yields a return on investnent of 26.1% for Puerto Rico and 23-62 for the Virgin Islands. It should be cautioned, however, that

?cash pure

of a currently available factory-buile aysten is probably beyond the means of many residents. Substantial cost reduction or expanded financing will be necéssary for any meaningful penetration of the residential retrofit market. Incorporating solar hot water systens in new housing has the advantage of long term mortgage financing and thus may find a market in San Juan where annual housing starts average 1,300; however, the low level

of annual housing starts (100) in the Virgin Islands do not provide comparable potential. Solar hot water systems

designs in the Caribbean should be based on the high

insolation value throughout the year, lover average house~

hhold demand for hot water, and the absence of need for

freeze protection. Reduction in collector and tank size

and piping plus ?sweat equity" should make the technology

quite viable in the future.

Photevolcaie

While not yet ready for conmercialization,

photovoltaic cells may find a prine early market inthe

Virgin Teland

conventional energy, abundant sunshine, lover per capita

Advantage

include the high cost of

power denand (vhich could make roof-nounting more practical) and the fact that approximately 60% of electrical pover is used during daylight hovr:

Initial system engineering experiments are essential in order to be ready for adaption when cost goals are net.

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4. Solar Steam. Again, the solar radiation in this region ?aay provide unique opportunities for central station and intersediate load center applications for solar steam, both for process heat and pover generation,

5. QTEC. Although little work has been Jone in the vicinity

of the Virgin Islands regarding thermal gradients and

OTEC, long term potential does exist. With appropriate technology support, OTEC could become a viable energy

source in the 1990

?The answers to the Virgin Islands? energy dilemma are needed now but unfortunately the renevable technologies discussed above are not yet fully available. Near-term relief will have to come through conventional system inprovenents, inproved managenent practices, and conservation measures. The Virgin Islands Energy Office has recognized this reality in its Energy Conservation Plan (Reference 7) by recommending managenent Practices and facility improvements which could account for .683 x 10!2 Btus of annual savings (i.e., 9% of fuel consuaption for electricity

?and di

WLination). In the meantime, a pragmatic rene

ble energy plan

supported by well-conceived field tests must precede wide-spread use of

solar, wind, and ocean resources.

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CONCLUDING REMARKS

In the first part of this paper, insight is provided into the

initial planning re

ted to the use of renewable energy sources in the

stateside portion of the southern region of the United States. Much

work lies ahead to properly apply solar and other renewable enersy

Sources; hovever, this effort is undervay and is expected to progress

through @ concerted effort by both the private sector and governnent.

The Caribbean region poses a very real and urgent energy prob em vhich is perhaps more crucial than most people sppreciate. The problem is typified by the conditions in Puerto Rico and the Virgin Is Lands. Being almost totally dependent upon imported ofl, and without coal or substantial forest resources, the situation is one of the nost

fous in the United States or its territories. The 3.5 million resi- Gents of these two island comunities increasingly find their exploy- nent, their living situation, and their government dependent upon energy availability and cost. Oi1, which once was viewed as the "Life Line", now has a ?strangle hold" on their long term existence. The econonie ?and social impact will be severe if oil imports are interrupted. Thus, it is imperative that # long term solution be found and implemented. Some of the possible options have been explained and discussed. Con~ tinued effort is essential.

Solving the energy problen is of utmost importance to these communities in order to attain self-sufficiency and socio-economic pro~ gress, The United States government also has a vital interest in the Islands? energy problem since foreign ofl dependence makes then subject to political instat

?Lity and intervention by anyone guaranteeing continual Flow of ofl. Also, there are a large nusber of other island

Governments who stand to benefit through technology transfer from pro-

are

made in Puerto Rico and the Virgin Islands. Thus, there are

humerous beneficiaries of steps toward energy self-sufficiency.

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White the islands are Limited in supplies of fossil fuels,

they are rich in indigenous reneuable energy resources. The

Lands

are ideal areas to test renewable concepts because of their linited

Beographic areas, ample solar, wind, ocean resources and the higher

cost of conventional energy. Puerto Rico and the Virgin Islands pro

vide a valuable testing and dovelopaent site and could be made into a

showcase for renewable energy options, including OTEC, Solar Therm}, Photovoltaics, Biomass and Wind.

This vas recently confirmed by the U.

Science (Reference 6), which stated that:

"Puerto Rico, in dealing vith its om energy problems, should

grasp its opportunity to become an international energy laboravory,

Seeking and testing solutions especially appropriate to the oil-cepen=

dent tropical and subtropical regions of the world, The Istand?s seo

graphical position and its established energy research and development

facilities enhance this potential, which should be called to the at=

Eention of agencies and instituticns vith investments to make in act

celerating development overseas"

National Acadeny of

Te is not enough that an energy resource is available; the

technology, the capital, and the managenent resources must also be

Present. the development and transfer of renewable technologies must be

Joint effort of government and the private sector in which de~ velopment priorities of the island communities are respected and in Which private industries enjoy proper return on their investment and inventiveness. There is a strong historical tendency to look toward

the nother country for guidance and, of course, technology transfer.

However, islands are not chips off a mainland block but unique entities

with their om priorities. Stated in other terms: "Ocean islands ?are not mainiands in siniature anymore than a cat is a miniature tiger", (eference 16), Being cognizant of the unique priorities and constraints

of the island communities, government's role should be geared towar:

1, development of adequate data bases, energy plans, and

policies;

2. research, development, and denonst ratios

3. field tests: and

42 support of industry's technology and market development

progr:

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While the electric utilities and subsequently the consumers vill bear the cost of any energy, the involvenont of the private sector is critical to the need for initial investment capital. Coverament cannot alone finance the transition co renevable energy.

External technical assistance and support is essential to the islands. Such support is needed from the U.S. Department of Energy and other agencies as well as international organizations, such as World

Bank, IDB, and AID. These organizations should be prepared to give high priority ?o supporting such efforts, using regional approaches where

possible for the mobilization of human and technical resources.

At this time, analyses and planning studies have been completed for Puerto Rico and considerable work has been accomplished, which is applicable to the Virgin Islands and other portions of the Caribbean, We now need to press for increased government action and support, along with the full participation of the private sector in order to achieve results. The tine is quite limited and the stakes are high, If we can Provide the leadership, the impact in terme of economic progress and

?bility will be very important to che United States and all its neigh bors, Not to provide the leadership is simply out of character with the skills, resoure

+ and dedication of the people of this country.

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